SAE International™ SURFACE VEHICLE STANDARD

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(R) Vehicle Electromagnetic Immunity—Bulk Current Injection

Foreword—This SAE Standard adopts ISO 11451-4: Road vehicles—Electrical disturbances by narrowband radiated electromagnetic energy—Vehicle test methods—Part 4: Bulk current injection, with the only change being that Appendix C has been modified in accordance with the concepts of SAE J1812 and SAE J551-1.

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1. Scope—This part of SAE J551 specifies Bulk Current Injection (BCI) test methods and procedures for testing the electromagnetic immunity of electronic components for passenger cars and commercial vehicles. The electromagnetic disturbance, considered in this part of SAE J551, will be limited to continuous narrow band electromagnetic fields.

SAE J551-1 specifies general, definitions, practical use, and basic principles of the test procedure.

1.1 Rationale—Through years of effort to harmonize the SAE and ISO documents, SAE J551-12 and SAE J551-13 are technically identical with their ISO counterparts. To keep SAE out of copyright difficulties, we are adopting the ISO documents by reference in SAE J551-1 and cancelling SAE J551-12 and SAE J551-13 documents. We have reserved the document numbers so that should technical differences arise, we can document the differences in logical fashion.

2. References

2.1 Applicable Publications—The following publications form a part of the specification to the extent specified herein. Unless otherwise indicated the latest revision of SAE publications shall apply.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J551-1—Performance Levels and Methods of Measurement of Electromagnetic Compatibility of Vehicles and Devices (60 Hz to 18 GHz)
SAE J1812—Function Performance Status Classification for EMC Testing of Automotive Electronic and Electrical Devices

3. Test Conditions

3.1 Test Temperature and Supply Voltage—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 °C ± 5 °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.

3.2 Frequency Range—To test automotive electronic systems, the applicable frequency range of the Bulk Current Injection (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.

3.3 Modulation—The Device Under Test (DUT) determines 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%

3.4 Dwell Time—At each frequency, the DUT shall be exposed to the test level for the minimum response time needed to control the DUT. In all cases, this minimum time of exposure shall be as shown in Equation 1:

$$t_{min} = 2 \text{ s} \qquad \text{(Eq. 1)}$$

3.5 Frequency Steps—The tests will be conducted with the maximum frequency step sizes shown in Table 1:

TABLE 1—FREQUENCY STEPS

Frequency Band	Maximum Frequency Step Size
1 to 10 MHz	1 MHz
10 to 200 MHz	2 MHz
200 to 400 MHz	20 MHz

Alternatively, logarithmic frequency steps, with the same minimum number of frequency steps in each frequency band, can be used. The values, as agreed by the users of this document, shall be documented in the test report.

NOTE—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 J551-1.)

3.6 Test Severity Levels—The user should specify the test severity level(s) over the frequency band. Suggested test severity levels are included in Appendix C of this document. (Refer to SAE J551-1.)

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 modulated tests. (Refer to SAE J551-1.)

4. Test Instrument Description and Specification

4.1 BCI System—BCI is a method of carrying out immunity tests by inducing disturbance signals directly into the wiring harness by means of a current injection probe. The injection probe is a current transformer through which the wires of the DUT are passed. Immunity tests are then carried out by varying the test severity level and frequency of the induced disturbance.

BCI shall be conducted on each individual system fitted to the vehicle.

4.2 Instrumentation—Figure 1 shows an example of a set-up of the BCI measurement system.

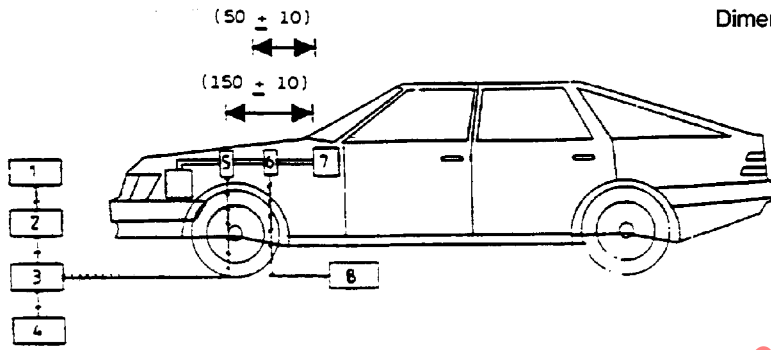
An injection probe or set of probes capable of operating over the test frequency range is required to interface the test equipment to the DUT. The probe shall be capable of withstanding a continuous input power over the test frequency range regardless of the system loading.

The monitoring probe, or set of probes, shall be capable of operating over the test frequency range. Prior to testing, the monitoring probe(s) shall be terminated and characterized per manufacturers instructions. During testing, the RF measurement devices (receiver and RF cable) used to terminate the monitoring probe(s) shall have the same impedance as the equipment used during pretest characterization. Any variations shall be noted in the test report.

4.3 Test Set-Up—The vehicle should be tested as built and no additional grounding connections are allowed. 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.

Dimensions in millimeters



Legend

1 Signal generator
2 Broadband amplifier
3 RF 50 Ω dual direction coupler
4 RF power level measuring device or equivalent
5 RF injection probe
6 RF measuring probe (required for monitor current probe method, optional for substitution method)
7 DUT
8 Spectrum analyzer or equivalent (optional for substitution method)

FIGURE 1—EXAMPLE OF BCI TEST CONFIGURATION

5. Test Procedure

5.1 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, conductors included in the probe(s) (e.g., "all except ground(s)") if this differs from the standard all conductors test, and any other special instructions and/or changes from the standard test. Every DUT 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 Test Method

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.

There are two test methods for the BCI test: the substitution injection probe method and the monitor current probe method (closed loop)

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

5.2.1 SUBSTITUTION INJECTION PROBE METHOD—This method is based upon the use of NET POWER as the reference parameter used for characterization and test.

In this method, the test level (current) specified in the test plan shall be characterized in the 50 ohm injection probe characterization fixture shown in Figure A1. The net RF power levels required to achieve the test current in the 50 ohm fixture shall be recorded.

The test with the DUT is then conducted by subjecting the DUT to the test signals based on the net power levels recorded during the 50 ohm fixture current characterization.

Measurements using this method can be affected by coupling between the injection probe and the wiring harness as well as by reflected energy. During the test, the net power shall be maintained relative to the characterization point up to a limit of 2 dB increase in forward power.

NOTE 1—If the forward power has to be increased by 2 dB or more, this shall be indicated in the test report. (Also refer to SAE J551-1.)

NOTE 2—If the SWR in the test system can be demonstrated to be less than 1.2:1, then forward power may be used as the reference parameter to establish the test level.

Mount the current injection probe around the harness 150 mm ± 10 mm from the connector or the outlet aperture of the DUT being tested on the vehicle.

Where the harness contains a number of branches to a DUT, the test should be repeated with the injection current probe(s) clamped around each of the branches 150 mm ± 10 mm from the branch termination. Under these test conditions, the monitor probe, if used, shall be left at its previous distance (50 mm ± 10 mm) from the DUT.

Using either the precharacterized level of net power (see Appendix A) or a relatively high level of fixed net power, a search for events shall be conducted over the frequency range of the injection probe.

For each event the lowest net power to the probe shall be recorded as the threshold of immunity even if this is found with the injection probe in different positions at different frequencies. (Refer to SAE J551-1 for net power requirements.)

A current monitoring probe may be mounted on the DUT harness between the current injection probe and the DUT, at a distance 50 mm ± 10 mm from the DUT. If the DUT wiring harness will not allow the monitoring probe to be placed at the 50 mm ± 10 mm distance, place the monitoring probe on the DUT harness as close as possible to the DUT and document this distance in the test report. The use of a current monitoring probe is optional. It may provide extra useful information but it may also modify the test conditions. Where this probe is used, the measured current cannot be used to determine the performance of the DUT, but should be retained and used during investigative work for the causes of events and the variances in test conditions after system modifications.

5.2.2 MONITOR CURRENT PROBE METHOD—The RF power to the injection probe shall be increased until:

a. The predetermined maximum test current level is reached. This induced current is measured using the monitor probe.
b. The maximum net power (defined in the test plan) to the injection probe is achieved.

The monitor probe shall be characterized using the method of Appendix B.

Reference paragraph 5.2.1 for positioning of injection and monitoring probes on the DUT harness and testing of harness branches.

Record the threshold of susceptibility as a function of frequency versus applied current to DUT harness and power to injection probe.

5.3 Test Report—When required in the test plan, a test report should be submitted detailing information regarding the test equipment, test site, systems tested, frequencies, power levels, system interactions, and any other relevant information regarding the test.

6. Notes

6.1 Marginal Indicia—The change bar (l) located in the left margin is for the convenience of the user in locating areas where revisions have been made to the previous issue of the report. An (R) symbol to the left of the document title indicates a complete revision of the report.

PREPARED BY THE SAE EMI STANDARDS COMMITTEE

CANCELLED BY THE SAE ELECTROMAGNETIC COMPATIBILITY (EMC) STANDARDS COMMITTEE

APPENDIX A

A.1 (Normative) Current Injection Probe Characterization Method—To determine the injection current flowing, the net power measurement across a characterization fixture is used.

Mount the injection probe centered in the characterization fixture (see Figure A1) and while sweeping the test frequency range monitor the net power required to achieve the current at which testing is to be conducted.

As an alternative method, once testing of the system is complete and all data has been recorded, mount the injection probe in the characterization fixture. At each frequency showing an event, the recorded net power levels are applied to the probe. The currents now observed in the characterization fixture are those at which events within the system occurred.

Figure A2 shows an example of a test equipment configuration for the current probe characterization.

NOTE—The fixture dimensions are dependent upon the probe size.

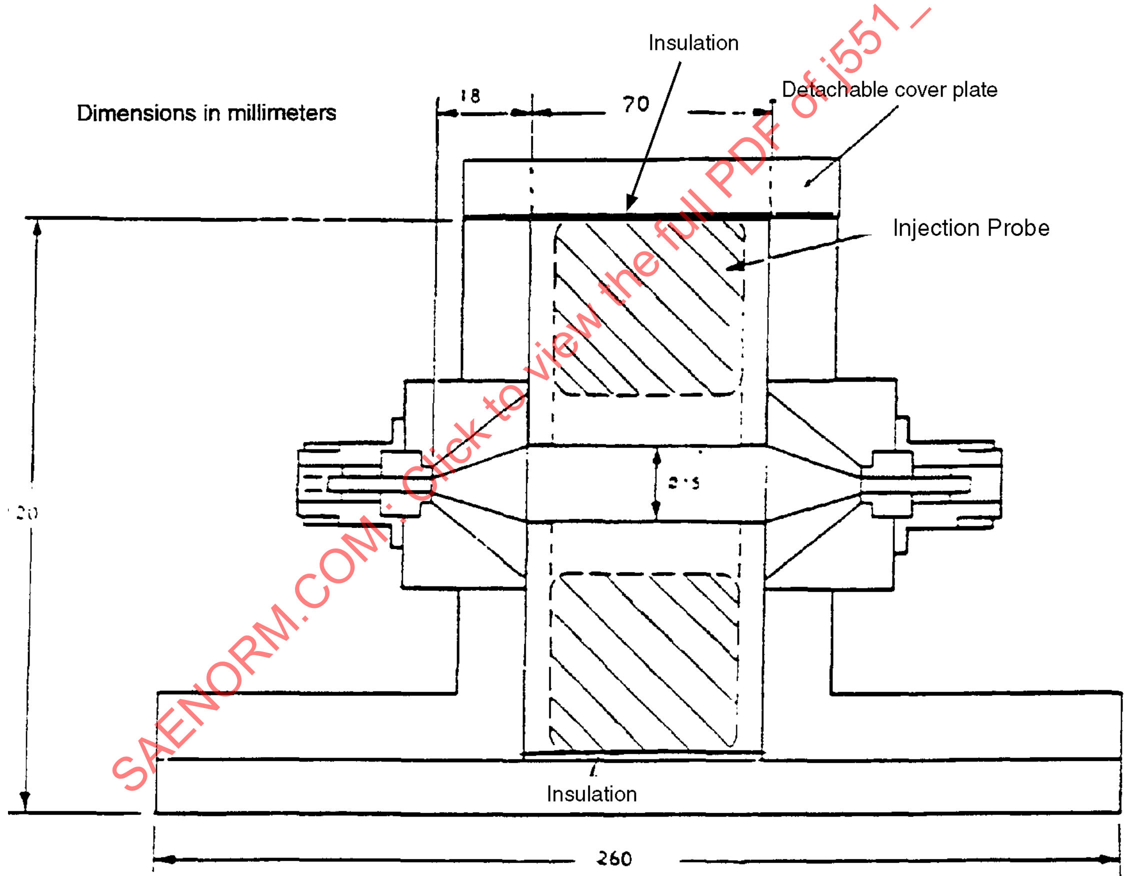
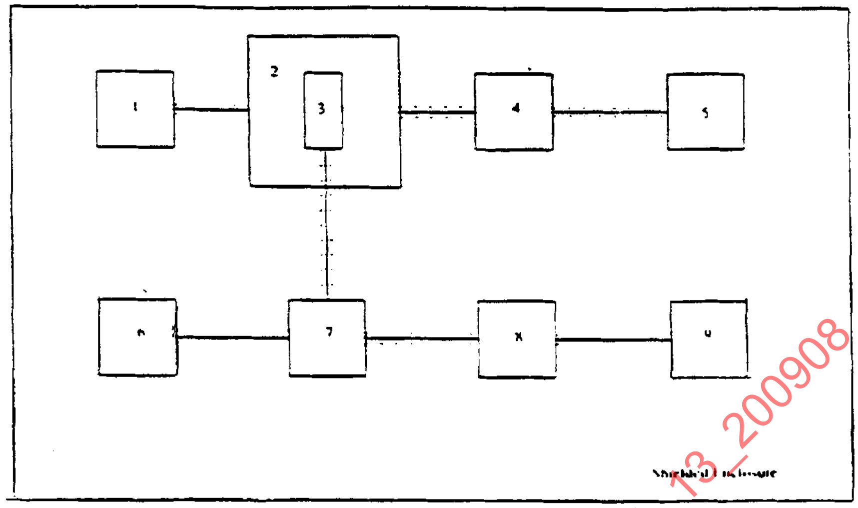


FIGURE A1—INJECTION PROBE CHARACTERIZATION FIXTURE



Legend

1 50 Ω coaxial load VSWR 1, 2:1 maximum
2 Characterization fixture
3 Injection probe 50 Ω
4 50 Ω attenuator
5 Spectrum analyzer or equivalent
6 RF power level measuring device or equivalent
7 RF 50 Ω dual direction coupler (with 30 dB minimum coupling coefficient)
8 Broadband amplifier with 50 Ω output impedance
9 RF signal generator

FIGURE A2—EXAMPLE OF CURRENT INJECTION PROBE CHARACTERIZATION CONFIGURATION