SAE International™	SURFACE VEHICLE STANDARD	J551-1	REV. OCT2006
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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

This revision of SAE J551-1 reflects changes to existing parts of the series and the addition of a new test method.

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SAE J551-2 Withdrawn as a complete standard.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SAE J551-4 Withdrawn as a complete standard.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 Vehicle Electromagnetic Immunity—Off-Vehicle Source
SAE J551-12 Vehicle Electromagnetic Immunity—On-Board Transmitter Simulation
SAE J551-13 Vehicle Electromagnetic Immunity—Bulk Current Injection (BCI)
[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
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 or device powered by an internal combustion engine or electric motor. Operation of all engines (main and auxiliary) of a vehicle or device is included. All equipment normally operating when the engine is running is included. Operator controlled equipment is included or excluded as specified in the individual document parts.

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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 to the referenced edition of these documents 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 document with the exceptions to be documented in SAE J551-2 and SAE J551-4, 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 overvoltages and line transients is not covered by this document.

2. REFERENCES

2.1 Applicable Publications

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

2.1.1 SAE Publications

Available from SAE, 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 J551-11 Vehicle Electromagnetic Immunity—Off-Vehicle Source

SAE J551-12 Vehicle Electromagnetic Immunity—On-Board Transmitter Simulation

SAE J551-13 Vehicle Electromagnetic Immunity—Bulk Current Injection (BCI)

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 ANSI, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, www.ansi.org or IEEE, 445 Hoes Lane, Piscataway, NJ 08854-1331, Tel: 732-981-0060, www.ieee.org.

ANSI C63.2 American National Standard for Instrumentation—Electromagnetic Noise and Field Strength, 10 kHz to 40 GHz—Specifications

ANSI 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

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

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

2.1.3 CISPR Publications

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

CISPR 12 Edition 5.1 2005-04 Vehicles, boats, and internal combustion engine driven devices—Radio disturbance characteristics—Limits and methods of measurement for the protection of receivers except those installed in the vehicle/boat/device itself or in adjacent vehicles/boats/devices

CISPR 25 Second Edition 2002-08—Radio disturbance characteristics for the protection of receivers used on board vehicles, boats, and on devices—Limits and methods of measurement

2.1.4 IEC Publications

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

IEC Publication 60050-161 International Electrotechnical Vocabulary—Electromagnetic Compatibility

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

2.1.5 IEEE Publication

Available from IEEE, 445 Hoes Lane, Piscataway, NJ 08854-1331, Tel: 732-981-0060, www.ieee.org.

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

2.1.6 ISO Publications

Available from ANSI, 25 West 43rd Street, New York, NY 10036-8002, 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 for information purposes only and are not a required part of this specification.

2.2.1 SAE Publications

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

SAE paper 810333 "Implementation of EMC Testing of Automotive Vehicles," Kinderman, J.C., et al., February 1981

SAE paper 831011 "An Indoor 60 Hz to 40 GHz Facility for Total Vehicle EMC Testing," Vrooman, June 1983

2.2.2 ANSI Publications

Available from ANSI, 25 West 43rd Street, New York, NY 10036-8002, 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 CISPR Publication

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

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

2.2.4 ISO Publication

Available from ANSI, 25 West 43rd Street, New York, NY 10036-8002, 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, 445 Hoes Lane, Piscataway, NJ 08854-1331, 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 Inter. 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 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 (ALSE)

A shielded room with RF absorbing material on its internal ceiling and walls.

NOTE: The common practice is to have the metallic floor of the ALSE exposed (semi-anechoic condition), or absorbing material may be placed over the entire floor area (fully anechoic condition). (Adapted from ISO 11451-1.)

3.2 Amplitude Modulation (AM)

The process by which the amplitude of a carrier wave is varied following a specified law. The result of the process is an AM signal. (Adapted from ISO 11451-1.)

3.3 Artificial Network (AN); Line Impedance Stabilization Network (LISN)

A network inserted in the supply leads of apparatus to be tested which provides, in a given frequency range, a specified load impedance for the measurement of disturbance voltages and which isolates the apparatus from the power supply in that frequency range. (Adapted from IEC 60050-161-04-05.)

3.4 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.

3.5 Bulk Current

The total amount of common mode current in a harness. (ISO 11451-1.)

3.6 Bulk Current Injection Probe

A device for injecting current in a conductor without interrupting the conductor and without introducing significant impedance into the associated circuits.

3.7 Class

A performance level agreed upon by the purchaser and the supplier and documented in the test plan. (CISPR 25:1995.)

3.8 Coupling

A means or a device for transferring power between systems. (IEC 60050-726-14-01.)

3.9 Current Probe (Measuring or Monitoring)

A device for measuring the current in a conductor without interrupting the conductor and without introducing significant impedance into the associated circuits. (Adapted from IEC 60050-161-04-35.)

3.10 Degradation (of performance)

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

NOTE: The term “degradation” can apply to temporary or permanent failure. (IEC 60050-161-01-19.)

3.11 Device

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

3.12 Directional Coupler

A three- or 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 dependant upon that of the former. (Adapted from IEC 60050-726-14-02.)

3.13 Electromagnetic Compatibility (EMC)

The ability of an equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment. (IEC 60050-161-01-07.)

3.14 Electromagnetic Disturbance

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

NOTE: An electromagnetic disturbance may be an electromagnetic noise, an unwanted signal or a change in the propagation medium itself. (IEC 60050161-01-05.)

3.15 Electromagnetic Immunity (to a disturbance)

The ability of a device, equipment or system to perform without degradation in the presence of an electromagnetic disturbance. (Adapted from IEC 60050-161-01-20.)

3.16 (Electromagnetic) Susceptibility

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

NOTE: Susceptibility is the lack of immunity. (IEC 60050-161-01-21.)

3.17 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.)

3.18 Forward Power

That power supplied by the output of an amplifier (or generator) traveling towards the load. (Adapted from ISO 11451-1.)

3.19 Ground (Reference) Plane

A flat conductive surface whose potential is used as a common reference. (IEC 60050-161-04-36.)

3.20 Immunity Level

The 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. (IEC 60050-161-03-14.)

3.21 Informative Appendix

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

3.22 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.)

3.23 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.

3.24 Net Power

Forward power minus reflected power at the same location on the transmission line. (Adapted from ISO 11451-1.)

3.25 Normative Appendix

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

3.26 Polarization (of a Wave or Field Vector)

The property of a 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. The property may be characterized by the locus described by the extremity of the considered field vector. (IEC 60050-726-04-01.)

3.27 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.

3.28 Reflected Power

That power traveling toward the amplifier (or generator) reflected by the load caused by impedance mismatch between the transmission line and the load. (Adapted from ISO 11451-1.)

3.29 Representative Frequency

A selected frequency from a sub-band that is used to determine the maximum emission level for that sub-band. For example, the representative frequency for the 30 to 34 MHz sub-band is 32 MHz. (CISPR 12, 5th Edition.)

3.30 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.

3.31 RF Ambient (Electromagnetic Environment)

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

3.32 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.

3.33 RF Disturbance Power

It is the amount of RF power measured (difference remaining) between two measurements the first being made without suppression and the second made with suppression is present.

3.34 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.

3.35 Shielded Enclosure / Screened Room

A mesh or sheet metallic housing designed expressly for the purpose of separating electromagnetically the internal and the external environment. (IEC 60050-161-04-37.)

3.36 Standing Wave Ratio (in a Transmission Line) (SWR); Voltage Standing Wave Ratio (VSWR)

The ratio, along a transmission line, of a maximum to an adjacent minimum magnitude of a particular field component of a standing wave. (Adapted from IEC 60050-726-07-09.)

NOTE: SWR or VSWR is usually measured in terms of line voltage or line current.

3.37 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.

3.38 Transmission Line System (TLS)

A field generating device which works like a TEM wave generator. Examples are: strip-line, TEM cell, parallel plate, etc. (adapted from ISO 11451-1.)

3.39 Transverse Electromagnetic Mode; TEM mode; 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.)

3.40 Vehicle; Ground-Vehicle

A self-propelled machine (excluding aircraft and rail vehicles and boats over 10 meters 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	Test Type	Frequency Range	Test Distance	Comparable Standard
2[(1)]	Broadband	30 to 1000 MHz	10 or 3 m	CISPR 12
	Narrowband	0.15 to 1000 MHz	10 or 3 m	CISPR 12
4[(2)]	Broad and Narrow	0.15 to 2500 MHz	NA	CISPR 25
5	Broad and Narrow	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	Off-vehicle source	10 kHz to 18 GHz	ISO 11451-2
12	On-vehicle source	1.8 MHz to 1.3 GHz	ISO 11451-3
13	Bulk Current Injection	1 MHz to 400 MHz	ISO 11451-4
15	Electrostatic Discharge	N/A	ISO 10605
16	Reverberation	80 MHz to 2 (10) GHz	None
17	Power Line Magnetic Fields	50/60Hz	None

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 and Supply Voltage

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.

When the vehicle engine is required to be operating, ensure that the electrical charging system is functional. In tests when the vehicle engine is not required to be operating, maintain battery voltage above 12.2 V for the 12 volt system or 24.4 V for the 24 volt system.

6.1.2 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)

6.1.3 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 shall be 2 seconds minimum.

6.1.4 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.

6.1.4.1 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.

6.1.4.2 Linear Method (Alternate)

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. For SAE J551-12, “On-Board Transmitter simulation”, use the step sizes defined in that document.

6.1.5 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.

6.1.6 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 seconds) 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 seconds which ever 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 NET 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 net 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 net power in the characterization phase.

   Measurements using the substitution method can be affected by coupling between the antenna and the vehicle as well as by reflected energy. During the test, the net power shall be set to the characterization net power level with a limit of –0 to a +2 dB increase in the forward power.

NOTE 1: If forward power has to be increased by 2 dB or more, this shall be indicated in the test report.

NOTE 2: If 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.

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

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

   where:

   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	Net Power	$\frac{(2+m^2)}{2(1+m)^2} \times (\text{Net Power})$
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 net power and CW characterized net 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 seconds).

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 unreproducible susceptibilities.

NOTE: Turning off the signal generator may cause unreproducible 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-meansquare 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, waveshape, and the modulation frequency.

7. NOTES

7.1 Marginal indicia

The change bar (l) located in the left margin is for the convenience of the user in locating areas where technical 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.

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. This criteria is 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 which 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_1**, **Status II** (status I allowed) performance up to severity level **L_2**, etc.

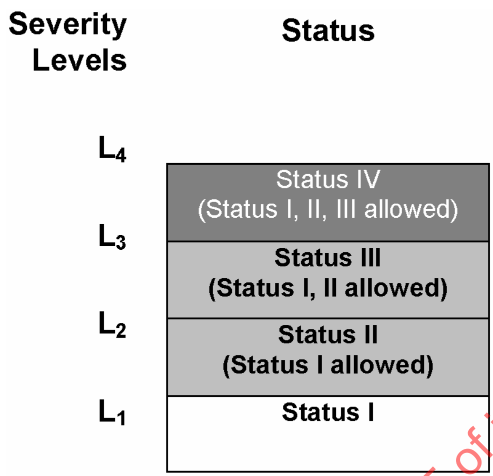

FIGURE A1 - ILLUSTRATION OF FUNCTION PERFORMANCE STATUS CLASSIFICATION

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 Groups (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 how the function can be expressed for 3 different Groups (Figure A.2).

Severity Levels	Group 1	Group 2	Group 3
L_4	Status IV (Status I, II, III allowed)	Status IV (Status I, II, III allowed)	Status IV (Status I, II, III allowed)
L_3	**Status III (Status I, II allowed)**	**Status III (Status I, II allowed)**	**Status III (Status I, II allowed)**
L_2	**Status II (Status I allowed)**	**Status II (Status I allowed)**	**Status II (Status I allowed)**
L_1	**Status I**	**Status I**	**Status I**

Status	Group 1	Group 2	*Group 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 GROUPS

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:

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

where:

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

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

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

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:

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

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 ($0 \le m \le 1$)
θ is the frequency of modulating signal (i.e., voice, baseband, 1 kHz CW, etc)
ω 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:

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

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