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SURFACE VEHICLE STANDARD

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(R) Performance Levels and Methods of Measurement of Electromagnetic Compatibility of Vehicles, Boats (up to 15 m), and Machines (50 Hz TO 18 GHz)

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 Limits and Methods of Measurement of Radio Disturbance Characteristics of Vehicles, Motorboats and Spark-ignited Engine-driven Devices
[Part 3 reserved for future use]
SAE J551–4 Test Limits and Methods of Measurement of Radio Disturbance Characteristics of Vehicles and Devices, Broadband and Narrowband, 150 kHz to 1000 MHz
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)
SAE J551–14 Vehicle Electromagnetic Immunity—Reverberation Chamber [Draft Only]
SAE J551–15 Vehicle Electromagnetic Immunity—Electrostatic Discharge (ESD)
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.

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 Part 2 of this document 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 PUBLICATION—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J551-2—Limits and Methods of Measurement of Radio Disturbance Characteristics of Vehicles, Motorboats and Spark-ignited Engine-driven Devices [Part 3 reserved for future use]
SAE J551-4—Test Limits and Methods of Measurement of Radio Disturbance Characteristics of Vehicles and Devices, Broadband and Narrowband, 150 kHz to 1000 MHz
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)
SAE J551-14—Vehicle Electromagnetic Immunity—Reverberation Chamber [Draft Only]
SAE J551-15—Vehicle Electromagnetic Immunity—Electrostatic Discharge (ESD)
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 or IEEE, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331.

ANSI C63.2–1996—American National Standard for Instrumentation—Electromagnetic Noise and Field Strength, 10 kHz to 40 GHz - Specifications
ANSI C63.4–1992—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 C95.1–1999—American National Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz
ANSI/IEEE STD 100–1993—Standard Dictionary of Electrical and Electronic Terms
ANSI/IEEE Dictionary of Technological Terms

2.1.3 CISPR PUBLICATIONS—Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002.

CISPR 12 5th Edition—Limits and methods of measurement of radio disturbance characteristics of vehicles, motorboats, and spark-ignited engine-driven devices
CISPR 16–1: Edition 1.1 1998—Specification for radio disturbance and immunity measuring apparatus and methods–Part 1: Radio disturbance and immunity measuring apparatus
CISPR 25:1995 Limits and methods of measurement of radio disturbance characteristics for the protection of receivers used on-board vehicles

2.1.4 IEC PUBLICATIONS—Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002.

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, Inc., 445 Hoes Lane, PO Box 1331, Piscataway NJ 08855-1331.

IEEE STD 291–1991 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, 11 West 42nd Street, New York, NY 10036-8002.

ISO 10605:1992 Road vehicles—Electrical disturbances from electrostatic discharges
ISO 11451:1997 Road vehicles—Electrical disturbances by narrowband radiated electromagnetic energy—Vehicle test methods
ISO 11451-1—Road vehicles—Component test methods for electrical disturbances from narrowband radiated electromagnetic energy—Part 1: General and definitions
ISO 11451-2—Road vehicles—Electrical disturbances by narrowband radiated electromagnetic energy—Component test methods—Part 2: Absorber-lined chamber
ISO 11451-3—Road vehicles—Component test methods for electrical disturbances from narrowband radiated electromagnetic energy—Part 3: Transverse electromagnetic mode (TEM) cell
ISO 11451-4—Road vehicles—Components test methods for electrical disturbances from narrowband radiated electromagnetic energy—Part 4: Bulk current injection (BCI)
ISO 11451-6—Road vehicles—Electrical disturbances by narrowband radiated electromagnetic energy—Component test methods—Part 6: Parallel plate antenna

2.1.7 NCRP PUBLICATIONS—Available from The National Council on Radiation Protection (NCRP), ?????

MENTIONS IN TEXT ABOUT A STANDARD BUT NO NUMBER IS GIVEN.

2.1.8 UL PUBLICATIONS—Available from Underwriters Laboratories, 333 Pfingsten Road, Northbrook, IL 60062-2096.

IT MENTIONS UL STANDARDS IN THE TEXT BUT DOES NOT GIVE ANY NUMBERS.

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.

HS–3600 –1999 Edition—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 or IEEE, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331.

ANSI C63.5–1998—American National Standard for Electromagnetic Compatibility–Radiated Emissions Measurements in Electromagnetic Interference (EMI) Control–Calibration of Antennas (9 kHz to 40GHz)
ANSI C63.14–1998—Standard Dictionary for Technologies of Electromagnetic Compatibility (EMC), Electromagnetic Pulse (EMP), and Electrostatic Discharge (ESD)
ANSI C63.16–1993—American1 National Standard Guide for Electrostatic Discharge Test Methodologies and Criteria for Electronic Equipment

2.2.3 CISPR PUBLICATIONS—Available from ANSI, 25 West 43rd Street, New York, NY 10036-8002.

CISPR 16–2: First Edition 1996—Part 2—Specification for radio disturbance and immunity measuring apparatus and methods–Part 2: Methods of Measurement of Disturbances and Immunity
CISPR 22—Limits and methods of measurement of radio interference characteristics of information technology equipment

2.2.4 ISO PUBLICATIONS—Available from ANSI, 25 West 43rd Street, New York, NY 10036-8002.

ISO 10305:1992—Generation of standard em fields for calibration of power density meters 20 kHz to 1000 MHz

2.2.5 IEEE PUBLICATION—Available from IEEE, Inc., 445 Hoes Lane, PO Box 1331, Piscataway NJ 08855-1331.

IEEE STD 211–1997 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 (abbreviation)—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 (abbreviation)—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 Antenna Correction Factor—The factor which is applied to the voltage measured at the input connector of the measuring instrument comprised of the antenna factor, cable factor and other factors to give the field strength at the antenna. (Adapted from CISPR 25:1995.)

3.4 Antenna Factor—The ratio of the average field strength (V/m) surrounding the antenna to the voltage (V) present at its output terminals. Antenna factor is expressed in the units (1/meters).

3.5 Antenna Matching Unit—A unit for matching the impedance of an antenna to that of the 50 measuring receiver over the antenna measuring frequency range. (CISPR 25:1995.)

3.6 Artificial Network AN (abbreviation); Line Impedance Stabilization Network LISN (abbreviation USA)— 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.)

3.7 Average Detector—A detector the output voltage of which is the average value of the envelope of an applied signal.

NOTE— The average must be taken over a specified time interval. (IEC 60050(161)–04–26.)

3.8 Bandwidth—The width of a frequency band over which a given characteristic of an equipment or transmission channel does not differ from its reference value by more than a specified amount or ratio. (Adapted from IEC 60050(161)–06–09.)

3.9 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.

3.10 Broadband Emission—An emission which has a bandwidth greater than that of a particular measuring apparatus or receiver. (IEC 60050(161)–06–11.)

3.11 Broadband Emission (Short Duration)—An emission that possesses a spectrum broad in width as compared to the nominal bandwidth of the measuring instrument, and whose spectral components are sufficiently close together and uniform so that the measuring instrument cannot resolve them and the duration is less than six seconds. (Adapted from ANSI C-63.4.)

3.12 Bulk Current—The total amount of common mode current in a harness. (ISO 11451–1.)

3.13 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.

3.14 Characteristic Level—The controlling (or dominant) emission level experienced in each frequency sub-band. The characteristic level is the maximum measurement obtained for both antenna polarizations and for all the specified measurement positions of the vehicle or device. Known ambient signals shall not be considered part of the characteristic level. (CISPR 12, 5th Edition.)

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

3.16 Component Conducted Emissions—The noise voltages/currents of a nature existing on the supply or other wires of a component/module. (Adapted from CISPR 25:1995.)

3.17 Compression Point—The input signal level at which the gain of the measuring system becomes nonlinear such that the indicated output deviates from an ideal linear receiving system's output by the specified increment in dB. (CISPR 25:1995.)

3.18 Coupling—A means or a device for transferring power between systems. (IEC 60050 (726)–14–01.)

3.19 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.)

3.20 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.)

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

3.22 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.)

3.23 Disturbance Suppression—Action which reduces or eliminates electromagnetic disturbance. (IEC 60050(161)–03–22.)

3.24 Disturbance Voltage / Interference Voltage—Voltage produced between two points on separate conductors by an electromagnetic disturbance, measured under specified conditions. (Adapted from IEC 60050(161)–04–01.)

3.25 Electromagnetic Compatibility EMC (abbreviation)—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.)

3.26 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 60050(161)–01–05.)

3.27 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.)

3.28 Electromagnetic Interference EMI (abbreviation)—Degradation of the performance of an equipment, transmission channel or system caused by an electromagnetic disturbance.

NOTE— The English words “interference” and “disturbance” are often used indiscriminately. (IEC 60050(161)–01–06.)

3.29 (Electromagnetic) Radiation

1. The phenomena by which energy in the form of electromagnetic waves emanates from a source into space.
2. Energy transferred through space in the form of electromagnetic waves.

NOTE— By extension, the term “electromagnetic radiation” sometimes also covers induction phenomena. (IEC 60050(161)–01–10.)

3.30 (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.)

3.31 Electrostatic Discharge ESD (Abbreviation)—A transfer of electric charge between bodies of different electrostatic potential in proximity or through direct contact. (IEC 60050(161)–01–22.)

3.32 Forward Power—That power supplied by the output of an amplifier (or generator) traveling towards the load. (Adapted from ISO 11451–1.)

3.33 Frequency Sub-Bands—Frequency bands that contain approximately three bands in each octave (2:1 frequency ratio). Where the limit is not constant (i.e., slopes), the ratio of the highest frequency to lowest frequency in each band shall be no greater than 1.34. For example, the frequency range of 30 MHz to 1000 MHz is divided into 14 sub-bands. (CISPR 12, 5th Edition.)

3.34 Ground (Reference) Plane—A flat conductive surface whose potential is used as a common reference. (IEC 60050(161)–04–36.)

3.35 Ignition Noise Suppressor—That portion of a high-voltage ignition circuit intended to limit the emission of impulsive ignition noise. (CISPR 12, 5th Edition.)

3.36 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.)

3.37 Impulse Noise—Noise characterized by transient disturbances separated in time by quiescent intervals.

NOTE— The typical frequency spectrum of these disturbances will be substantially uniform over the pass band of the transmission system. (Adapted from ANSI/IEEE Std 100.)

3.38 Impulsive Ignition Noise—The unwanted emission of electromagnetic energy, predominantly impulsive in content, arising from the ignition system within a vehicle or device. (CISPR 12, 5th Edition.)

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

3.40 Interference Suppression—Action which reduces or eliminates electromagnetic interference. (IEC 60050(161)–03–23.)

3.41 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.)

3.42 Measuring Instrument Impulse Bandwidth—The maximum value of the output response envelope divided by the spectrum amplitude of an applied impulse.

3.43 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.

3.44 Narrowband Emission—An emission which has a bandwidth less than that of a particular measuring apparatus or receiver. (IEC 60050(161)–06–13.)

3.45 Net Power—Forward power minus reflected power at the same location on the transmission line. (Adapted from ISO 11451–1.)

3.46 Normative Appendix—An appendix containing information whose use is mandatory when applying this standard.

3.47 Peak Detector—A detector, the output voltage of which is the peak value of an applied signal. (IEC 60050(161)–04–24.)

3.48 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.)

3.49 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.

3.50 Quasi-peak Detector—A detector having specified electrical time constants which, when regularly repeated identical pulses are applied to it, delivers an output voltage which is a fraction of the peak value of the pulses, the fraction increasing towards unity as the pulse repetition rate is increased. (IEC 60050(161)–04–21.)

3.51 Receiver Terminal Voltage—The external voltage measured in dB (V) at the input of a radio interference measuring instrument conforming to the requirements of CISPR Publication 16-1: Edition 1.1 1998 or ANSI C63.2. (Adapted from CISPR 25:1995.)

3.52 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.)

3.53 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.)

3.54 Residential Environment—The residential environment 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.

3.55 Resistive Distributor Brush—A resistive pick-up brush in an ignition distributor cap. (CISPR 12, 5th Edition.)

3.56 RF Ambient (Electromagnetic Environment)—The totality of electromagnetic phenomena existing at a given location. (Adapted from IEC 60050(161)–01–01.)

3.57 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.

3.58 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.

3.59 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.

3.60 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.)

3.61 Standing Wave Ratio (in a Transmission Line); SWR (abbreviation); Voltage Standing Wave Ratios; VSWR (abbreviation)—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.

3.62 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.

3.63 Tracking Generator—A test signal oscillator (CW) that is frequency locked to the receive frequency of a measuring instrument. (CISPR 12, 5th Edition.)

3.64 Transmission Line System TLS (abbreviation)—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.)

3.65 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.)

3.66 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	Broadband	30 to 1000 MHz	10 or 3 m	CISPR 12
	Narrowband	0.15 to 1000 MHz	10 or 3 m	CISPR 12
4	Broad and Narrow	0.15 to 1000 MHz	NA	CISPR 25
5	Broad and Narrow	0.15 to 30 MHz	10 m	None

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
14	Reverberation Chamber	200 MHz to 18 GHz	None
15	Electrostatic Discharge	N/A	ISO 10605
17	Power Line Magnetic Fields	50/60Hz	ISO 11451-6

NOTE— Future systems may require new tests.

5. Standard Emissions Test Requirements and Conditions—Standard test conditions are defined in SAE J551 Parts –2, -4, and –5.

6. Standard Immunity Test Procedures—The common characteristics for all of the immunity test parts of this document are described in this section.

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 D. Sample frequency lists are included. Figures D1 and D2 in Appendix D illustrates typical values of Q in each frequency segment.

*6.1.4.2 Linear Method (Alternate)—*Table D1 in Appendix D 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.

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

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 ($0 \le m \le 1$)

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.

PREPARED BY THE SAE EMI AND EMR STANDARDS COMMITTEE

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—Four 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—The test procedures used and methods of application are to be described in specific standards. The function performance status classification resulting from these tests would be applicable only to those particular standards.

A.3.2 Functional Status Classifications—This element classifies the operational status of the function for an electrical/electronic device within the vehicle. Three classes have been established as follows:

Class A—Any function that provides a convenience (e.g., entertainment, comfort).
Class B—Any function that enhances, but is not essential to the operation or control of the vehicle (e.g., speed display).
Class C—Any function that is essential to the operation or control of the vehicle (e.g., braking, engine management).

A.3.3 Region of Performance—This element describes the region, bounded by two test signal levels, that defines the expected performance objectives of the device under test.

Region I The function shall operate as designed during and after exposure to a disturbance.
Region II The function may deviate from design but will return to normal after the disturbance is removed.
Region III The function may deviate from designed performance during exposure to a disturbance but simple operator action may be required to return the function to normal, once the disturbance is removed.
Region IV The device/function may deviate, but shall not exhibit any damage after the disturbance is removed.

A.3.4 Test Signal Level—The test signal severity level is the stress level (voltage, volts per meter, etc.) applied to the device under test for any given test method and region of performance during the test.

The test signal severity should be determined by the vehicle manufacturer and supplier (examples for how the test signal severity level could be applied are included in the Figure A1).

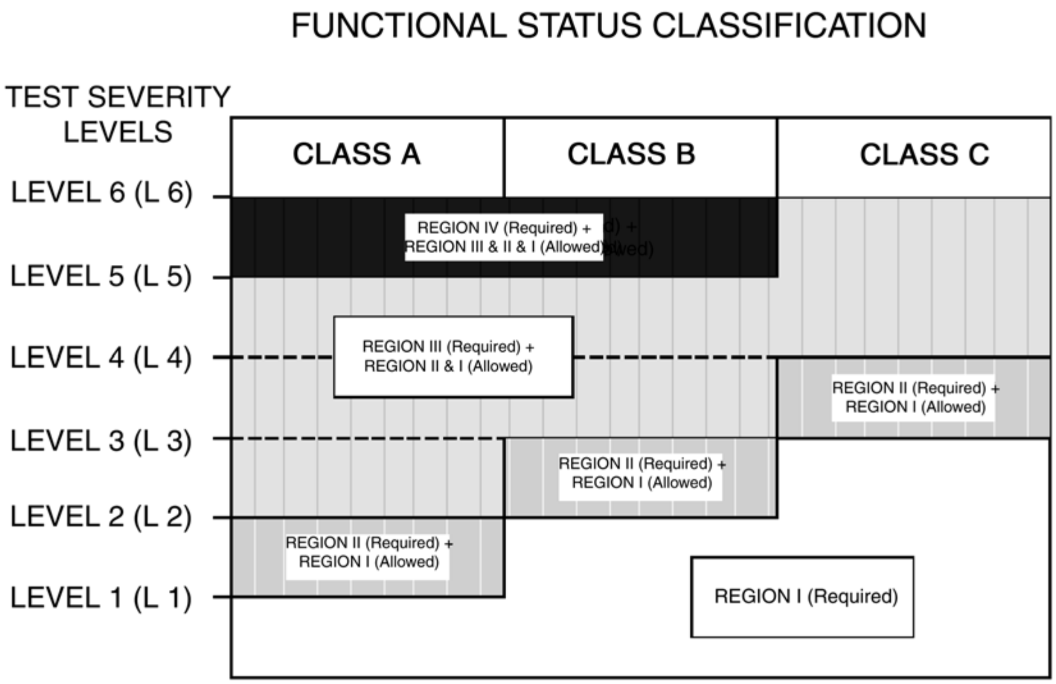


FIGURE A1—FUNCTION PERFORMANCE STATUS CLASSIFICATIONS

A.4 Example of Test Signal Severity Level Selection Table—Table A1 illustrates an example table of test signal severity levels for Radiated Immunity Testing as applicable to SAE J551-11 – Radiated Immunity Testing

TABLE A1—EXAMPLE OF TEST SIGNAL SEVERITY LEVEL SELECTION TABLE

Test Signal Severity Levels	E Field Strength (volts/meter)
L6	E
L5	0.8 x E
L4	0.6 x E
L3	0.4 x E
L2	0.2 x E
L1	0.1 x E

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}.
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:

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

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 ($0 \le m \le 1$)
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

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

It may be calculated as follows:

$$P_{AM} = k\left(1 + \frac{m^2}{2}\right)E'^2 \quad \text{(Eq. B5)}$$

B.3 Peak Conservation—For peak test level conservation, the peak amplitude of the unmodulated and modulated signals are defined to be identical.

$$E_{CW\ peak} = E_{AM\ peak} \quad \text{(Eq. B6)}$$

There are two ways to adjust the signal to maintain peak conservation.

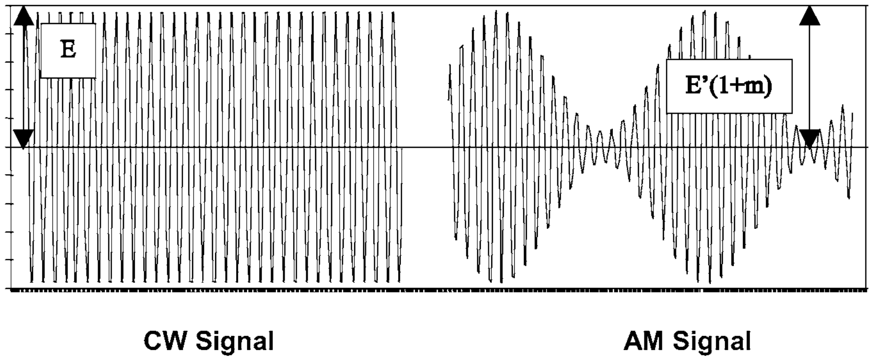


FIGURE B1—CONSTANT PEAK TEST LEVEL COMPARISON

B.3.1 Measure the Ratio of Modulated Power to CW Power—The relationship between CW power and AM power (using peak test level conservation) is given by Equation B7:

$$\frac{P_{AM}}{P_{CW}} = \frac{k\left[\left(1+\frac{m^2}{2}\right)E'^2\right]}{kE^2} = \left(1+\frac{m^2}{2}\right)\left(\frac{E'}{E}\right)2 = \frac{\left(1+\frac{m^2}{2}\right)}{(1+m)^2} \quad \text{(Eq. B7)}$$

Therefore:

$$P_{AM} = P_{CW}\frac{2+m^2}{2(1+m)^2} \quad \text{(Eq. B8)}$$

For m=0.8 (AM 1 kHz 80%), this relationship gives:

$$P_{AM} = 0.407\ P_{CW} \quad \text{(Eq. B9)}$$

B.3.2 Measure the Ratio of Power in the Unmodulated Peak Test Level Conservation Signal to the CW Power—The power of the CW carrier in the reduced signal (used to develop the peak test level conservation wave) is often compared to the power of the CW signal used for certification.

The relationship is:

$$\frac{P_{CWbefore\ modulation}}{P_{CW}} = \left(\frac{1}{1+m}\right)^2 \quad \text{(Eq. B10)}$$

Therefore:

$$P_{CWbefore\ modulation} = P_{CW}\left(\frac{1}{1+m}\right)2 \quad \text{(Eq. B11)}$$

for m=0.8 (AM 1kHz 80%), this relationship gives:

$$P_{CWbefore\ modulation} = 0.309P_{CW} \quad \text{(Eq. B12)}$$

APPENDIX C

ROD ANTENNA (MONOPOLE) /MATCHING NETWORK—PERFORMANCE EQUATIONS AND CHARACTERIZATION THE EQUIVALENT CAPACITANCE SUBSTITUTION METHOD (NORMATIVE)

C.1 Rod (Monopole) Performance Equations— The following equations are used to determine the effective height, self-capacitance and height correction factor of rod or monopole antennas of unusual dimensions. They are valid only for rod antennas shorter than λ/4.

$$h_e = \frac{\lambda}{2\pi}\tan\left(\frac{\pi h}{\lambda}\right) \quad \text{(Eq. C1)}$$

$$c_a = \frac{55.6h}{1n\left(\frac{h}{a}\right) - 1}\left(\frac{\tan\frac{2\pi h}{\lambda}}{\frac{2\pi h}{\lambda}}\right) \quad \text{(Eq. C2)}$$

$$C_h = 20\log(h_e) \quad \text{(Eq. C3)}$$

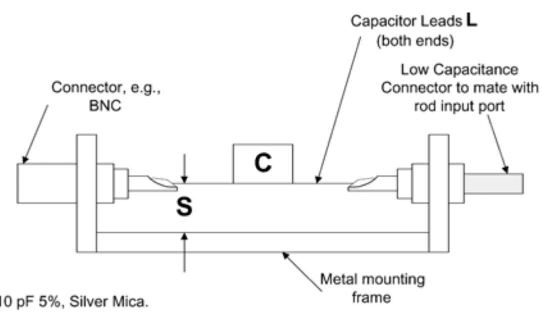
where:

h_e is the effective height of the antenna in meters
h is the actual height (length) of the rod element in meters
λ =is the wavelength in meters
C_a is the self-capacitance of the rod antenna in pF
a is the radius at the base of the rod element in meters
C_h is the height correction factor in dB(m)

C.2 Dummy Antenna Considerations

NOTE— The capacitor used as the dummy antenna should be mounted in a small metal box or on a small metal frame. The leads must be kept as short as possible and kept close to the surface of the metal box or frame. A spacing of 5 to 10 mm is recommended. See Figure C1.

The T-connector used in the antenna factor measurement setup may be built into the dummy antenna box. The resistor pad to provide matching to the generator may also be built into the dummy antenna box.



C: 10 pF 5%, Silver Mica.

S: Lead Spacing, 5 to 10 mm (10 mm from all surfaces if enclosed in box).

L: Lead length, as short as possible but not greater than 12 mm. (Total lead length not greater than 40 mm including both capacitor leads and length of rod port connector.)

FIGURE C1—EXAMPLE OF CAPACITOR MOUNTING IN DUMMY ANTENNA

C.3 ***Characterization Method—***The equivalent capacitance substitution method uses a dummy antenna in place of the actual rod element and is based on IEEE Std 291-1991. The primary component of the dummy antenna is a capacitor equal to the self-capacitance of the rod or monopole. This dummy antenna is fed by a signal source and the output from the coupler or base unit of the antenna is measured using the test configuration shown in Figure C2. The antenna factor in dB(1/m) is given by Equation C4, where the input impedance of the matching unit or receiver is much greater than the resistive component of source impedance of the antenna.

$$AF = V_D - V_L - C_h \quad \text{(Eq. C4)}$$

where:

V_D is the measured output of the signal generator in dB(μV)
V_L is the measured output of the coupler in dB(μV)
C_h is the correction factor for the effective height in dB(m)

For the 1 m rod commonly used in EMC measurements, the effective height (h_e) is 0.5 m, the height correction factor (C_h) is –6 dB(m) and the self-capacitance (C_a) is 10 pF.

NOTE— See Section C.1 to calculate the effective height, height correction factor and self– capacitance of rod antennas of unusual dimensions.

Either of two procedures shall be used: (a) the network analyzer, or (b) the signal generator and radionoise meter method. The same dummy antenna is used in both procedures. See Section C.2 for guidance in making a dummy antenna. Measurements shall be made at a sufficient number of frequencies to obtain a smooth curve of antenna factor versus frequency over the operating range of the antenna or 9 kHz to 30 MHz, whichever is smaller.

a. Network Analyzer Procedure.

1. Calibrate the network analyzer with the cables to be used in the measurements.
2. Setup the antenna to be characterized and the test equipment as shown in Figure C2(a).
3. Subtract the signal level (in dB) in the reference channel from the signal level (in dB) in the test channel and subtract C_h (–6 dB for the 1 m rod) to obtain the antenna factor (in dB) of the antenna.

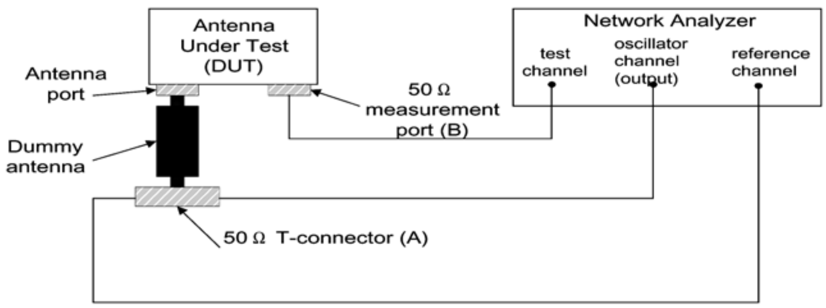
NOTE— Attenuator pads are not needed with the network analyzer because the impedances of the channels in the network analyzer are very nearly 50 Ω and any errors are corrected during network analyzer characterization. Attenuator pads may be used, if desired, but including them complicates the network analyzer characterization.

b. Radio-Noise Meter and Signal Generator Procedure

1. Setup the antenna to be characterized and the test equipment as shown in Figure C2(b).
2. With the equipment connected as shown and a 50 Ω termination on the T-connector (A), measure the received signal voltage V_L in dB(μV) at the RF port (B).
3. Leaving the RF output of the signal generator unchanged, transfer the 50 Ω termination to the RF port (B) and transfer the receiver input cable to the T-connector (A). Measure the drive signal voltage V_D in dB(μV).
4. Subtract V_L from V_D and subtract C_h (–6 dB for the 1 m rod) to obtain the antenna factor (in dB) of the antenna.

The 50 Ω termination shall have very low VSWR (less than 1.05:1). The radio-noise meter shall be characterized and have low VSWR (less than 2:1). The output of the signal generator shall be frequency and amplitude stable.

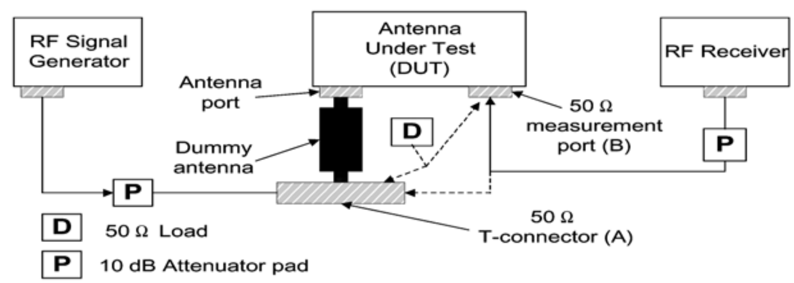
NOTE— The signal generator need not be characterized, since it is used as a transfer standard.



NOTES:
1. Place the dummy antenna as close to the DUT port as possible. Place the T-connector as close to the dummy antenna as possible. Use the same length and type of cables between the T-connector and the reference channel input, and the T-connector and the 50 Ω measurement port test channel.

2. Attenuator pads are notneeded with the network analyzer and are not recommended.

(a) Method Using the Network Analyzer



NOTES:
1. Place the dummy antenna as close to the DUT port as possible. Place the T-connector as close to the dummy antenna as possible.

2. If VSWR of receiver and signal generator is low, pads may not be needed or may be reduced to 6 dB or 3 dB

3. The dummy antenna may incorporate other matching components to control VSWR at its input and signal generator level measuring ports.

(b) Method using the Radio-Noise Meter and Signal Generator

FIGURE C2—MEASUREMENT OF 1 M ROD (MONOPOLE) ANTENNA FACTOR

APPENDIX D

SETTING IMMUNITY TEST FREQUENCIES IN A LOGARITHMIC SEQUENCE (INFORMATIVE)

***D.1 Relationship between Q and the Number of Test Point Frequencies*—**For a **decade** progression,

Test frequency steps are calculated as follows:

$$f_{injection} = f_{initial} \times 10^{\left(\frac{k}{n}\right)} \qquad \text{(Eq. D1)}$$

where:

$f_{injection}$ is the frequency to inject
$f_{initial}$ is the start frequency
k is the index number of the injection frequency (i.e., 0, 1,2, ...)
n is the number of test frequency steps per decade

Then:

$$f_{(j+1)} = f_j \times 10^{\left(\frac{1}{n}\right)} \qquad \text{(Eq. D2)}$$

Let the frequency of the maximum DUT response be midway between two adjacent test frequencies such that:

$$f_{DUT} = \frac{f_{(j+1)} + f_i}{2} \qquad \text{(Eq. D3)}$$

For the case of a DUT response described by a linear second order system, if $f_{(j+1)}$+f_j define the –3 dB bandwidth of the DUT, then the Q of the system is given by:

$$Q = \left(\frac{f_{DUT}}{f_{(j+1)} - f_j}\right) = \left(\frac{1}{2}\right) \times \left(\frac{f_j \times 10^{\left(\frac{1}{n}\right)} + f_j}{f_j \times 10^{\left(\frac{1}{n}\right)} - f_j}\right) = \left(\frac{1}{2}\right) \times \left(\frac{10^{\left(\frac{1}{n}\right)} + 1}{10^{\left(\frac{1}{n}\right)} - 1}\right) \qquad \text{(Eq. D4)}$$

Therefore:

$$Q = \left|\frac{1}{2}\right| \times \left(\frac{10^{\left|\frac{1}{n}\right|} + 1}{10^{\left(\frac{1}{n}\right)} - 1}\right) \qquad \text{(Eq. D5)}$$

Solving for n:

$$n = \frac{1}{\log_{10}\left(\frac{2Q + 1}{2Q - 1}\right)} \qquad \text{(Eq. D6)}$$

Similarly, for an **octave** progression, the corresponding equations used for calculating the frequency steps, Q and n are:

$$f_{injection} = f_{initial} \times 2^{\left|\frac{k}{n}\right|} \qquad \text{(Eq. D7)}$$

where:

$f_{injection}$ is the frequency to inject
$f_{initial}$ is the start frequency
k is the index number of the injection frequency (i.e., 0, 1,2, ...)
n is the number of test frequency steps per octave

Therefore:

$$Q = \frac{1}{2} \times \left(\frac{2^{\left(\frac{1}{n}\right)} + 1}{2^{\left(\frac{1}{n}\right)} - 1} \right) \qquad \text{(Eq. D8)}$$

And:

$$n = \frac{1}{\log_2\left(\frac{2Q+1}{2Q-1}\right)} \qquad \text{(Eq. D9)}$$

D.2 Determination of Soak Time—The soak time τ in terms of a stated total time T spent **per decade** is then:

$$\tau = \frac{T}{n} = (T)\log_{10}\left(\frac{2Q+1}{2Q-1}\right) \qquad \text{(Eq. D10)}$$

The soak time τ in terms of a stated total time T spent **per octave** is then:

$$\tau = \frac{T}{n} = (T)\log_{2}\left(\frac{2Q+1}{2Q-1}\right) \qquad \text{(Eq. D11)}$$

D.3 Calculation of Test Frequencies using a Logarithmic Progression—Figures D1 and D2 illustrate a list of frequencies related in a logarithmic progression for two (2) values of Q. The values of this table can be calculated using the equations of this appendix.

Example 1

Figure D1 shows the list of frequencies over a decade for a Q of 36 starting at 30 MHz. (Q of 36 corresponds to 25 steps per octave or 83 steps per decade)

30.0	30.8	31.7	32.6	33.5	34.5	35.4	36.4
37.4	38.5	39.6	40.7	41.8	43.0	44.2	45.5
46.7	48.1	49.4	50.8	52.2	53.7	55.2	56.8
58.4	60.0	61.7	63.4	65.2	67.0	68.9	70.9
72.9	74.9	77.0	79.2	81.4	83.7	86.0	88.5
90.9	93.5	96.1	98.8	102	104	107	110
114	117	120	123	127	130	134	138
142	146	150	154	158	163	167	172
177	182	187	192	198	203	209	215
221	227	233	240	247	254	261	268
276	283	291	300				

FIGURE D1—LIST OF FREQUENCIES OVER A DECADE FOR A Q OF 36

Example 2:

Figure D2 shows the list of frequencies over a decade for a Q of 22 starting at 30 MHz. (Q of 22 corresponds to 15 steps per octave or 50 steps per decade)

30.0	31.4	32.9	34.4	36.1	37.8	39.5	41.1
43.4	45.4	47.5	49.8	52.1	54.6	57.2	59.8
62.7	65.6	68.7	72.0	75.3	78.9	82.6	86.5
90.6	94.9	99.3	104	109	114	119	125
131	137	144	150	157	165	173	181
189	198	207	217	228	238	250	261
274	286	300					

FIGURE D2—LIST OF FREQUENCIES OVER A DECADE FOR A Q OF 22

TABLE D1—FREQUENCY STEPS AND ASSOCIATED VALUES OF Q FOR THE LINEAR STEP METHOD

Frequency band	Maximum frequency step size	Range of Expected values of Q
10 kHz to 100 kHz	10 kHz	0.6–6
100 kHz to 1 MHz	100 kHz	0.6–6
1 MHz to 10 MHz	1 MHz	0.6–6
10 MHz to 200 MHz	2 MHz	3–60 (9 at 30 MHz)
200 MHz to 1 GHz	20 MHz	6–30
1 GHz to 18 GHz	200 MHz	3–90

NOTE— If, at the specified test levels, the vehicle exhibits a condition bordering on response, the frequency steps in Table D1 should be reduced to identify the most critical frequencies and minimum threshold of susceptibility.

D.4 Example of Calculating n and τ—If the user specifies a Q of 30, and the average sweep time per decade T=20 s, the number of test frequency points per decade (n) and the corresponding soak time per test point (τ) are determined as follows:

$$n = \frac{1}{\log_{10}\left(\frac{2Q+1}{2Q-1}\right)} = \frac{1}{\log_{10}\left(\frac{2 \times 30 + 1}{2 \times 30 - 1}\right)} = 69 \quad \text{Points/decade} \qquad \text{(Eq. D12)}$$

$$\tau = \frac{20\ \text{s}}{69\ \text{points/decade}} = 290 \quad \text{ms} \qquad \text{(Eq. D13)}$$

SAE J551-1 Revised APR2002

Rationale—SAE J551–1 was last revised in 1996. In that time, there has been considerable activity within the EMR and EMI committee and in international standards development activity in which SAE has had a significant input. This revised standard reflects this effort.

Relationship of SAE Standard to ISO Standard—Parts of this SAE series of documents are based on International standards or draft international standards. These include ISO 10605, ISO 11451, IEC CISPR 12 and IEC CISPR 25.

Application—This SAE Standard covers the measurement of electromagnetic emissions and immunity. Each part of the SAE J551 series 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 other 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.

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 Part 2 of this document 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. (See applicable UL or other appropriate agency documents.)

Reference Section

SAE J551-2—Limits and Methods of Measurement of Radio Disturbance Characteristics of Vehicles, Motorboats and Spark-ignited Engine-driven Devices [Part 3 reserved for future use]

SAE J551-4—Test Limits and Methods of Measurement of Radio Disturbance Characteristics of Vehicles and Devices, Broadband and Narrowband, 150 kHz to 1000 MHz

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)

SAE J551-14—Vehicle Electromagnetic Immunity—Reverberation Chamber [Draft Only]

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

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

SAE J1812—Function Performance Status Classification for EMC Immunity Testing

HS–3600 –1999 Edition—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

ANSI C63.2–1996—American National Standard for Instrumentation—Electromagnetic Noise and Field Strength, 10 kHz to 40 GHz - Specifications

ANSI C63.4–1992—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 C63.5–1998—American National Standard for Electromagnetic Compatibility–Radiated Emissions Measurements in Electromagnetic Interference (EMI) Control–Calibration of Antennas (9 kHz to 40GHz)

ANSI C63.14–1998—Standard Dictionary for Technologies of Electromagnetic Compatibility (EMC), Electromagnetic Pulse (EMP), and Electrostatic Discharge (ESD)

ANSI C63.16–1993—American1 National Standard Guide for Electrostatic Discharge Test Methodologies and Criteria for Electronic Equipment

ANSI C95.1–1999—American National Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz

ANSI/IEEE STD 100–1993—Standard Dictionary of Electrical and Electronic Terms

ANSI/IEEE Dictionary of Technological Terms

CISPR 12 5th Edition—Limits and methods of measurement of radio disturbance characteristics of vehicles, motorboats, and spark-ignited engine-driven devices

CISPR 16–2: First Edition 1996—Part 2—Specification for radio disturbance and immunity measuring apparatus and methods–Part 2: Methods of Measurement of Disturbances and Immunity

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

CISPR 25:1995 Limits and methods of measurement of radio disturbance characteristics for the protection of receivers used on-board vehicles

IEC Publication 60050(161)—International Electrotechnical Vocabulary—Electromagnetic Compatibility

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

IEEE STD 291–1991 IEEE—Standard Methods for Measuring Electromagnetic Field Strength of Sinusoidal Continuous Waves, 30 Hz to 30 GHz

ISO 10305:1992—Generation of standard em fields for calibration of power density meters 20 kHz to 1000 MHz

ISO 10605:1992 Road vehicles—Electrical disturbances from electrostatic discharges

ISO 11451:1997 Road vehicles—Electrical disturbances by narrowband radiated electromagnetic energy— Vehicle test methods

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

ISO 11451-2—Road vehicles—Electrical disturbances by narrowband radiated electromagnetic energy—Component test methods—Part 2: Absorber-lined chamber

ISO 11451-3—Road vehicles—Component test methods for electrical disturbances from narrowband radiated electromagnetic energy—Part 3: Transverse electromagnetic mode (TEM) cell

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

ISO 11451-6—Road vehicles—Electrical disturbances by narrowband radiated electromagnetic energy—Component test methods—Part 6: Parallel plate antenna

IEEE STD 211–1997 IEEE—Standard Definition of Terms for Radio Wave Propagation

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