# SURFACE VEHICLE STANDARD

| J551-1 | JAN2015 |
|---|---|
| Issued 1994-03<br>Revised 2015-01<br><br>Superseding J551-1 JUN2010 | |

# Performance Levels and Methods of Measurement of Electromagnetic Compatibility of Vehicles, Boats (up to 15 m), and Machines (16.6 Hz to 18 GHz)

## RATIONALE

The document is being reviewed and revised in accordance to the SAE 5-year review policy. The document is revised to incorporate the latest changes in SAE J551-5, J551-15, J551-16, J551-17 and J1812 as well as the changes in its corresponding international standards; ISO 11451-1, CISPR 12, CISPR 25, IEC 60050-161 and IEC 60050-726.

## FOREWORD

This document brings together methodology for testing the electromagnetic emissions and immunity characteristics of vehicles and devices. The writers of this document have participated extensively in the drafting of CISPR Subcommittee D and ISO TC 22 Subcommittee 3 Working Group 3 documents. By intent, the methods and limits of this document closely resemble the counterpart international standards.

The SAE J551 series consists of the following parts:

SAE J551-1 General and Definitions

SAE J551-2 Withdrawn as a complete standard. Reserved for use as an exception document to IEC CISPR 12

[Part 3 reserved for future use]

SAE J551-4 Withdrawn as a complete standard. Reserved for use as an exception document to IEC CISPR 25

SAE J551-5 Performance Levels and Methods of Measurement of Magnetic and Electric Field Strength from Electric Vehicles, Broadband, 9 kHz to 30 MHz

[Parts 6 through 10 reserved for future use]

SAE J551-11 Withdrawn as a complete standard. Reserved for use as an exception document to ISO 11451-2

SAE J551-12 Withdrawn as a complete standard. Reserved for use as an exception document to ISO 11451-3

SAE J551-13 Withdrawn as a complete standard. Reserved for use as an exception document to ISO 11451-4

[Part 14 reserved for future use]

SAE J551-15 Vehicle Electromagnetic Immunity - Electrostatic Discharge (ESD)

SAE J551-16 Electromagnetic Immunity - Off-Vehicle Source (Reverberation Chamber Method) - Part 16 - Immunity to Radiated Electromagnetic Fields





**TO PLACE A DOCUMENT ORDER:** **Tel: 877-606-7323 (inside USA and Canada)**
**Tel: +1 724-776-4970 (outside USA)**
**Fax: 724-776-0790**
**Email: CustomerService@sae.org**
**SAE WEB ADDRESS:** **http://www.sae.org**

**SAE values your input. To provide feedback on this Technical Report, please visit**
**http://www.sae.org/technical/standards/J551/1_201501**

SAE J551-17 Vehicle Electromagnetic Immunity - Power Line Magnetic Fields

## 1. SCOPE

This SAE Standard covers the measurement of radio frequency radiated emissions and immunity. Each part details the requirements for a specific type of electromagnetic compatibility (EMC) test and the applicable frequency range of the test method.

The methods are applicable to a vehicle, boat, machine or device powered by an internal combustion engine or battery powered electric motor. Operation of all engines or motors (main and auxiliary) of a vehicle, boat, machine or device is included. All equipment normally operating when the vehicle, boat, machine or device is in operation is included. Operator controlled equipment is included or excluded as specified in the individual document parts.

As a special case, CISPR 12 applies to battery powered floor finishing equipment, but robot carpet sweepers are excluded. By reference, IEC CISPR 12 and CISPR 25 are adopted as the standards for the measurement of vehicle emissions. In the event that an amendment is made or a new edition is published, the new IEC document shall become part of this standard six months after the publication of the IEC document. SAE reserves the right to identify exceptions to the published IEC documents with the exceptions to be documented in SAE J551-2 and SAE J551-4, respectively. Also by reference, ISO 11451-2, ISO 11451-3 and ISO 11451-4 are adopted as standards for the measurement of vehicle immunity. In the event that an amendment is made or a new edition is published, the new ISO document shall become part of this standard six months after the publication of the ISO document. SAE reserves the right to identify exceptions to the published ISO documents with the exceptions to be documented in SAE J551-11, SAE J551-12 and SAE J551-13, respectively.

The recommended levels apply only to complete vehicles in their final manufactured form. Vehicle-mounted rectifiers used for charging in electric vehicles are included in this series of documents when operated in their charging mode.

Emissions from intentional radiators are not controlled by this document. (See applicable, appropriate regulatory documents.) The immunity of commercial mains powered equipment to over voltages and line transients is not covered by this document.

## 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.

#### 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 J551-5 Performance Levels and Methods of Measurement of Magnetic and Electric Field Strength from Electric Vehicles, Broadband, 9 kHz to 30 MHz

SAE J551-15 Vehicle Electromagnetic Immunity - Electrostatic Discharge (ESD)

SAE J551-16 Electromagnetic Immunity - Off-Vehicle Source (Reverberation Chamber Method) - Part 16 - Immunity to Radiated Electromagnetic Fields

SAE J551-17 Vehicle Electromagnetic Immunity - Power Line Magnetic Fields

SAE J1812 Function Performance Status Classification for EMC Immunity Testing

2.1.2 ANSI Publications

Available from American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, Tel: 212-642-4900, www.ansi.org.

ANSI/IEEE STD 100 Standard Dictionary of Electrical and Electronic Terms

2.1.3 IEC Publications

Available from IEC Central Office, 3, rue de Varembe, P.O. Box 131, CH-1211 Geneva 20, Switzerland, Tel: +41 22 919 02 11, www.iec.ch.

CISPR 12 Vehicles, boats and internal combustion engines - Radio disturbance characteristics - Limits and methods of measurement for the protection of off-board receivers

CISPR 25 Vehicles, boats and internal combustion engines - Radio disturbance characteristics - Limits and methods of measurement for the protection of on-board receivers

IEC Publication 60050-161 International Electrotechnical Vocabulary - Electromagnetic Compatibility

IEC Publication 60050-726 International Electrotechnical Vocabulary - Transmission Lines and Waveguides

2.1.4 IEEE Publications

Available from IEEE Operations Center, 445 Hoes Lane, Piscataway, NJ 08854-4141, Tel: 732-981-0060, www.ieee.org.

IEEE C63.2 Electromagnetic Noise and Field Strength Instrumentation, 10 kHz to 40 GHz Specifications

IEEE C63.4 American National Standard for Methods of Measurement of Radio - Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the range of 9 kHz to 40 GHz IEEE C95.1 IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz

IEEE STD 291 IEEE Standard Methods for Measuring Electromagnetic Field Strength of Sinusoidal Continuous Waves, 30 Hz to 30 GHz

2.1.5 ISO Publications

Available from American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, Tel: 212-642-4900, www.ansi.org.

ISO 10605 Road vehicles - Test methods for electrical disturbances from electrostatic discharge

ISO 11451-1 Road vehicles - Vehicle test methods for electrical disturbances by narrowband radiated electromagnetic energy - Part 1: General and definitions

ISO 11451-2 Road vehicles - Vehicle test methods for electrical disturbances from narrowband radiated electromagnetic energy - Part 2: Off-vehicle radiation source

ISO 11451-3 Road vehicles - Vehicle test methods for electrical disturbances from narrowband radiated electromagnetic energy - Part 3: On-board transmitter simulation

ISO 11451-4 Road vehicles - Vehicle test methods for electrical disturbances from narrowband radiated electromagnetic energy - Part 4: Bulk current injection (BCI)

## 2.2 Related Publications

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

### 2.2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 1-724-776-4970 (outside USA and Canada), www.sae.org.

SAE HS-3600 Surface Vehicle Electromagnetic Compatibility (EMC) Standards Manual

SAE Paper 810333 Kinderman, J.C., Blink, R.P., Eisenlord, D.J., Laskowski, M.G. et al., "Implementation of EMC Testing of Automotive Vehicles," 1981

SAE Paper 831011 Vrooman, G.F.E., "An Indoor 60 Hz to 40 GHz Facility for Total Vehicle EMC Testing," 1983

### 2.2.2 ANSI Publications

Available from American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, Tel: 212-642-4900, www.ansi.org.

ANSI C63.5 American National Standard for Electromagnetic Compatibility - Radiated Emissions Measurements in Electromagnetic Interference (EMI) Control - Calibration of Antennas (9 kHz to 40GHz)

ANSI C63.14 Standard Dictionary for Technologies of Electromagnetic Compatibility (EMC), Electromagnetic Pulse (EMP), and Electrostatic Discharge (ESD)

ANSI C63.16 American National Standard Guide for Electrostatic Discharge Test Methodologies and Criteria for Electronic Equipment

### 2.2.3 IEC Publication

Available from IEC Central Office, 3, rue de Varembe, P.O. Box 131, CH-1211 Geneva 20, Switzerland, Tel: +41 22 919 02 11, www.iec.ch.

CISPR 22 Limits and methods of measurement of radio interference characteristics of information technology equipment

### 2.2.4 ISO Publication

Available from American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, Tel: 212-642-4900, www.ansi.org.

ISO 10305 Generation of standard em fields for calibration of power density meters 20 kHz to 1000 MHz

### 2.2.5 IEEE Publications

Available from IEEE Operations Center, 445 Hoes Lane, Piscataway, NJ 08854-4141, Tel: 732-981-0060, www.ieee.org.

IEEE STD 211 IEEE Standard Definition of Terms for Radio Wave Propagation

Nichols, F. J., and Hemming, L. H., "Recommendations and Design Guides for the Selection and Use of RF Shielded Anechoic Chamber in the 30-1000 MHz Frequency Range," IEEE International Symposium on EMC, Boulder, CO, August 18-20, 1981, pp. 457-464

2.2.6 Other Publications

Adams, J. W., Taggart, H. E., Kanda, M., and Shafer, J., “Electromagnetic Interference (EMI) Radiative Measurements for Automotive Applications,” NBS Tech. Note 1014, June 1979

Tippet, J. C., Chang, D. C., and Crawford, M. L., “An Analytical and Experimental Determination of the Cutoff frequencies of higher-order TE modes in a TEM cell,” NBSIR 76-841, June 1976

Tippet, J. C., Modal Characteristics of Rectangular Coaxial Transmission Line, Thesis submitted June 1978 for degree of Doctor of Philosophy to University of Colorado, Electrical Engineering Dept., Boulder, CO

## 3. DEFINITIONS

The definitions listed as follows apply to certain terms used in the various parts of SAE J551 and are not intended to be an exhaustive list. For more information, check other resources such as ISO 11451-1, IEC publications 60050-161 and 60050-726 and the latest editions of ANSI/IEEE Dictionaries of Technological terms. Definitions without a source reference were defined within the SAE committee activities.

### 3.1 ABSORBER-LINED SHIELDED ENCLOSURE

Shielded enclosure/screened room with radio frequency absorbing material on its internal ceiling and walls.

Note 1 to entry: The common practice is for the room to have a metallic floor, but absorbing material can also be used on the floor. [SOURCE: ISO 11451-1].

### 3.2 AMPLITUDE MODULATION AM

Process by which the amplitude of a carrier wave is varied following a specified law, resulting in an AM signal.

### 3.3 ARTIFICIAL MAINS NETWORK AMN

Provides a defined impedance to the EUT at radio frequencies, couples the disturbance voltage to the measuring receiver, and decouples the test circuit from the supply mains.

[SOURCE: ISO 11451-1]

NOTE 1 TO ENTRY: There are two basic types of AMN, the V-network (V-AMN) which couples the unsymmetrical voltages and the delta-network which couples the symmetric and the asymmetric voltages separately. The terms line impedance stabilization network (LISN) and V-AMN are used.

NOTE 2 TO ENTRY: This network is inserted in the power mains of the vehicle in charging mode which provides, in a given frequency range, a specified load impedance and which isolates the vehicle from the power mains in that frequency range. [SOURCE: ISO 11451-1].

### 3.4 ARTIFICIAL NETWORK AN; LINE IMPEDANCE STABILIZATION NETWORK (LISN)

Network inserted in the supply lead or signal/load lead of apparatus to be tested which provides, in a given frequency range, a specified load impedance for the measurement of disturbance voltages and which can isolate the apparatus from the supply or signal sources/loads in that frequency range” [SOURCE: ISO 11451-1].

NOTE 1 TO ENTRY: This network is inserted in the DC power lines of the vehicle in charging mode which provides, in a given frequency range, a specified load impedance and which isolates the vehicle from the DC power supply in that frequency range.

3.5 ASYMMETRIC ARTIFICIAL NETWORK AAN

Network used to measure (or inject) asymmetric (common mode) voltages on unshielded symmetric signal (e.g., telecommunication) lines while rejecting the symmetric (differential mode) signal.

NOTE 1 TO ENTRY: This network is inserted in the communication/signal lines of the vehicle in charging mode to provide a specific load impedance and/or a decoupling (e.g., between communication/signal lines and power main).

[SOURCE: ISO 11451-1]

3.6 BONDED (GROUND CONNECTION AND DC RESISTANCE)

Used to describe a grounding connection within this standard, where the purpose of the bonding is to provide the lowest possible impedance (resistance and inductance) connection between two metallic parts.

NOTE 1: The DC resistance of this connection shall not exceed 2,5 mΩ.

NOTE 2: A low current (≤100 mA) 4-wire milliohm meter is recommended for this measurement.

[SOURCE: ISO 11451-1]

3.7 BROADBAND ARTIFICIAL NETWORK (BAN)

A network that presents a controlled impedance to the device under test over a specified frequency range while allowing the device under test to be interfaced to its support system. It is used in power, signal and control lines.

3.8 BULK CURRENT

Total amount of common mode current in a harness [SOURCE: ISO 11451-1].

3.9 COMPRESSION POINT

Input signal level at which the measurement system becomes non-linear.

NOTE 1: When the measurement system is non-linear, the output value will deviate from the value given by an ideal linear system. [SOURCE: ISO 11451-1].

3.10 COUPLING

Means or device for transferring power between systems .

[SOURCE: ISO 11451-1]

3.11 CURRENT INJECTION PROBE

Device for injecting current in a conductor without interrupting the conductor and without introducing significant impedance into the associated circuits [SOURCE: ISO 11451-1].

3.12 CURRENT (MEASURING) PROBE

Device for measuring the current in a conductor without interrupting the conductor and without introducing significant impedance into the associated circuits.

[SOURCE: ISO 11451-1]

3.13 DEVICE

1. An electrical or electronic component, module subassembly or system. Each could include a wiring harness(es).

2. (As used in CISPR 12) A machine driven by an internal combustion engine which is not primarily intended to carry persons or goods. Devices include, but are not limited to, chainsaws, irrigation pumps, snow blowers, air compressors, and landscaping equipment (see Machine).

3.14 DEGRADATION (OF PERFORMANCE)

Undesired departure in the operational performance of any device, equipment, or system from its intended performance.

NOTE 1: The term “degradation” can apply to temporary or permanent failure.

[SOURCE: ISO 11451-1]

3.15 DUAL DIRECTIONAL COUPLER

Four-port device consisting of two transmission lines coupled together in such a manner that a single travelling wave in any one transmission line will induce a single travelling wave in the other, the direction of propagation of the latter wave being dependent upon that of the former.

[SOURCE: ISO 11451-1]

3.16 ELECTROMAGNETIC COMPATIBILITY EMC

Ability of equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbance to anything in that environment.

[SOURCE: ISO 11451-1]

3.17 ELECTROMAGNETIC DISTURBANCE

Any electromagnetic phenomenon which can degrade the performance of a device, equipment, or system or adversely affect living or inert matter.

EXAMPLE: An electromagnetic disturbance can be an electromagnetic noise, an unwanted signal, or a change in the propagation medium itself.

[SOURCE: ISO 11451-1]

3.18 ELECTROMAGNETIC INTERFERENCE (EMI)

Degradation of the performance of equipment, transmission channel, or system caused by electromagnetic disturbance.

NOTE 1: The English words “interference” and “disturbance” are often used indiscriminately.

[SOURCE: ISO 11451-1]

3.19 ELECTROMAGNETIC IMMUNITY (TO A DISTURBANCE)

Ability of a device, equipment, or system to perform without degradation in the presence of an electromagnetic disturbance.

[SOURCE: ISO 11451-1]

3.20 (ELECTROMAGNETIC) SUSCEPTIBILITY

Inability of a device, equipment, or system to perform without degradation in the presence of an electromagnetic disturbance.

NOTE 1: Susceptibility is the lack of immunity.

[SOURCE: ISO 11451-1]

3.21 ELECTROSTATIC DISCHARGE (ESD)

A transfer of electric charge between bodies of different electrostatic potential in proximity or through direct contact. (IEC 60050-161-01-22).

3.22 FORWARD POWER

Power supplied by the output of an amplifier or generator [SOURCE: ISO 11451-1].

3.23 FUNCTIONAL PERFORMANCE STATUS

Expected performance objectives for the function of the device under test subjected to the test conditions, agreed between the customer and the supplier which is specified in the test plan [SOURCE: ISO 11451-1].

3.24 GROUND (REFERENCE) PLANE

Flat conductive surface whose potential is used as a common reference.

[SOURCE: ISO 11451-1]

3.25 IMMUNITY LEVEL

Maximum level of a given electromagnetic disturbance incident on a particular device, equipment, or system for which it remains capable of operating at a required degree of performance.

[SOURCE: ISO 11451-1]

3.26 IMPEDANCE STABILIZATION IS

Network inserted in the telecommunication lines of the vehicle (in charging mode) which provides a specific load impedance and/or a decoupling (e.g., between telecommunication signal and power main).

3.27 INFORMATIVE APPENDIX

Applies here to classify an appendix that contains information that is advisory or explanatory in nature, as opposed to being mandatory.

3.28 MACHINE

An implement equipped with an internal combustion engine or electric motor but not self-propelled. Includes, but are not limited to, chain saws, irrigation pumps, and air compressors. (Adapted from CISPR 12, 5th edition)

3.29 MODULATION FACTOR (m)

The ratio of the peak variation of the envelope to the reference value. The reference value is usually taken to be the amplitude of the unmodulated wave. The value of m varies between 0 and 1.

3.30 NET POWER

Forward power in Watts minus reflected power in Watts at the same location on the transmission line.

3.31 NARROWBAND EMISSION

Emission which has a bandwidth less than that of a particular measuring apparatus or receiver.

[SOURCE: ISO 11451-1]

3.32 NORMATIVE APPENDIX

An appendix containing information whose use is mandatory when applying this standard.

3.33 POLARIZATION (of wave or field vector)

Property of sinusoidal electromagnetic wave or field vector defined at a fixed point in space by the direction of the electric field strength vector or of any specified field vector, when this direction varies with time.

NOTE 1: The property can be characterized by the locus described by the extremity of the considered field vector.

[SOURCE: ISO 11451-1]

3.34 PORTABLE TRANSMITTER

Hand-held radio frequency communication device.

NOTE 1: A portable transmitter could be a commercial device (e.g. cellular phone) or a simulated one.

[SOURCE: ISO 11451-1]

3.35 POWER MAINS

General purpose alternating current (AC) or direct current (DC) electric power supply.

[SOURCE: ISO 11451-1]

3.36 PULSE MODULATION PM

Process by which the amplitude of a carrier wave is varied following a specified law, resulting in a PM signal.

[SOURCE: ISO 11451-1]

3.37 QUALITY FACTOR (Q)

If a DUT has a frequency response with a center frequency $f_{DUT}$ and a –3 dB bandwidth (BW), Q is defined as the ratio of $f_{DUT}$ /BW.

3.38 (ELECTROMAGNETIC) RADIATION

Phenomenon by which energy in the form of electromagnetic waves emanates from a source into space; energy transferred through space in the form of electromagnetic waves.

NOTE 1: By extension, the term “electromagnetic radiation” sometimes also covers induction phenomena.

[SOURCE: ISO 11451-1]

3.39 REFLECTED POWER

Power reflected by the load due to impedance mismatch between RF-source and load.

[SOURCE: ISO 11451-1]

3.40 RESIDENTIAL ENVIRONMENT

Environment which has a 10 m protection distance between the source and the point of radio reception and where the source uses the public low voltage power system or battery power. For example, rooming houses, private dwellings, entertainment halls, theaters, schools, public streets, etc.

3.41 RF AMBIENT

The totality of electromagnetic phenomena existing at a given location. (Adapted from IEC 60050-161-01-01.)

3.42 RF BOUNDARY

An element of an EMC test set-up that separates that part of the harness and/or peripherals that is included in the RF environment and that part that is excluded. It may consist of, for example, ANs, BANs, filter feed-through pins, RF absorber coated wire, and/or shielding.

3.43 SHALL

Used to express a command; i.e., conformance with the specific recommendation is mandatory and deviation is not permitted. The use of the word “shall” is not qualified by the fact that compliance with the standard is considered voluntary.

3.44 SHIELDED ENCLOSURE SCREENED ROOM

Mesh or sheet metallic housing designed expressly for the purpose of separating electromagnetically the internal and external environment.

[SOURCE: ISO 11451-1]

3.45 STANDING WAVE RATIO SWR AND VOLTAGE STANDING WAVE RATIO VSWR

Ratio along a transmission line of a maximum to an adjacent minimum magnitude of a particular field component of a standing wave.

$$SWR = \frac{[1+r]}{(1-r)}$$

Where r is the absolute value of the coefficient of reflection.

[SOURCE: ISO 11451-1]

3.46 WIRELESS POWER TRANSFER (WPT)

The transfer of electrical energy from a power source to an electrical load via electric and/or magnetic field or waves between a primary and a secondary device.

3.47 TEST PLAN

The test plan is a document provided by the test requestor to define the tests to be done, the object of the testing, the vehicle or device under test (DUT) operating status, the conditions for the test and performance objectives. It directs the implementation of the test, by reference to the standard test procedure, or by detailing revisions or additions for the specific vehicle or DUT.

3.48 TRANSMISSION LINE SYSTEM TLS

Field-generating device that works in a similar way to a TEM (transverse electromagnetic) wave generator

EXAMPLE: Stripline, TEM cell, parallel plate

3.49 TRANSVERSE ELECTROMAGNETIC MODE (TEM); PRINCIPAL MODE (DEPRECIATED)

A mode in which both the longitudinal components of the electric and magnetic field strength vectors are everywhere zero. (Adapted from IEC 60050-726-03-08.)

3.50 VEHICLE; GROUND VEHICLE

A self-propelled machine (excluding aircraft and rail vehicles and boats over 10 m in length). Vehicles may be propelled by an internal combustion engine, electrical means, or both. Vehicles include but are not limited to automobiles, trucks, buses, mopeds, motorcycles, agricultural tractors, materials handling equipment, snowmobiles and small motorboats. (Adapted from CISPR 12, 5th Edition.)

4. OVERVIEW OF TEST METHODS

4.1 Radiated Emissions

The attributes for the radiated emissions tests are shown in Table 1.

***Table 1 - Radiated emissions test attributes***

| SAE J551 Part | Frequency Range | Test Distance | Comparable Standard |
|---|---|---|---|
| 2(1) | 30 to 1000 MHz | 10 or 3 m | CISPR 12 |
| 4(2) | 0.15 to 2500 MHz | NA | CISPR 25 |
| 5 | 0.15 to 30 MHz | 10 m | None |

1. SAE J551-2 is reserved for use to document differences from IEC CISPR 12. At the present time J551-2 is not used.
2. SAE J551-4 is reserved for use to document differences from IEC CISPR 25. At the present time J551-4 is not used.

NOTE: Future systems may require new tests.

4.2 Immunity

The attributes for the immunity tests are shown in Table 2.

***Table 2 - Immunity test attributes***

| SAE J551 Part | Test Type | Frequency Range | Comparable Standard |
|---|---|---|---|
| 11(1) | Off-vehicle source | 10 kHz to 18 GHz | ISO 11451-2 |
| 12(2) | On-vehicle source | 1.8 MHz to 1.3 GHz | ISO 11451-3 |
| 13(3) | Bulk Current Injection | 1 MHz to 400 MHz | ISO 11451-4 |
| 15 | Electrostatic Discharge | N/A | ISO 10605 |
| 16 | Reverberation | 80 MHz to 2 (or 10) GHz | None |
| 17 | Power Line Magnetic Fields | 50/60Hz | None |

1.SAE J551-11 is reserved for use to document differences from ISO 11451-2. At the present time J551-11 is not used.
2.SAE J551-12 is reserved for use to document differences from ISO 11451-3. At the present time J551-12 is not used
3.SAE J551-13 is reserved for use to document differences from ISO 11451-4. At the present time J551-13 is not used.

NOTE: Future systems may require new tests.

## 5. STANDARD EMISSIONS TEST REQUIREMENTS AND CONDITIONS

Standard test conditions are defined in IEC CISPR 12 and CISPR 25 and in SAE J551-5.

## 6. STANDARD IMMUNITY TEST PROCEDURES

The common characteristics for all of the immunity test parts of this document are described in this section.

Unless otherwise specified, tolerance for all test conditions and test parameters shall be ±10%.

### 6.1 Test Conditions

#### 6.1.1 Test Temperature

Maintain sufficient cooling in the chamber to prevent engine overheating while operating the test vehicle. Record the air temperature in the test chamber if it exceeds 23 °C ± 5 °C.

#### 6.1.2 Supply voltage

##### 6.1.2.1 Vehicle LV power supply

For tests that require the vehicle engine to be running, the electrical charging system shall be functional. For tests where the vehicle engine is not required to be running, unless other values are specified in the test plan, the battery voltage shall be maintained above 12 V for 12 V systems and above 24 V for 24 V systems.

##### 6.1.2.2 Hybrid or electric vehicle not connected to power mains

The minimum high voltage value shall be defined in the test plan.

##### 6.1.2.3 Hybrid or electric vehicle in charging mode (AC or DC)

The vehicle shall be immobilized, engine off and in charging mode.

The state of charge (SOC) of the traction battery shall be kept between 20 % and 80 % of the maximum SOC during the whole frequency range measurement (this may lead to split the measurement in different sub-bands with the need to discharge the vehicle's traction battery before starting the next sub-bands). If the current consumption can be adjusted in case of conductive charging, then the current shall be set to at least 80% of its nominal value. For WPT the transferred power shall be kept between 20% and 80% of the nominal value unless otherwise specified in the test plan. The air gap should be set to the value defined in the test plan, if it is adjustable.

The DC power supply voltage during the test shall be nominal ±10 %.

The AC power supply voltage during the test shall be nominal −14 % +10 %. The rated value of the frequency shall be nominal ±1 % the vehicle engine is not required to be running, unless other values are specified in the test plan, the LV power supply voltage shall be maintained above 12 V for 12 V systems and above 24 V for 24 V systems.

All the other equipment which can be switched on permanently by the driver or passenger shall be off.

NOTE: CISPR 12 and CISPR 25 may have different system voltage requirements.

6.1.3 Modulation

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 standard, the following shall be used:

a. No modulation (CW)

b. 1 kHz sinewave amplitude modulation (AM) 80% (See Appendix B, Constant Peak Test Method)

6.1.4 Dwell Time

At each frequency, the vehicle shall be exposed to the test level for a time equal to the response time of the vehicle system. If a dwell time is not specified in the test plan, or system response time is not specified, then the dwell time shall be 2 s minimum.

6.1.5 Frequency Steps

Two methods are presented. The logarithmic method is based on the Q of the DUT and is therefore the preferred method. The linear method is based on a fixed maximum frequency step size.

6.1.5.1 Logarithmic Method (Preferred)

Setting the immunity test frequencies using a logarithmic relationship is a technique that produces equally spaced frequency steps on a logarithmic scale. The number of steps per octave or decade are based on the expected Q of the DUT. The values agreed upon by the users of this standard shall be documented in the test report. The method of generating this frequency list is developed in Appendix C. Sample frequency lists are included. Figures C1 and C2 in Appendix C illustrates typical values of Q in each frequency segment.

6.1.5.2 Linear Method (Alternate)

Setting the immunity test frequencies using a linear relationship is a technique that produces equally spaced frequency steps on a linear scale. The linear method is based on a fixed maximum step size. The values agreed upon by the users of this standard shall be documented in the test report.

Table C1 in Appendix C illustrates the maximum frequency step size applicable to SAE J551 immunity tests using the linear step technique. Apply the steps according to the applicable frequency range of each SAE J551 part. Smaller step sizes are encouraged.

6.1.6 Test Signal Quality

The intent of narrowband immunity test is to expose the DUT to a single frequency. Often, certain test frequencies will produce significant harmonics of the fundamental. To ensure that harmonics do not skew the results, either do not test at any frequency that produces harmonics above –12 dBc or carefully document the condition in the test report. If a frequency is skipped due to harmonics, record it in the test report.

6.1.7 Threshold of Response

If a response or event is observed when applying or approaching the required test level, reduce the power 10 dB. Start incrementing the net power at a slow rate (e.g., 1.0 dB per 2 s) until the event is observed. Record this power level as the threshold value. The dwell time at each power increment should be determined by the response time of the DUT or 2 s, whichever is longer.

6.2 Test Methods

Immunity testing is commonly done using either one of two different techniques, (a) substitution and (b) closed loop leveling. This paragraph explains the control parameters of each.

a. The Substitution Method - The substitution method uses FORWARD POWER as the reference parameter that sets the test level during characterization and the immunity test. The specific test level (E-field, current, voltage or power) is characterized at each frequency per 6.1.4, by adjusting the forward power to produce the desired test level. This number is recorded and used as the reference parameter for the immunity test. This is done in an empty chamber (absorber lined shielded enclosure, TEM cell, tri-plate etc.) for immunity testing or with a characterization test fixture for bulk current injection. The vehicle test is conducted by subjecting the vehicle to the test levels at each frequency as determined in terms of forward power in the characterization phase.

b. The Closed-loop Leveling Method - This method does not require a characterization prior to the test, however, a pre-characterized sensor must be used to monitor the control parameter throughout the duration of the test .The signal generator level is adjusted based upon input from the control parameter until the desired test level is obtained.

6.2.1 Characterization

Verification of test item parameters shall be performed in accordance with individual test method's requirements. The test level versus frequency data shall be established using a CW signal. The method and results for each characterization point shall also be documented

6.2.2 Tests with a Vehicle

CAUTION: Hazardous radio frequency 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. IEEE C95.1 is the US National Standard addressing exposure of humans to electromagnetic fields.

The test shall employ the following process.

a. At each frequency, increase the level, linearly or logarithmically, up to the chosen test level. The rate of increase of the test level shall be controlled to ensure that excessive overshoot does not occur. The test level parameter is: (see Appendix A for guidance to set test level parameters):

1. The FORWARD POWER, related to the test signal severity level, for the substitution method. See Equation 1.

$$FORWARD\ POWER\ (Test\ signal) = FORWARD\ POWER\ (Char)\frac{[Test\ signal\ severity\ level]^k}{Char\ Level} \quad \text{(Eq. 1)}$$

where:

FORWARD POWER is in Watts
with k=1 for power test levels
k=2 for field, current or voltage test levels

2. The TEST SIGNAL SEVERITY LEVEL - Set to the desired field, current, voltage, or power for the closed-loop leveling method.

Table 3 gives the CW and AM test levels for the substitution method and for the closed loop leveling method.

***Table 3 - CW and Am test levels***

| | CW | AM |
|---|---|---|
| SUBSTITUTION Method | Forward Power | $\frac{(2+m^2)}{2(1+m)^2} \times (Forward\ Power)$ |
| CLOSED-LOOP Leveling Method | Test Signal Severity Level | Test Signal Severity Level |

where:

m is the modulation factor ($0 \leq m \leq 1$)

Both methods use a constant peak test level for CW and AM tests. The relationship between AM forward power and CW characterized forward power results from this principle (see Appendix B).

b. Maintain the test level for the minimum response time needed to exercise the vehicle (this minimum time of exposure shall be greater or equal to 2 s).

c. As necessary, decrease the test level by at least 20 dB before moving to the next frequency. The rate of decrease of the level shall be controlled to avoid irreproducible susceptibilities.

NOTE: Turning off the signal generator may cause irreproducible susceptibilities of the vehicle.

d. Step to the next frequency.

6.3 Test Severity Levels

For both substitution and closed-loop leveling methods and for CW and AM tests, the test severity levels of this standard are expressed in terms of equivalent RMS (root mean square level) value of an unmodulated wave (see Appendix B).

EXAMPLE: Test severity level of 20 V/m means that CW and AM test will be conducted for a 28 V/m peak value.

CAUTION: Field Strength Measurement of AM Modulated Wave - When using devices such as oscilloscopes, non-frequency selective voltmeters, or broadband field strength sensors to measure a modulated immunity test signal; correction factors shall be applied to adjust the reading to represent the equivalent RMS value for the peak of the modulation envelop. Modulation correction is determined by dividing (subtracting when using dB units) the reading of a continuous wave (CW) signal by the reading for a modulated signal (AM) of the same peak amplitude. The modulation correction might vary with frequency, amplitude, wave shape, and the modulation frequency.

7. NOTES

7.1 Marginal indicia

A change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

## APPENDIX A - FUNCTION PERFORMANCE STATUS CLASSIFICATION (BASED ON SAE J1812) (INFORMATIVE)

### A.1 SCOPE AND FIELD OF APPLICATION

This appendix provides a general method for defining function performance status classification for automotive electronic devices. These criteria are used to set limits for tests specified in this series of documents.

### A.2 GENERAL

Components or systems shall only be tested with the conditions as described in the main part of the document representing the simulated automotive electromagnetic environments to which the devices would actually be subjected. This will help to assure a technically and economically optimized design for potentially susceptible components and systems.

It should also be noted that this appendix is not intended to be a product specification and cannot function as one. Nevertheless, using the concepts described in this appendix and by careful application and agreement between manufacturer and supplier, this document could be used to describe the functional status requirements for a specific device. This could then, in fact, be a statement of how a particular device could be expected to perform under the influence of the specified interference signals.

### A.3 ESSENTIAL ELEMENTS OF FUNCTION PERFORMANCE STATUS CLASSIFICATION

Three elements are required to describe a function performance status classification. They can be generically applied to all immunity testing for electromagnetic disturbances (both conducted and radiated). These elements are:

#### A.3.1 Test Method and Test Signal

This element refers to the respective test signal(s) applied to the device under test and the method of test. This information is contained in the appropriate section of each part of this document.

#### A.3.2 Function Performance Status

This element defines the expected performance objectives for the function of the device under test subjected to the test conditions. The four Function Performance status (s) of the function (expected behavior of the function observed during test) are listed below:

1. **Status I:** Normal performance within the specification limits during and after exposure to a disturbance
2. **Status II:** Temporary degradation or loss of function or performance that is self-recoverable after the disturbance is removed
3. **Status III**: Temporary degradation or loss of function or performance which requires operator intervention or system reset after the disturbance is removed
4. **Status IV:** The device/function shall not have sustained any damage after the disturbance is removed.

#### A.3.3 Test Signal Level

This element defines the specification of test signal level and essential parameters. The test signal severity level is the stress level (voltage, volts per meter, etc.) applied to the device under test.

## A.4 APPLICATION OF FUNCTION PERFORMANCE STATUS AND TEST SIGNAL SEVERITY LEVEL

This illustration demonstrates the relationship between the test signal severity levels (Severity Levels) and their corresponding Function performance status (Status). In other words, based on the table listed below:

The function must exhibit: **Status I** performance up the severity level $L_{1i}$, **Status II** (status I allowed) performance up to severity level $L_{2i}$, etc.

In the test severity levels, the numerical index (1, 2, 3, 4) denotes the function performance status (I, II, III, IV) and the index i denotes the category (for illustration of an example, see appendix B).

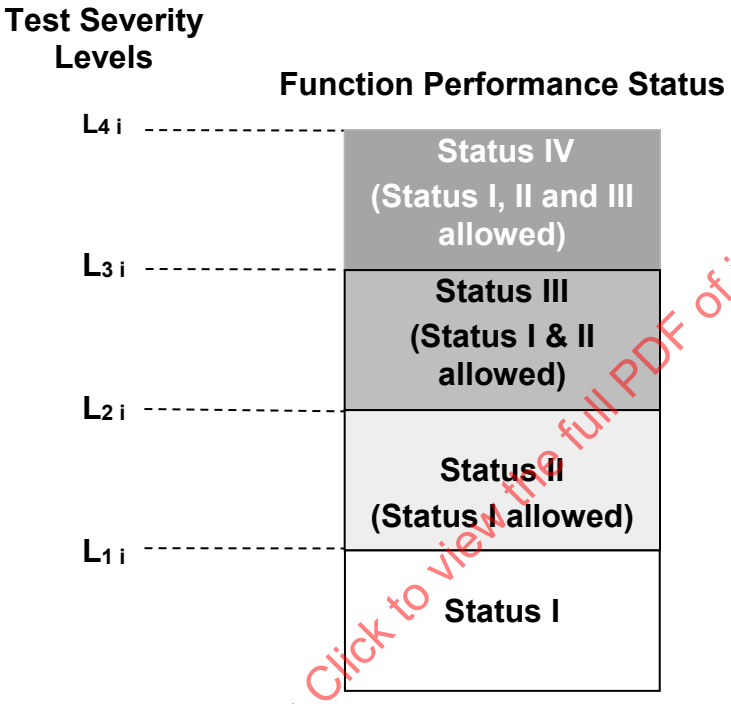


***Figure A1 - Illustration of function performance status classification***



## A.5 EXAMPLE OF APPLICATION OF FUNCTION PERFORMANCE STATUS CLASSIFICATION

In certain applications, the function performance status classification is required to be expressed in multiple categories (such as critical nature of the function as related to the operation of the vehicle or frequency bands of the test signals etc.).

This example illustrates the concept of how the function can be expressed for 3 different Categories (Figure A2).

NOTE: In the test severity levels, the numerical index (1, 2, 3, 4) denotes the function performance status (I, II, III, IV) and the index i denotes the category (1, 2, 3). For example, $L_{42}$ is the severity level for function classified as Status IV & category 2.

| Severity Levels | Category 1 | Category 2 | Category 3 |
|---|---|---|---|
| $L_{4i}$ | Status IV (Status I, II, III allowed) | Status IV (Status I, II, III allowed) | Status IV (Status I, II, III allowed) |
| $L_{3i}$ | Status III (Status I, II allowed) | Status III (Status I, II allowed) | Status III (Status I, II allowed) |
| $L_{2i}$ | Status II (Status I allowed) | Status II (Status I allowed) | Status II (Status I allowed) |
| $L_{1i}$ | Status I | Status I | Status I |

| Status | Category 1 | Category 2 | Category 3 |
|---|---|---|---|
| IV | $L_{41}$ | $L_{42}$ | $L_{43}$ |
| III | $L_{31}$ | $L_{32}$ | $L_{33}$ |
| II | $L_{21}$ | $L_{22}$ | $L_{23}$ |
| I | $L_{11}$ | $L_{12}$ | $L_{13}$ |

***Figure A2 - Illustration of FSPC with 3 categories***

NOTE: Refer to SAE J1812 for additional information.

APPENDIX B - CONSTANT PEAK TEST LEVEL
(FROM ISO 11451-1)
(INFORMATIVE)

This appendix explains the principle of constant peak test level and subsequent implications of power levels. See Figure B1.

B.1 UNMODULATED SIGNAL

The electric field strength of an unmodulated sine wave signal $E_{CW}$, can be written in the form as shown in Equation B1:

$$E_{CW} = E\cos(\omega t) \quad \text{(Eq. B1)}$$

where:

E is the peak value of $E_{CW}$.
$\omega$ is the frequency of the unmodulated signal (CW) (e.g., RF carrier)

The mean power of the unmodulated signal is calculated by Equation B2:

$$P_{CW} = kE^2 \quad \text{(Eq. B2)}$$

where:

$P_{CW}$ is the power for the unmodulated signal
k is a proportionality factor which is constant for a specific test setup

B.2 MODULATED SIGNAL

The electric field strength of an amplitude modulated signal, $E_{AM}$, can be written in the form as shown in Equation B3:

$$E_{AM} = E'[1 + m\cos(\theta t)]\cos(\omega t) \quad \text{(Eq. B3)}$$

where:

E' is the peak amplitude of the unmodulated signal
$E'(1+m) = E_{AMpeak}$ is the peak amplitude of the modulated signal $E_{AM}$
m is the modulation factor ($0 \leq m \leq 1$)
$\theta$ is the frequency of modulating signal (i.e., voice, baseband, 1 kHz CW, etc.)
$\omega$ is the frequency of the unmodulated signal (CW) (e.g., RF carrier)

The total mean power in an amplitude modulated signal is the sum of the power in the carrier component [$kE'^2$] and the total power in the sidebands component.

It may be calculated as follows:

$$P_{AM} = k\left(1 + \frac{m^2}{2}\right)E'^2 \quad \text{(Eq. B4)}$$

$\left(\frac{k}{2}E'^2m^2\right)$