SAE International™ **SURFACE VEHICLE STANDARD**

SAE J551-2	CAN-CELLED SEP2006
Issued 1994-03 Cancelled 2006-09 Superseding J551-2 MAR1994	

Test Limits and Methods of Measurement of Radio Disturbance Characteristics of Vehicles, Motorboats, and Spark-Ignited Engine-Driven Devices

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1. Scope—The limits in this SAE Standard are designed to provide protection for receivers of all types of radio transmissions when used in buildings. As a result, receivers of radio transmissions used out-of-doors may not be protected by the limits specified.

This publication applies to the emission of electromagnetic energy which may cause interference to radio reception and which is emitted from:

a. Vehicles propelled by an internal combustion engine, electrical means or both (see SAE J551-1 for definition)
b. Motorboats propelled by an internal combustion engine, electrical means or both

NOTE—For the purposes of this publication, motorboats are considered to be a subset of vehicles unless specifically mentioned to the contrary.

c. Devices equipped with spark-ignited internal combustion engines (see SAE J551-1 for definition)

This publication does not apply to aircraft, traction systems (railway, tramway, and trolley bus), or to incomplete vehicles.

1.1 Rationale—This document is being cancelled in favor of using the technically identical intrnational standards CISPR 12 and CISPR 25. The linkage to these documents is included in the revised SAE J551-1 and SAE J1113-1.

2. References

2.1 Applicable Publications—The following publications form a part of this specification to the extent specified herein. The latest issue of SAE publications shall apply.

2.1.1 SAE PUBLICATION—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 J551-1—Performance Levels and Methods of Measurement of Electromagnetic Compatibility of Vehicles and Devices (60 to 18 GHz)

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

ANSI C63.5—Electromagnetic Compatibility—Radiated Emission Measurements in Electromagnetic Interference (EMI) Control—Calibration of Antennas

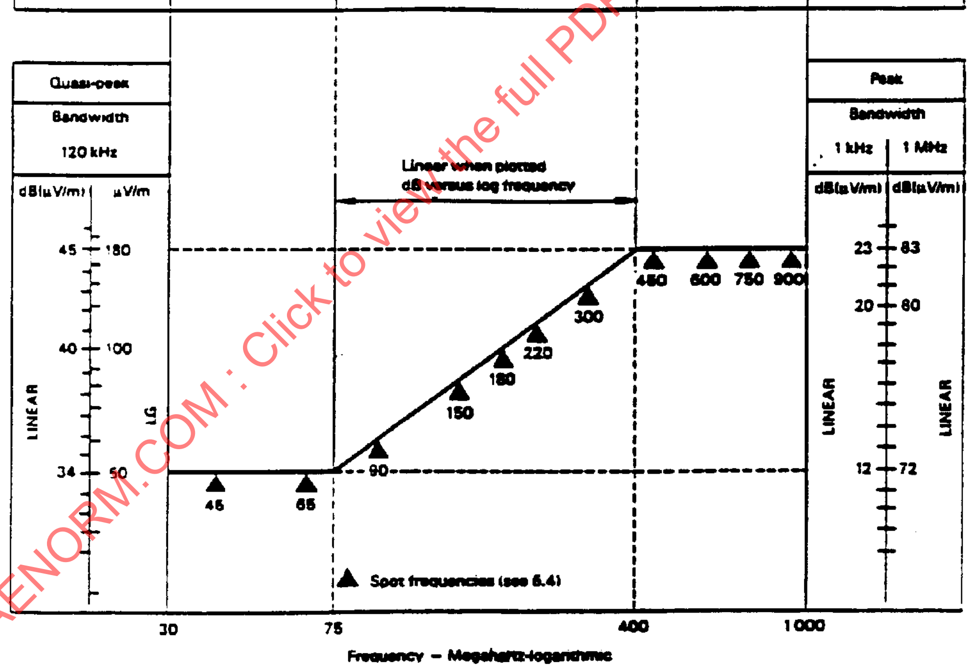
2.1.3 CISPR PUBLICATIONS—Available from ANSI, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, www.ansi.org.

CISPR 16 (1987)—CISPR specification for radio interference measuring apparatus and measurement methods
CISPR Report 37/2—Measurement of the insertion loss of ignition noise suppressors
CISPR Report 56—Antenna and transmission line calibration
CISPR Report 65Construction features of motor vehicles affecting the radiation of ignition noise

3. *Definitions*—See SAE J551-1.

4. *Limits of Disturbance*—The limits for emissions are given in the table of Figure 1 and shown graphically in Figure 1. Only one of the bandwidths listed needs to be chosen for testing. For more accurate determination, the table given in Figure 1 shall be used.

Bandwidth	Limit L (dB(µV/m)), at frequency f (MHz)			Measurement type
	30–75 MHz	75–400 MHz	400–1 000 MHz	
120 kHz	$L = 34$	$L = 34 + 15.13 \lg (f/75)$	$L = 46$	Quasi-peak
1 kHz	$L = 12$	$L = 12 + 15.13 \lg (f/75)$	$L = 23$	Peak
1 MHz	$L = 72$	$L = 72 + 15.13 \lg (f/75)$	$L = 83$	Peak



NOTES

1 For vehicles equipped with electric propulsion motors, see 4.3.2.2.
2 For peak type measurements, see 4.5.3.
3 The correlation factor between quasi-peak and peak measurements is +20 dB at 120 kHz bandwidth.
4 Limits from 1 to 22 GHz are under consideration.

FIGURE 1—LIMITS OF DISTURBANCE

5. *Methods of Measurement*

NOTE—Methods of measurement from 1 to 22 GHz are under development.

5.1 Measuring Instrument Requirements

5.1.1 Measuring Instrument

5.1.1.1 *Type*—The measuring instrument shall comply with the requirements of CISPR 16.

NOTE—Manual or automatic frequency scanning may be used. Spectrum analyzers and scanning receivers are particularly useful for interference measurements. Special consideration shall be given to overload, linearity, selectivity, and the normal response to pulses. The peak detection mode of spectrum analyzers and scanning receivers provides a display indication which is never less than the quasi-peak indication for the same bandwidth. It may be convenient to measure emissions using peak detection because of the faster scan possible than with quasi-peak detection.

When quasi-peak limits are being used, any peak measurements close to the limit shall be measured using the quasi-peak detector.

5.1.1.2 *Minimum Scan Time*—The scan rate of a spectrum analyzer or scanning receiver shall be adjusted for the CISPR frequency band and detection mode used. The minimum sweep time/frequency (i.e., most rapid scan rate) is listed in Table 1:

TABLE 1—MINIMUM SCAN TIME

Band		Peak Detection	Quasi-Peak Detection
A	9–150 kHz	Does not apply	Does not apply
B	0, 15–30 MHz	Does not apply	Does not apply
C, D	30–1000 MHz	1 ms/100 ms/MHz(1)	20 s/MHz

Band definition from CISPR 16 Part 1.
Certain signals (e.g., low repetition rate or intermittent signals) may require slower scan rates or multiple scans to ensure that the maximum amplitude has been measured.

1. When 9 kHz bandwidth is used, the 100 ms/MHz value shall be used.

5.1.1.3 *Measuring Instrument Bandwidth*—The bandwidth of the measuring instrument shall be chosen such that the noise floor is at least 6 dB lower than the limit curve. The bandwidths in Table 2 are recommended.

NOTE—When the bandwidth of the measuring instrument exceeds the bandwidth of a narrowband signal, the measured signal amplitude will not be affected. The indicated value of impulsive broadband noise will be lower when the measuring instrument bandwidth is reduced.

TABLE 2—MEASURING INSTRUMENT BANDWIDTH (6 DB)

Frequency Band MHz		Broadband Peak	Broadband q-Peak	Narrowband Peak	Narrowband Average
0.15 – 30		Does not apply	Does not apply	Does not apply	Does not apply
30 – 1000	FM broadcast	120 kHz	120 kHz	120 kHz	120 kHz
	Mobile service	120 kHz	120 kHz	9 kHz	9 kHz

If a spectrum analyzer is used for peak measurements, the video bandwidth shall be at least three times the resolution bandwidth.

For the narrowband/broadband discrimination according to Figure 1, both bandwidths (with peak and average detectors) shall be identical.

5.1.2 ANTENNA TYPES

5.1.2.1 *Reference Antenna*—The reference antenna shall be a balanced half-wave resonant dipole (see CISPR 16).

5.1.2.2 *Broadband Antennas*—Any linearly polarized receiving antenna is permitted, provided that it can be normalized to the reference antenna.

A broadband antenna is required when making measurements with an automated receiving system using a scanning measuring instrument. Such a broadband antenna is usable for measuring emission levels (over the frequency spectrum covered by this document), provided that its output can be normalized to the output of the reference antenna in the actual test environment at the actual test site.

NOTE—When broadband antennas are used, they should meet the requirements for complex antennas given in CISPR 16. Examples of factors to be considered include:

a. The effective aperture area of the antenna, including its polar response (horizontal and vertical planes)
b. The effect of a phase center which moves with frequency
c. The effect of ground reflection characteristics (including multiple ray reflections which may arise at specific frequencies at about 500 MHz vertical polarization and 900 MHz horizontal polarization).

5.1.3 CALIBRATION—See Appendix A.

5.1.4 ACCURACY—The measurement system, excluding source, shall measure electric field strength over the frequency range of 30 to 1000 MHz with a maximum uncertainty of ±5 dB. The frequency tolerance shall be less than ±1%.

NOTE—To ensure that the measurements defined in this document are within the stated tolerances, consideration should be given to all pertinent characteristics of measuring equipment (e.g., frequency and amplitude stability, image rejection, cross-modulation, overload levels, selectivity, time constants, and signal/noise ratio), as well as those affecting the antenna and transmission line.

5.1.5 REPEATABILITY—The repeatability of the measurement system shall be established and periodically checked to detect variability; the input/output characteristics of the measuring instrument shall be checked at shorter intervals of time.

NOTE—It is reasonable to expect variations of as much as ±3 dB in measurements made of an electric field (see A.16) within the range of 30 to 1000 MHz. These are caused by variations in ground conductivity and other factors influencing repeatability.

5.2 Measuring Location Requirements

5.2.1 OPEN AREA TEST SITE (OATS) REQUIREMENTS

5.2.1.1 The test site shall be a clear area free from electromagnetic reflecting surfaces within a circle of minimum radius 30 m measured from a point midway between the vehicle or device and the antenna.

NOTE—The site requirements defined in 4.2.1.1 are the application of CISPR 16 to large automotive objects.

5.2.1.2 The measuring set, test hut, or vehicle in which the measuring set is located may be within the test site, but only in the permitted region indicated by the crosshatched area of Figure 2.

5.2.1.3 *Ambient Requirements*—To ensure that there is no extraneous noise or signal of a magnitude sufficient to affect materially the measurement, measurements shall be taken before and after the main test, but without the engine under test running. In both of these measurements, the ambient noise (exclusive of known radio transmissions) shall be as low as possible, but at least 6 dB below the limits of disturbance given in Section 3. This requirement also applies to the reduced limit for testing wet vehicles.

5.2.2 ABSORBER-LINED SHIELDED ENCLOSURE (ALSE) REQUIREMENTS

5.2.2.1 *Correlation*—Anechoic chambers may be used provided that the results obtained can be correlated with those obtained using the OATS described in 4.2.1.

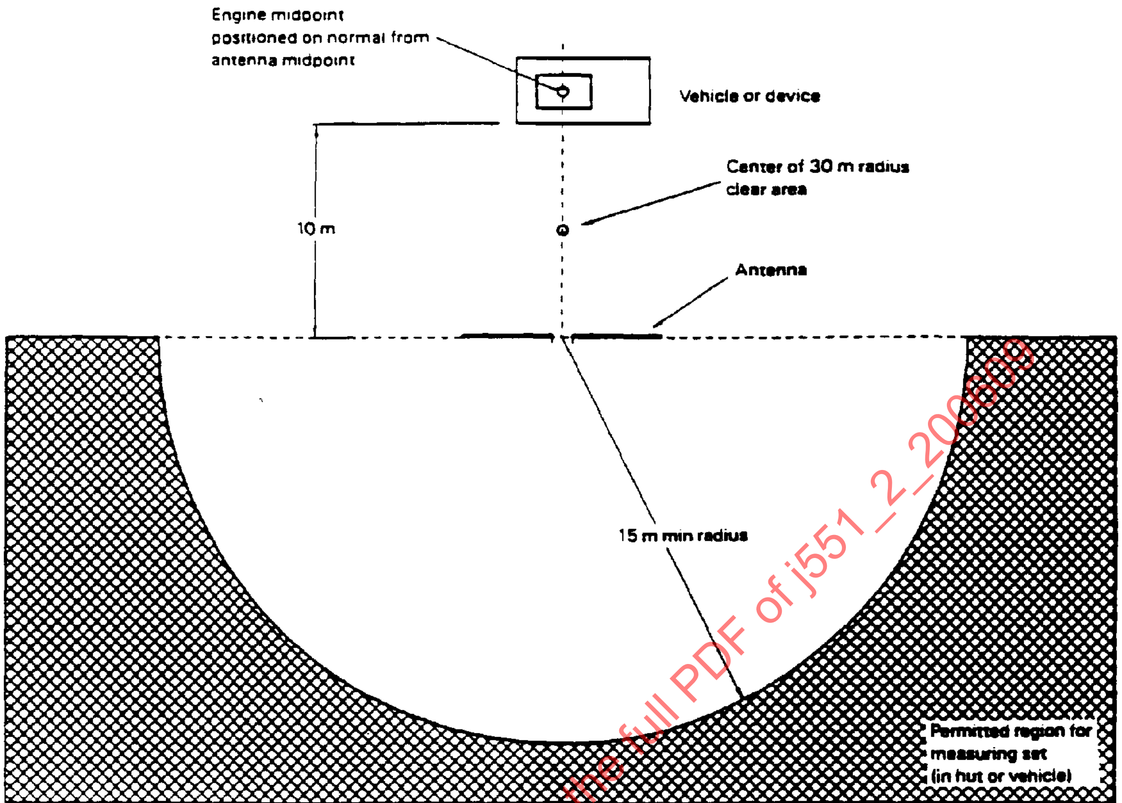
NOTE—Such chambers have the advantages of all-weather testing, controlled environment, and improved repeatability because of stable chamber electrical characteristics.

5.2.2.2 *Ambient Requirements*—The ambient noise level shall be as low as possible, but at least 6 dB below the limits of disturbance given in Section 3. The ambient level shall be verified periodically or when test results indicate the possibility of noncompliance.

5.2.3 ANTENNA POSITION REQUIREMENTS—At Each Measuring Frequency, Measurements Shall Be Taken For Horizontal And Vertical Polarization Figure 3 And Figure 4.

Electrical interaction between the antenna elements and the antenna support/guy system shall be avoided.

Theoretical considerations of antenna and transmission-line geometry demand that the transmission line not interact electrically with the antenna elements. One acceptable transmission-line geometry for a dipole antenna is to route the transmission line horizontally rearward for a distance of 6 m at a height of 3 m before descending to ground level or below. Other geometries are acceptable if they can be shown not to affect the measurements, or if the effects can be included in equipment calibration.



All dimensions ±0.2 m

FIGURE 2—MEASURING SITE

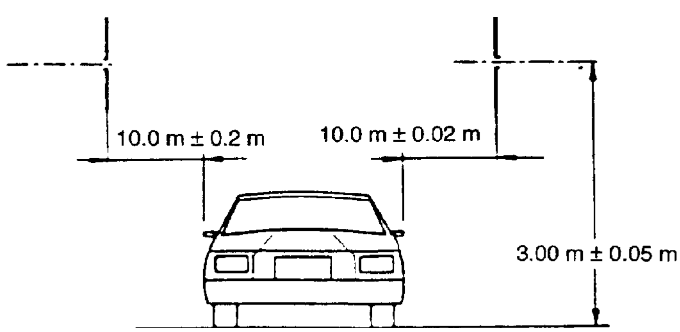


FIGURE 3—ANTENNA POSITION TO MEASURE EMISSIONS: VERTICAL POLARIZATION

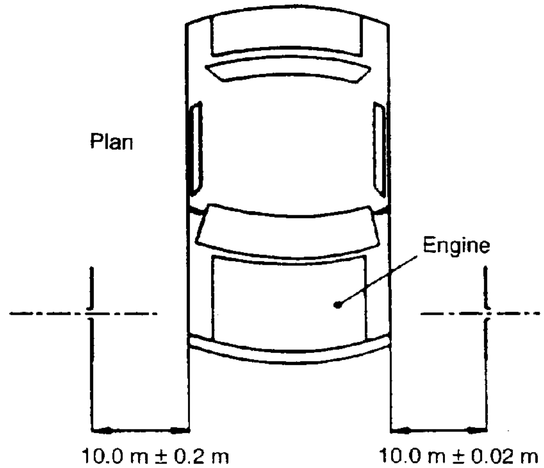


FIGURE 4—ANTENNA POSITION TO MEASURE EMISSIONS: HORIZONTAL POLARIZATION

5.2.3.1 *Height*—The center of the antenna shall be 3.00 m ± 0.05 m above the ground or water surface.

5.2.3.2 *Distance*—The horizontal distance of the antenna to the nearest metal part of the vehicle or device shall be 10.0 m ± 0.2 m.

5.2.3.3 *Auxiliary (Multiple) Antennas*—Auxiliary antennas are permitted, but if two antennas are facing each other, one shall be vertically polarized while the other is horizontally polarized.

The test site clear area requirement of 4.2.1.1 shall be applied also to the point midway between the vehicle or device and the auxiliary antenna(s).

5.3 Test Object Conditions

5.3.1 WEATHER CONDITIONS

5.3.1.1 *Dry Measurements*—Certification measurements made while the vehicle or device is dry, or made more than 10 min after the rain has stopped falling shall use the limit curve shown in Figure 1.

For outboard engines and devices, all surfaces other than those normally in contact with water shall be dry.

5.3.1.2 *Wet Measurements*—If circumstances dictate that certification measurements be made while precipitation is falling, or within 10 min after it has stopped, the vehicle or boat shall be deemed to comply with the requirements of this document if the measured levels do not exceed a level of 10 dB below that shown in Figure 1.

In the event of any dispute concerning compliance, it shall be resolved by carrying out measurements under dry conditions.

Compliance based on good faith wet measurements (and with the performance penalty mentioned in 4.3.1.2) shall remain valid until such time as it may be contested and dry measurements prove noncompliance. In such cases retrofitting of vehicle, devices, or boats sold during the period when there was deemed compliance shall not be required.

When compliance is deemed on the basis of wet measurements, then particular attention shall be paid to the surveillance of series production.

NOTE—Dew or light moisture may seriously affect readings obtained on devices having plastic enclosures.

5.3.2 VEHICLES—Measurements shall be made on the left and right sides of the vehicle Figure 3 and Figure 4.

Only the ancillary electrical equipment necessary to run the engine shall be operating. The engine shall be at normal operating temperature.

For vehicles or devices over 6 m in length, a measurement shall be made every 6 m or fraction thereof.

Different propulsion systems in the same vehicle (hybrid vehicle) shall be tested separately.

5.3.2.1 For vehicles equipped with an internal combustion engine, the engine shall be operated during each measurement as shown in Table 3:

TABLE 3—INTERNAL COMBUSTION ENGINE OPERATING SPEEDS

Number of Cylinders	Method of Measurement Quasi-Peak Engine Speed	Method of Measurement Peak Engine Speed
One	2500 rev/min	Above idling
More than one	1500 rev/min	Above idling

5.3.2.2 For vehicles equipped with an electric propulsion motor, the vehicle shall be operated during each measurement as follows:

a. The vehicle shall be driven on a dynamometer without a load, or on axle stands, with a constant speed of 20 km/h, or the maximum speed, if less than 20 km/h.

NOTE—Regenerative braking under consideration.

b. Measurements shall be taken with peak detector only

5.3.2.3 Auxiliary engines shall be operated in their normal intended manner and tested separately from the main engine, if possible.

Dependent upon the location of auxiliary engines, this requirement may dictate multiple tests of the vehicle with the several engines successively positioned in front of the antenna on successive tests.

5.3.3 DEVICES—Measurements shall be made in normal operation position(s) and height(s) and without load at idle speed and in the direction of the maximum interference emission. Where practical, the device under test shall be measured in three orthogonal planes.

As the case may be, the following conditions shall additionally be taken into account:

a. If the operating position and height are variable, the device to be tested shall be so positioned that the spark plug is 1.0 m ± 0.2 m above the ground.
b. No operator shall be present, but, if necessary, a mechanical arrangement shall be made, using nonmetallic material as far as possible, to keep the device in normal position(s) and at the specified engine speed.

5.3.4 MOTORBOATS—Inboard motorboats shall be tested in salt or fresh water as shown in Figure 5. The engine shall operate under the conditions specified in 4.3.2.

The test site shall be a clear area free from electromagnetic reflecting surfaces within a circle of minimum radius 30 m measured from a point midway between the engine under test and the antenna. The center of the antenna shall be 3.00 m ± 0.05 m above water level.

When tested separately, inboard, stern drive, and outboard engines shall be attached to a nonmetallic board or nonmetallic test fixture and tested in a similar way to that prescribed for inboard motorboats.

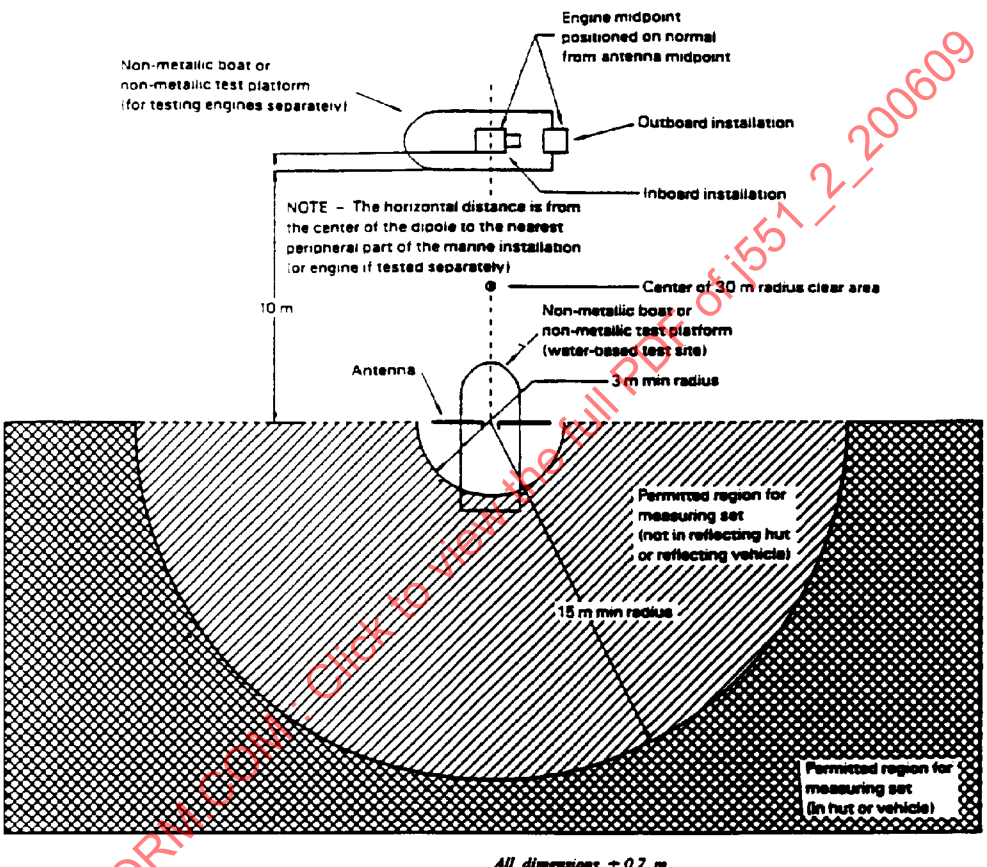


FIGURE 5—MOTORBOAT MEASURING SITE

5.3.4.1 Land-Based Testing Set—When the test equipment is on land, the test hut or vehicle in which the measuring set is located may be within the test site, but only in the permitted region indicated by the cross-hatched area of Figure 5. If the measuring set is not in a hut or vehicle, it may be located within the test site in either the shaded or cross-hatched area of Figure 5.

5.3.4.2 Water-Based Testing Set—The measuring set shall be installed in a nonmetallic boat or nonmetallic test fixture which may be within the test site, but only within the permitted region indicated by the shaded area of Figure 5.

5.4 Test Frequencies—The limits shall apply throughout the frequency range of 30 to 1000 MHz and therefore the disturbance characteristics shall be assessed throughout this frequency range.

5.4.1 FREQUENCY SUB-BANDS FOR ANALYSIS—For analysis, the frequency range of 30 to 1000 MHz shall be divided into a minimum of 14 bands with approximately three bands in each octave (2:1 frequency ratio). For bands that include the frequency range of 75 to 400 MHz (that is where the recommended limit is not constant), the ratio of the highest frequency to lowest frequency in each band shall be no greater than 1.33 (See Table 4.)

TABLE 4—EXAMPLE FREQUENCY SUB-BANDS

Frequency Sub-Band MHz	Characteristic Frequency MHz
30 to 34	32
34 to 45	40
45 to 60	55
60 to 80	70
80 to 100	90
100 to 130	115
130 to 170	150
170 to 225	200
225 to 300	270
300 to 400	350
400 to 525	460
525 to 700	600
700 to 850	750
850 to 1000	900

5.5 Data Collection

5.5.1 Each sub-band shall be scanned to determine its characteristic level. The characteristic levels for each sub-band shall be compared to the limit at the characteristic frequency for that sub-band, as determined by the methods of Section 5.

5.5.2 The results of measurements shall be expressed in accordance with one of the bandwidths shown in Figure 1. For statistical evaluation, the logarithmic unit dB (µV/m) shall be used.

5.5.3 For peak detector measurements, the limits given in Figure 1 may be related to bandwidths other than 1 kHz or 1 MHz by adding a correction factor of 20 log [bandwidth (kHz)/1 kHz] or 20 log {bandwidth (MHz)/1 MHz]. For example, to relate the limit to 120 kHz bandwidth, the correction is 20 log(120 kHz/1 kHz) = 42 dB.

6. Methods of Checking for Compliance With CISPR Requirements

6.1 Evaluation (General)

6.1.1 For evaluation of single vehicles or devices, either the complete data from a scan or the characteristic levels may be used.

6.1.2 For statistical analysis of multiple vehicles or devices, the characteristic levels shall be used. The levels shall be compared to the limit at the characteristic frequency for the appropriate sub-band.

6.2 Type Test

6.2.1 Compliance with the requirements given in Section 3 shall be checked as follows:

6.2.1.1 Single Sample—Measurements may be made on a prototype vehicle or a prototype device of a later production series. The results shall be at least 2 dB below the limits specified in Section 3.

6.2.1.2 Multiple Samples (Optional)—Five or more additional samples shall be tested and the results combined with the first test (see 5.1.2). The data for each frequency sub-band shall be evaluated statistically as defined in Appendix B; the result for each frequency sub-band shall be below the specified limits of Section 3 at the characteristic frequency for that sub-band.

6.2.2 Some differences in the construction of vehicles or devices are unlikely to have a significant effect on ignition noise emissions. For road vehicles, examples of such differences are given in Appendix C.

6.3 Surveillance of Series Production

6.3.1 SINGLE SAMPLE—The results of the measurements on one vehicle or device shall be a maximum of 2 dB above the specified limits of Section 3.

6.3.2 MULTIPLE SAMPLES (OPTIONAL)—Five or more additional vehicles or devices shall be tested and the results combined with the test in 5.3.1. The data for each frequency sub-band shall be evaluated statistically as defined in Appendix B; the result for each frequency sub-band shall fall below the specified limit of Section 3 at the characteristic frequency for that sub-band.

6.4 Quick Prototype Check for Development Testing—An optional test may be made to determine the approximate levels of emission of the vehicle or device to determine whether the characteristic levels in each sub-band are likely to meet the limit of Section 3. Specific measurements at the characteristic frequencies in 4.4 are suggested.

PREPARED BY THE SAE ELECTROMAGNETIC COMPATIBILITY (EMC) STANDARDS COMMITTEE

APPENDIX A

(INFORMATIVE)
ANTENNA AND TRANSMISSION LINE MAINTENANCE AND CALIBRATION[1]

This appendix contains, for guidance, an example of an antenna and transmission-line calibration procedure that complies with the intent of 4.1.3. Proper antenna and transmission-line calibration is essential to account for transmission-line loss and mismatch errors, and to characterize a broadband antenna, if used. Because coaxial cables used for transmission lines are subject to much wear and possible abuse, a suggested procedure is included to be used when cables require replacement.

This report is intended to be tutorial in nature, as an aid for those who may not be familiar with antenna and transmission-line calibration. Other methods, such as those using tracking generators, network analyzers, or narrowband signal sources may be equally satisfactory and nothing in this appendix should be interpreted as precluding their use.

A.1 Maintenance—Calibration of antennas and cables as a combination or individually is at the option of the user. It is highly recommended, however, that they be calibrated separately because:

a. Frequently, antennas are supplied without cables.
b. Any cable may be used with any antenna without need for recalibration of the combination.
c. Cables are easier to recalibrate than antennas and almost any test facility can recalibrate them. Some laboratories may not be able to calibrate complex antennas with their associated transmission lines easily.
d. Either the antenna or cable can be modified or replaced without need to recalibrate the other.

A.1.1 Periodic Checks Required

A.1.1.1 CABLES—Checks should be made monthly, contingent upon whether the cables are handled or flexed frequently, or if they are exposed to sun and weather for long periods.

NOTE—Even cables in conduits can develop problems, if temperature and humidity are uncontrolled.

A.1.1.2 ANTENNAS—Because they are subject to less wear than cables, antennas can be checked less frequently, possibly only once or twice per year.

A.1.1.3 PHYSICAL EXAMINATION

A.1.1.3.1 Cables—Serious kinks (very sharp bends), flat spots, abrasions, stretched spots, damaged connectors/ braid, contamination of the inner insulation, or aging of the cable shall require replacement and recalibration.

A.1.1.3.2 Antennas—Broken elements or other obvious mechanical problems shall be corrected or parts replaced. Recalibration shall be required.

A.1.1.4 ELECTRICAL EXAMINATION

A.1.1.4.1 Antennas and cables shall be checked for higher loss and other problems periodically. If a characteristic such as loss has changed, the antenna, the cable, or the combination shall be recalibrated. Severe changes in characteristics may require replacement and recalibration.

1. This appendix is based upon CISPR Report 56.

A.1.2 Recalibration—The following requirements apply when the transmission-line cable or antenna is replaced:

A.1.2.1 If the antenna calibration contains the loss and other characteristics of a specific cable in combination with the antenna, they shall be considered a matched pair. If either is replaced, the combination shall be recalibrated.

A.1.2.2 If the antenna and cable have been calibrated separately with separate losses, etc., replacement of either shall require recalibration only of that portion replaced.

A.2 Calibration/Recalibration

A.2.1 Impulse Electric Field Strength—Electric field strength shall be expressed in units of dB (μV/m/kHz). The relationship expressing electric field strength to the measurement system is shown in Equation A1:

$$F = R + AF + T \qquad \text{(Eq. A1)}$$

where:

F = Electric field strength dB (μV/m/kHz)
R = Instrument reading dB (μV/kHz)
AF = Antenna factor, defined in A.4 or A.5
T = Transmission-line factor, defined in A.6

A.3 Reference Antenna—The reference antenna for these measurements is the balanced half wavelength resonant dipole tuned to the measurement frequency. The reference point is the center of the two dipole elements.

A.4 Antenna Factor—The factor relating the field strength to the loaded antenna terminal voltage [2] at the reference point of the antenna is called the antenna factor, designated AF, expressed in dB. The antenna factor shall include the effects of baluns, impedance matching devices, any mismatch losses, and operation off the resonant frequency of the antenna.

NOTE—This factor is a function of frequency and is usually provided by manufacturers of resonant dipoles. Knowledge of the antenna factor for free space operation for resonant dipoles is sufficiently accurate for purposes of this report. Greater accuracy can be obtained by knowing the antenna factor for the particular resonant dipole being used in the test environment. A method for determining antenna factor is described in ANSI C63.5.

A.5 Alternate Antennas—The antenna factor for the alternate antenna is the antenna factor for the reference antenna (resonant dipole) minus the gain (dB) of the alternate antenna relative to the reference antenna.

A.6 Transmission Line—The transmission-line factor (loss) as a function of frequency shall be known. The factor is designated T and is shown in Equation A2:

$$T = 20 \times \log\left(\frac{\text{input voltage}}{\text{output voltage}}\right)\text{dB} \qquad \text{(Eq. A2)}$$

NOTE—It is recommended that the transmission line be double-braided or solid-shielded coaxial cable to achieve proper shielding. It is permissible that transmission-line loss and mismatch errors be accounted for by including the cable in the measuring instrument calibration. When this is done T is dropped from the equation for F in A.1.

2. As this is a voltage ratio, the calculations to convert to decibels shouuld be made using the factor of 20 log of the ratio of the parameters.

A.7 Calibration Instrumentation—The prime function of the calibration instrumentation is to provide a repeatable RF field for the comparison of an alternate antenna to the dipole antenna.

A.7.1 Reference Impulse Generator—The impulse generator output level (dB (µV)/unit bandwidth) shall be known to within ±1.0 dB.

NOTE 1—For convenience of testing, the reference instrument should be a broadband impulse generator capable of producing a uniform spectrum to within ±3.0 dB in the frequency range 30 to 1000 MHz.

NOTE 2—Experience indicates that an impulse generator that meets the requirements of this paragraph and has a nominal 100 dB (µV/kHz) level can produce a field of approximately 10 dB (µV/m/kHz) at the receiving antenna when an impedance matching attenuator of 10 dB is used at the output of the generator. This field strength varies depending on calibration antenna losses and radiation characteristics and on propagation anomalies. This approximate value is provided so that the antenna factor determination can be performed. It is then possible to estimate the required sensitivities and the tolerable losses in the measuring system.

A.7.2 Calibration Antenna—For ease in measurement and to assure freedom from variation caused by antenna adjustment, it is recommended that broadband antennas be used. Typical antennas are the biconical for up to 200 MHz and the log periodic for 200 to 1000 MHz.

A.8 Alternate Antenna Factor Determination—If an alternate antenna (see A.5) is used, the antenna factor shall be determined by a substitution technique in the intended test environment. The reference shall be the dipole (A.3). The radiated field to be measured for the substitution technique is generated by the calibration antenna and the impulse generator as specified in A.7.

NOTE—A tracking generator may be used in place of the impulse generator provided that (a) the output of the tracking generator is known within ±1 dB, and (b) the calibration electric field causes the measured field strength to be at least 6 dB above the least measurable field strength of the measuring instrument (see A.12).

A.9 Test Geometry—The alternate antenna shall be located at its intended test position. When substitution occurs, the dipole shall be placed so that its reference point is at the same place that the reference point for the alternate antenna normally occupies. The calibration antenna shall be 10 m in horizontal distance from the alternate antenna reference point in Figure A1 (taking the place of the nearest vehicle periphery) and shall be 1 m high.

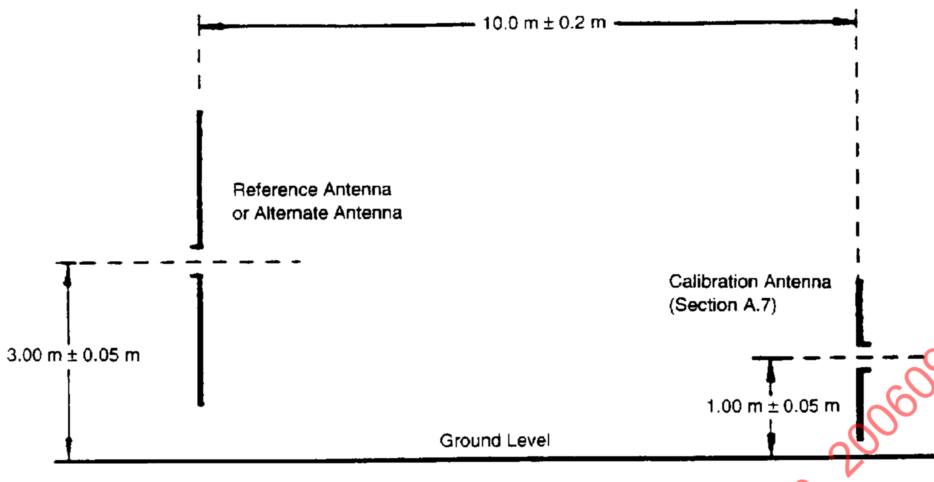


FIGURE A1—ALTERNATE ANTENNA FACTOR DETERMINATION

A.10 Reference Impulse Electric Field Amplitude—For accurate measurements to be made, the calibration impulse electric field shall be at least 3 dB above the least measurable field of the measuring system. A value of at least 10 dB is preferred.

A.11 Test Procedure—The procedure is to measure the reference field with the reference antenna positioned as in A.9 to obtain a meter reading (usually voltage). Then the alternate antenna is substituted and a second reading is taken.

The antenna factor for the alternate antenna is calculated as discussed in A.5. This procedure should be conducted for both horizontal and vertical polarizations to determine whether different antenna factors are required for each of the two cases.

NOTE—The antenna factor of the reference antenna may be assumed to be the same for both polarizations.

A.12 Frequencies—The number of frequencies at which antenna factor values are required depends on the alternate antenna being evaluated. A sufficiently large number of frequencies shall be considered to describe the function adequately.

A.13 Complete System Verification—The complete measurement system comprised of antenna, transmission cable, measuring instrument, and readout devices shall be verified by measuring an impulse electric field established with a wideband impulse generator and antenna(s) described in A.7. This verification shall be made on a periodic basis so that any change in system performance can be detected Figure A1.

APPENDIX B

(NORMATIVE)
STATISTICAL ANALYSIS OF THE RESULTS OF MEASUREMENTS

B.1 The following condition shall be fulfilled in order to ensure, with an 80% degree of confidence, that 80% of mass-produced vehicles/devices conform to a specified limit L as shown in Equation B1:

$$\overline{X} + kS_n \leq L \qquad \text{(Eq. B1)}$$

where:

$\overline{X}$ = Arithmetical mean of the results on n vehicles/devices
k = Statistical factor dependent on n, as given by Table B1:

TABLE B1—VARIATION OF K WITH N

n=6	7	8	9	10	11	12
k=1.42	1.35	1.30	1.27	1.24	1.21	1.20

$$S_n^2 = \Sigma(x - \bar{x})^2 / (n - 1) \qquad \text{(Eq. B2)}$$

where:

S_n = Standard deviation of results on n assembly line units
x = Individual result
L = Specified limit

$S_n, x, \bar{x}$ and L are expressed in identical units (e.g., dB (µV/m), dB (µV), etc.).

If a first sample of n vehicles/devices does not meet the specifications, a second sample of N vehicles/devices shall be tested and all results assessed as coming from a sample of n + N vehicles/devices.

NOTE—See CISPR 16 for a more comprehensive discussion of statistical theory and application.

APPENDIX C

(INFORMATIVE)
CONSTRUCTION FEATURES OF MOTOR VEHICLES AFFECTING THE EMISSION OF IGNITION NOISE[3]

For guidance in testing and approval, it should be noted that some differences in vehicle construction are unlikely to have a significant affect on the ignition noise emission. For this reason, measurements on one variant may be considered as being typical and such a variant may be used as the basis for the assessment of the design characteristics of road vehicles insofar as they affect the ignition noise emission.

C.1 The following construction differences[4] have little affect on ignition noise emission:

a. Two-door or four-door vehicles or station wagons of similar overall length.
b. Differences in radiator grille construction provided that grilles are of metal, offer approximately the same proportion of clear opening, and have approximately the same mounting.
c. Shape of fenders or contour of hood/bonnet.
d. Different size wheels or tires.
e. Ordinary nonresistive spark plugs of different makes, provided they have equivalent electrical characteristics (capacitance, inductance, resistance).
f. Coils and distributors of different makes, provided they have equivalent electrical characteristics (capacitance, inductance, resistance).
g. Decorative ornamentations, heaters, or air conditioners, occupying the same location.
h. Ordinary resistive spark plugs of different heat ranges, provided they have equivalent electrical characteristics (capacitance, inductance, resistance).
i. Size, shape, and location of the ancillary electrical equipment (including its harness), which is needed to run the propulsion motor.

C.2 The following construction differences[4] can be expected to have a significant affect on ignition noise emission:

a. Significant differences in compression ratio.
b. Use of plastic or metallic fenders, roofs, or body panels.
c. Size, shape, and location of metallic air cleaners and use of plastic rather than metallic air cleaners or vice-versa.
d. Location of distributor and coil on the engine or in the engine compartment.
e. Size and shape of the engine compartment and location of the high-voltage harness.
f. Significant differences in the clear opening of engine compartment around the wheels.
g. Right- or left-hand steering as it may affect the position of the other components or parts.
h. Vehicles having auxiliary engine(s) for purposes other than propulsion.

3. This appendix is based upon CISPR Report 65.
4. This is not all-inclusive, it is a set of examples only.

APPENDIX D

(INFORMATIVE)
MEASUREMENT OF THE INSERTION LOSS OF IGNITION NOISE SUPPRESSORS[5]

D.1 Introduction**—**Two methods of measurement of the insertion loss of ignition noise suppressors are used:

D.1.1 "CISPR Box Method" (50/75 Ω Laboratory Method)—Described in D.3.

D.1.2 Field Comparison Method—In this method, the insertion loss of the suppressor (or set of suppressors) is determined from the measurement of interference field intensity caused by the vehicle or device on the open test site. It is evaluated according to Equation D1:

$$A = E_1 - E_2 \quad \text{(Eq. D1)}$$

where:

E_1 = Intensity of the field caused by the ignition system without suppressors, expressed in dB (µV/m)
E_2 = Intensity of the field caused by the same ignition system but with suppressors (or set of suppressors) expressed in dB (µV/m)

NOTE—Field intensity is to be measured in accordance with Section 4.

D.2 Comparison of Test Methods

D.2.1 CISPR Box Method—With the help of the "CISPR box method," it is possible to compare only the characteristics of single suppressors of the same kind under standard laboratory conditions. At present, this method is used in the frequency range from 30 to 300 MHz. Results obtained have no significant correlation with the efficiency of suppressors observed in practice (see D.5). This method does not allow measurement of a set of suppressors consisting, for example, of four resistors and five cables with distributed attenuation. Nevertheless, it provides a means of quick control, for instance of suppressors during manufacture after previous verification of their effectiveness in actual conditions.

D.2.2 Field Comparison Method—The field comparison method may be considered the reference method since the results obtained give the insertion loss of suppressors observed in practice. It automatically takes into account all the factors influencing the insertion loss and it has no limitations in frequency range. Its main disadvantage is the need to perform measurements on an open test-site (or in a large building of special construction) and the need to test the complete vehicle or device.

D.3 CISPR Box Method (50/75 Ω Laboratory Method of Measurement of Insertion Loss of Ignition Noise Suppressors)

D.3.1 General Conditions and Limitations of Measurement—The insertion loss of an ignition noise suppressor is measured with the test circuit shown in Figure D1. This method is intended to be used only as a comparative method for suppression devices of the same type and is not intended to give direct correlation with emission measurements. The word "type" is understood to mean all suppression devices belonging to the same case of Figure D1.

5. Based on CISPR Report 37/2.

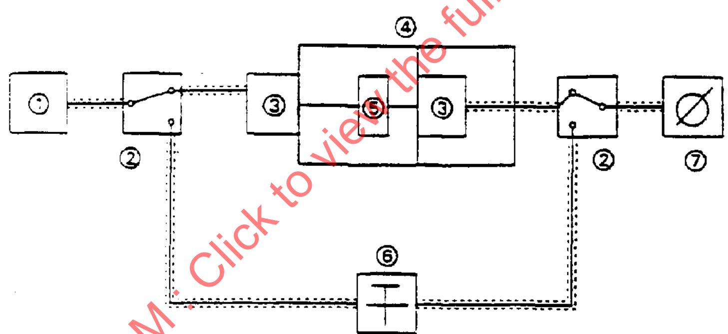
D.3.2 Test Procedure—In Figure D1, the coaxial switches (2) are adjusted so that the signal from the signal generator (1) is passed through the test box (4) and the specimen under test (5) giving an indication on the output indicator of the measuring instrument (7). Fixed "T" attenuators (3) have a loss of 10 dB.

The coaxial switches (2) are then turned so that the signal passes through the calibrated variable attenuator (6), which is adjusted to give the same indication on the output indicator of the measuring instrument (7). The insertion loss of the ignition noise suppressor is then given by the attenuation read on the calibrated variable attenuator (6) minus the attenuation of the fixed attenuators (3).

D.3.3 Test Box Construction—Details of the usual test box are shown in Figures D2 to D4. For the majority of applications, this box is applicable; however, hole positions and box size may require modification for some applications. The arrangement of the suppressors in the test box is shown in Figures D5 to D11. All noncoaxial connecting leads within the CISPR box to the suppressors under measurement shall be kept as short as possible, or of specified length where shown. In all arrangements, the spark plug is modified to accept a coaxial input and is constructed from a standard spark plug assembly having a direct connection between the spark plug terminal and the central electrode.

D.3.4 Results—For ignition noise suppressors having a high impedance, the insertion loss a_1 in a circuit having a characteristic impedanze z_1 can be converted to the insertion loss a_2 in a circuit having a characteristic impedance z_2; Equation D2 applies:

$$a_2 = a_1 + 20 \log(z_1 / z_2) \quad \text{(Eq. D2)}$$



1 signal generator
2 coaxial switch
3 fixed "T" attenuator (10 dB)
4 test box
5 specimen under test
6 calibrated variable attenuator
7 measuring instrument

NOTE — Items 1, 2, 3, 6 and 7 must have the same characteristic impedance.

FIGURE D1—TEST CIRCUIT