

Submitted for recognition as an American National Standard

**Test Limits and Methods of Measurement of Radio Disturbance Characteristics
of Vehicles and Devices, Broadband and Narrowband, 150 kHz to 1000 MHz**

Foreword—This Document has not changed other than to put it into the new SAE Technical Standards Board Format. The document number has changed from J551/4 to J551-4. We now use dashes instead of slashes.

This SAE Standard is based on CISPR 25 which has been developed by CISPR Subcommittee D and has been approved to be published. The SAE Electromagnetic Radiation Standards Committee has been an active participant in Subcommittee D and in the development of CISPR 25.

This document provides test limits and procedures for the “protection of vehicle receivers from radio frequency (RF) emissions caused by on-board vehicle components.”

NOTE—Appendix B provides helpful methodology for resolution of interference problems.

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1. **Scope**—This SAE Standard contains test limit¹ and procedures for the measurement of radio disturbances in the frequency range of 150 kHz to 1000 MHz. The document applies to any electronic/electrical component intended for use in vehicles. Refer to International Telecommunications Union (ITU) Publications for details of frequency allocations. The test limits are intended to provide protection for receivers installed in a vehicle from disturbances produced by components/modules in the same vehicle.²

The receiver types to be protected are: broadcast radio and TV³, land-mobile radio, radio telephone, amateur and citizens' radio.

The limits in this document are recommended and subject to modification as agreed between the vehicle manufacturer and the component supplier. This document shall also be applied by manufacturers and suppliers of components and equipment which are to be added and connected to the vehicle harness or to an on-board power connector after delivery of the vehicle.

This document does not include protection of electronic control systems from RF emissions, or from transient or pulse type voltage fluctuations. These subjects are covered in other sections of SAE J551 and in SAE J1113.

1. Only a vehicle test can be used to determine the component compatibility to a vehicle limit.
 2. Adjacent vehicles can be expected to be protected in most situations.
 3. Adequate TV protection will result from compliance with the levels at the mobile service frequencies.

The World Administrative Radiocommunications Conference (WARC) lower frequency limit in region 1 was reduced to 148.5 kHz in 1979. For vehicular purposes, tests at 150 kHz are considered adequate. For the purpose of this document, test frequency ranges have been generalized to cover radio services in various parts of the world. Protection of radio reception at adjacent frequencies can be expected in most cases.

2. References

2.1 Applicable Publications—The following publications contain provisions which, through reference in this text, constitute provisions of this document. At the time of publication, the editions indicated were valid. All documents are subject to revision, and parties to agreements based on this document are encouraged to investigate the possibility of applying the most recent editions of the documents indicated. Members of IEC and ISO maintain registers of currently valid International Standards.

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

SAE J551-1 MAR94—Performance Levels and Methods of Measurement of Electromagnetic Compatibility of Vehicles and Devices (60 Hz to 18 GHz)

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

CISPR 16-1:1993-08—Specification for radio disturbance and immunity measuring apparatus and methods. Part 1: Radio disturbance and immunity measuring apparatus.

3. Definitions—See SAE J551-1.

4. Requirements Common to Vehicle and Component/Module Emissions Measurement

4.1 General Test Requirements and Test Plan

4.1.1 TEST PLAN NOTE—A test plan should be established for each item to be tested. The test plan should specify the frequency range to be tested, the emissions limits, the disturbance classification [broadband (long or short duration) or narrowband], antenna types and locations, test report requirements, supply voltage, and other relevant parameters.

4.1.2 DETERMINATION OF CONFORMANCE WITH LIMITS—If the type of disturbance is unknown, tests shall be made to determine whether measured emissions are narrowband and/or broadband to apply limits properly as specified in the test plan. Figure 1 outlines the procedure to be followed in determining conformance with limits.

4.1.3 CATEGORIES OF DISTURBANCE SOURCES (AS APPLIED IN THE TEST PLAN)—Electromagnetic disturbance sources can be divided into three types:

Electromagnetic disturbance sources can be divided into three types:⁴

- a. Continuous/long duration broadband and automatically actuated short duration devices
- b. Manually actuated short duration broadband
- c. Narrowband

4. For examples see 4.1.4 and 4.1.5 and Table 1.

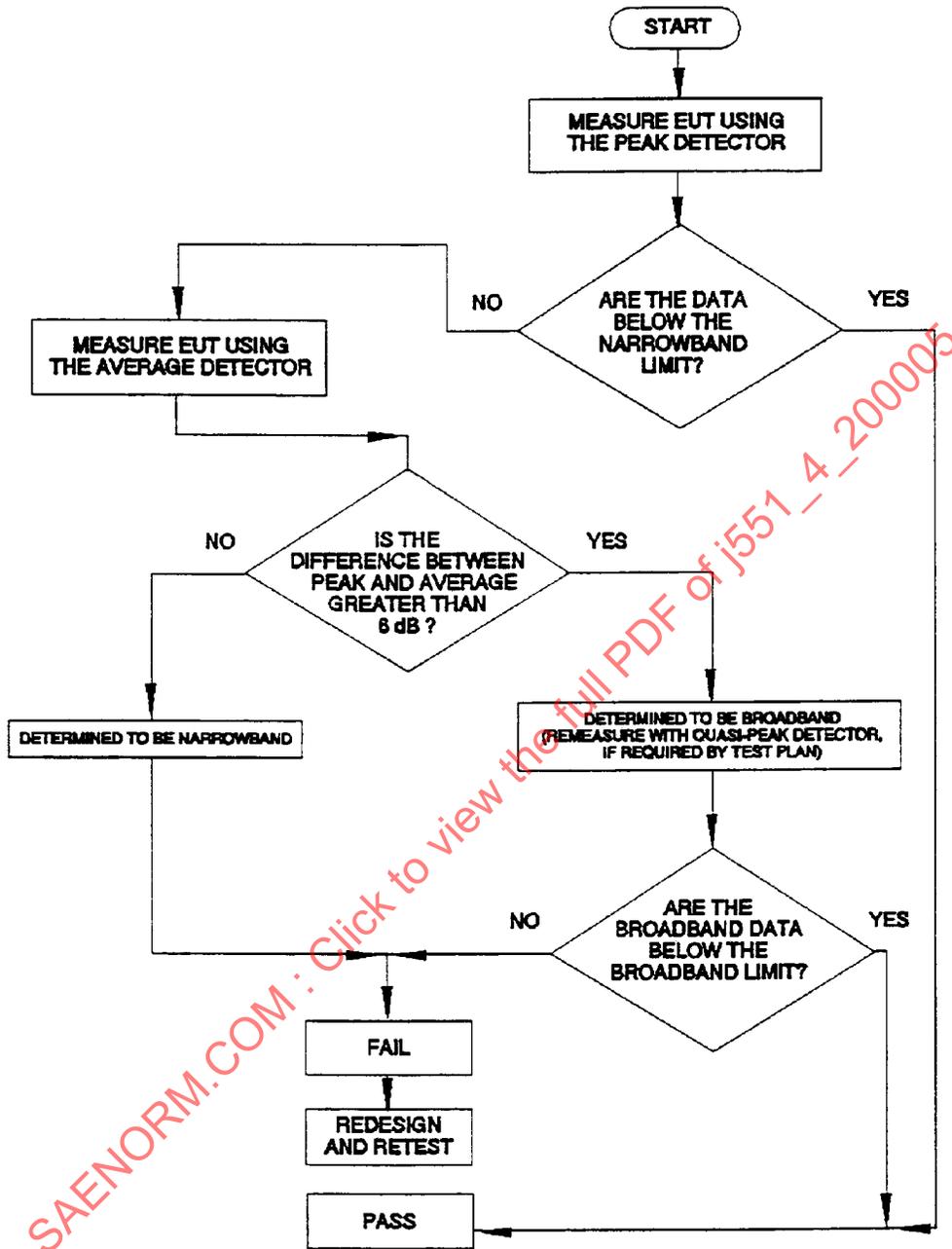


FIGURE 1—METHOD OF DETERMINATION OF CONFORMANCE OF RADIATED/CONDUCTED DISTURBANCE

4.1.4 EXAMPLES OF BROADBAND DISTURBANCE SOURCES

NOTE—The examples in Table 1 are intended as a guide to assist in determining which test limits to use in the test plan.

TABLE 1—EXAMPLES OF BROADBAND DISTURBANCE SOURCES BY DURATION

Continuous	Long Duration ⁽¹⁾	Short Duration ⁽¹⁾
Ignition system	Wiper motor	Power antenna
Active ride control	Heater blower motor	Washer pump motor
Fuel injection	Rear wiper motor	Door mirror motor
Instrument regulator	Air conditioning compressor	Central door lock
Alternator	Engine cooling	Power seat

1. As defined in the test plan.

4.1.5 NARROWBAND DISTURBANCE SOURCES—Disturbances from sources employing microprocessors, digital logic, oscillators or clock generators, etc., cause narrowband emissions.

4.1.6 OPERATING CONDITIONS—All continuous and long duration systems shall be operated at their maximum RF noise creating conditions. All intermittently operating systems (i.e., thermostatically controlled) that can operate continuously safely, shall be caused to operate continuously.

When performing the narrowband test, broadband sources (i.e., ignition system, in particular) may create noise of higher amplitude. In this situation, it will be necessary to test for narrowband noise with the ignition switch ON, but the engine not running.

4.1.7 TEST REPORT—The report shall contain the information agreed upon by the customer and the supplier.

4.2 Measuring Equipment Requirements—All equipment shall be calibrated on a regular basis to assure continued conformance of equipment to required characteristics. The measuring equipment noise floor shall be at least 6 dB less than the limit specified in the test plan.

4.3 Shielded Enclosure—The ambient electromagnetic noise levels shall be at least 6 dB below the test limits specified in the test plan for each test to be performed. The shielding effectiveness of the shielded enclosure shall be sufficient to assure that the required ambient electromagnetic noise level requirement is met.

The shielded enclosure shall be of sufficient size to ensure that neither the vehicle/EUT nor the test antenna shall be closer than (a) 2 m from the walls or ceiling, and (b) 1 m to the nearest surface of the absorber material used.

4.4 Absorber-Lined Shielded Enclosure (ALSE)—For radiated emission measurements, however, the reflected energy can cause errors of as much as 20 dB. Therefore, it is necessary to apply RF absorber material to the walls and ceiling of a shielded enclosure that is to be used for radiated emissions measurements. No absorber material is required for the floor. The following ALSE requirements shall also be met for performing radiated RF emissions measurements:

4.4.1 REFLECTION CHARACTERISTICS—The reflection characteristics of the ALSE shall be such that the maximum error caused by reflected energy from the walls and ceiling is less than 6 dB in the frequency range of 70 to 1000 MHz.

4.4.2 OBJECTS IN ALSE—In particular, for radiated emissions measurements, the ALSE shall be cleared of all items not pertinent to the tests. This is required in order to reduce any effect they may have on the measurement. Included are unnecessary equipment, cable racks, storage cabinets, desks, chairs, etc. Personnel not actively involved in the test shall be excluded from the ALSE.

4.5 Receiver—Scanning receivers which meet the requirements of CISPR 16-1 are satisfactory for measurements. 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.

4.5.1 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 2:

TABLE 2—MINIMUM SCAN TIME

	Band	Peak Detection	Quasi-Peak Detection
A	9 to 150 kHz	Does not apply	Does not apply
B	0.15 to 30 MHz	100 ms/MHz	200 s/MHz
C,D	30 to 1000 MHz	1 ms/100 ms/MHz ⁽¹⁾	20 s/MHz

- When 9 kHz bandwidth is used, the 100 ms/MHz value shall be used. Certain signals (e.g., low repetition rate or intermittent signals) may require slower scan rates or multiple scans to insure that the maximum amplitude has been measured.

Band definition from CISPR 16-1

4.5.2 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 3 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 3—MEASURING INSTRUMENT BANDWIDTH (6 DB)

Frequency Band MHz	Broadband Peak	Broadband q-Peak	Narrowband Peak	Narrowband Average
0.15 – 30	9 kHz	9 kHz	9 kHz	9 kHz
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. Antenna and Impedance Matching Requirements—Vehicle Test

5.1 Type of Antenna—An antenna of the type to be supplied with the vehicle shall be used as the measurement antenna. Its location and attitude are determined according to the production specifications.

If no antenna is to be furnished with the vehicle (as is often the case with a mobile radio system), the antenna types in Table 4 shall be used for the test. The antenna type and location shall be included in the test plan.

TABLE 4—ANTENNA TYPES

Band	Antenna Type
Broadcast	
LW AM	1 m monopole
MW AM	1 m monopole
SW AM	1 m monopole
VHF FM	1 m monopole
Mobile Services	
30 – 54	loaded quarter wave monopole
70 – 87	quarter wave monopole
144 – 172	quarter wave monopole
420 – 512	quarter wave monopole
800 – 1000	quarter wave monopole

5.2 Measurement System Requirements

5.2.1 BROADCAST BANDS—For each band, the measurement shall be made with instrumentation which has the specified characteristics.

5.2.1.1 AM Broadcast

- Long Wave (150 to 300 kHz)
- Medium Wave (0.53 to 2.0 MHz)
- Short Wave (5.9 to 6.2 MHz)⁵

The measuring system shall have the following characteristics:

- Output Impedance of Impedance Matching Device: 50 Ω resistive.
- Gain: The gain (or attenuation) of the measuring equipment shall be known with an accuracy of ± 0.5 dB. The gain of the equipment shall remain within a 6 dB envelope for each frequency band as shown in Figure 2. Calibration shall be performed in accordance with Appendix A.
- Compression Point: The 1 dB compression point shall occur at a sine wave voltage level greater than 60 dB(μ V).
- Measurement System Noise Floor: The noise floor of the combined equipment including measuring instrument, matching amplifier, and preamplifier (if used) shall be at least 6 dB lower than the limit level.
- Dynamic Range: From the noise floor to the 1 dB compression point.
- Input Impedance: The impedance of the measuring system at the input of the matching network shall be at least 10 times the open circuit impedance of the artificial antenna network in Appendix A.

5. Although there are several other shortwave broadcast bands, this particular band has been chosen because it is most commonly used in vehicles. It is expected that other shortwave bands will be protected by conformance to the limits in this band.

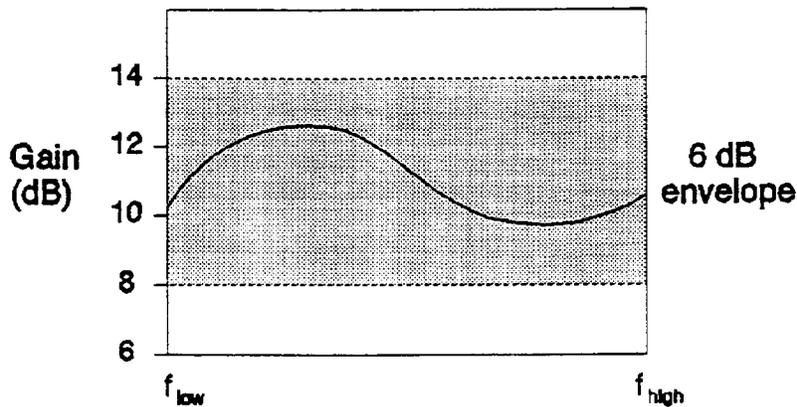


FIGURE 2—EXAMPLE GAIN CURVE

- 5.2.1.2 *FM Broadcast (87 to 108 MHz)*—Measurements shall be taken with a measuring instrument which has an input impedance of 50 Ω . If the standing wave ratio (SWR) is greater than 2:1, an input matching network shall be used. Appropriate correction shall be made for any attenuation/gain of the matching unit.
- 5.2.2 *COMMUNICATION BANDS (30 TO 1000 MHz)*—The test procedure assumes a 50 Ω measuring instrument and a 50 Ω antenna in the frequency range 30 to 1000 MHz. If a measuring instrument and an antenna with differing impedances are used, an appropriate network and correction factor shall be used.
6. **Method of Measurement**—As a general principle, the disturbance voltage shall be measured at the terminals of the radio receiving antenna placed at the correct vehicle location(s).

To determine the disturbance characteristics of individual disturbance sources or disturbance systems, all sources shall be forced to operate independently across their range of normal operating conditions (transient effects to be determined).

The disturbance voltage shall be measured at the receiver end of the antenna coaxial cable using the ground contact of the connector as reference. The antenna connector shall be grounded to the housing of the on-board radio (center conductor of the antenna coax is not connected to the on-board radio). The radio housing shall be grounded to the vehicle body using the production harness. The use of a high-quality double shielded cable for connection to the measuring receiver is required.

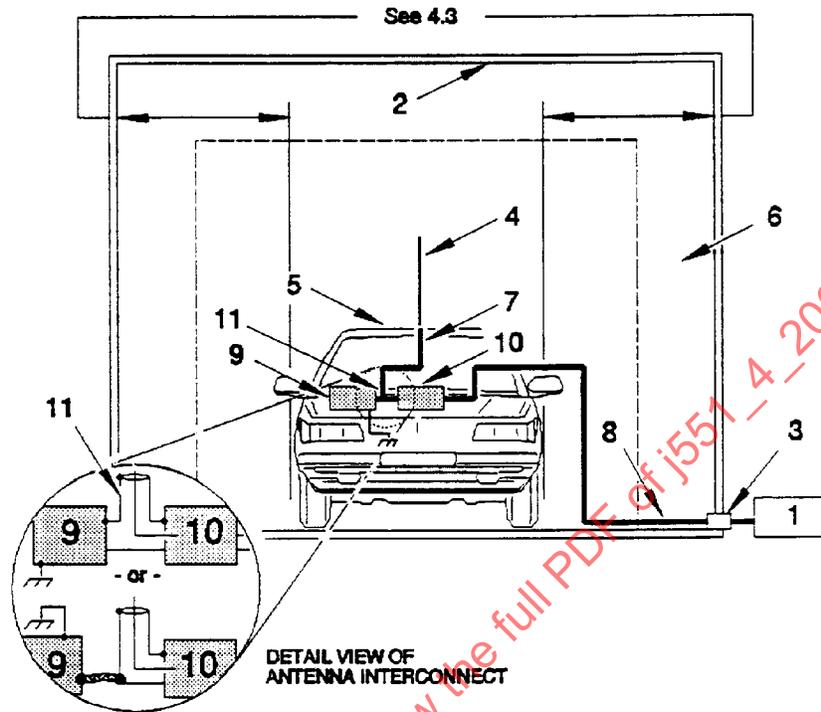
NOTE—The use of ferrite or other suppression material on the exterior of the coax is recommended, particularly below 2 MHz, for suppression of surface currents.

A coaxial bulkhead connector shall be used for connection to the measuring receiver outside the shielded room. See Figure 3.

Some vehicles may allow a receiver to be mounted in several locations (e.g., under the dash, under the seat, etc.). In these cases, a test shall be carried out as specified in the test plan for each receiver location.

7. **Limits for Vehicle Radiated Disturbances**—The limits of disturbance may be different for each disturbance source. Long duration disturbance sources such as a heater blower motor must meet a more stringent requirement than short duration disturbance sources. Short duration disturbance sources may be decided upon by the vehicle manufacturer. For example, door mirror operation may be allowed at a higher level of disturbance, as it is operated for only 1 or 2 s at a time. Coherent energy from microprocessors is more objectionable because it resembles desired signals and is continuous.

For acceptable radio reception in a vehicle, the disturbance voltage at the end of the antenna cable shall not exceed the values shown in Table 5.



1. Measuring instrument
2. ~~ALSE~~
3. Bulkhead connector
4. Antenna (see 5.1)
5. EUT
6. Typical absorber material
7. Antenna coaxial cable
8. High quality double shielded coaxial cable
9. Housing of on-board radio
10. Impedance matching unit (when required)
11. Optional tee connector with one leg removed

FIGURE 3—VEHICLE RADIATED EMISSIONS—EXAMPLE FOR TEST LAYOUT
(END VIEW WITH MONOPOLE ANTENNA)

TABLE 5—LIMITS OF DISTURBANCE—COMPLETE VEHICLE

Band	Frequency (MHz)	Terminal Noise Voltage at Receiver	Terminal Noise Voltage at Receiver	Terminal Noise Voltage at Receiver	Terminal Noise Voltage at Receiver	Terminal Noise Voltage at Receiver
		Antenna Terminal dB (μ V) Broadband Continuous QP	Antenna Terminal dB (μ V) Broadband Continuous P	Antenna Terminal dB (μ V) Broadband Short Duration QP	Antenna Terminal dB (μ V) Broadband Short Duration P	Antenna Terminal dB (μ V) Broadband Short Duration P
LW	0.15 – 0.30	9	22	15	28	6
MW	0.53 – 2.0	6	19	15	28	0
SW	5.9 – 6.2	6	19	6	19	0
VHF	30 – 54	6 (15 ⁽¹⁾)	28	15	28	0
VHF	70 – 87	6 (15 ⁽¹⁾)	28	15	28	0
VHF	87 – 108	6 (15 ⁽¹⁾)	28	15	28	6
VHF	144 – 172	6 (15 ⁽¹⁾)	28	15	28	0
UHF	420 – 512	6 (15 ⁽¹⁾)	28	15	28	0
UHF	800 – 1000	6 (15 ⁽¹⁾)	28	15	28	0

All broadband values listed in this table are valid for the bandwidth specified in Table 3.

Stereo signals may be more susceptible to interference than monaural signals in the FM-broadcast band. This phenomenon has been factored into the VHF (87 to 108 MHz) limit.

It is assumed that protection of services operating on frequencies immediately below 30 MHz will most likely be provided if the limits for services above 30 MHz are observed.

1. Limit for ignition systems only.

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