

ANECHOIC TEST FACILITY RADIATED SUSCEPTIBILITY 20 MHz TO 18 GHz ELECTROMAGNETIC FIELD

Foreword—This Document has not changed other than to put it into the new SAE Technical Standards Board Format.

1. Scope—This information report gives typical requirements for an anechoic chamber in which the system susceptibility of an operating motor vehicle to electromagnetic fields can be determined in the frequency range of 20 MHz to 18 GHz. Because of the large cone sizes required for 20 MHz cut-off, several anechoic facilities have been designed with lower cut-off frequencies of 200 MHz or greater. Testing below cut-off is then accomplished using customized antennas at reduced accuracy. Users should carefully review their testing requirements before undertaking the construction of a test facility the magnitude of an anechoic chamber. Other test approaches include, but are not limited to, open field testing per SAE J1338 and mode stirred reverberation chambers.

2. References

2.1 Applicable Publications—The following publications form a part of the specification to the extent specified herein. Unless otherwise indicated the latest revision of SAE publications shall apply.

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

SAE J1338 JUN81—Open Field Whole-Vehicle Radiated Susceptibility 10 kHz-18 GHz, Electric Field

2.2 Related Publications—The following publications are provided for information purposes only and are not a required part of this document.

1. J. C. Kinderman, et al., "Implementation of EMC Testing of Automotive Vehicles", SAE Paper 810333, SAE, 400 Commonwealth Drive, Warrendale, PA 15096 (Feb. 1981)
2. Gary F. E. Vrooman, "An Indoor 60 Hz to 40 GHz Facility for Total Vehicle EMC Testing", SAE Paper 831011, SAE, 400 Commonwealth Drive, Warrendale, PA 15096 (June 1983)
3. Donald A. Weber, et al., "Development of a Vehicle Electromagnetic Test Environment", SAE Paper 831015, SAE, 400 Commonwealth Drive, Warrendale, PA 15096 (June 1983)
4. Wayne L. Minten, "Vehicle Testing for Electromagnetic Compatibility", SAE Paper 810332, SAE, 400 Commonwealth Drive, Warrendale, PA 15096 (Feb. 1981)
5. H. E. Taggart, "Radiated EMI Instrumentation Errors", EMC Technology, Vol. 1, No. 4, October 1982, pp 26-35
6. A. A. Smith, Jr., "Control of Errors on Open Area Test Sites", EMC Technology, Vol. 1, No. 4, October 1982, pp 50-58

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7. W. S. Bennett, "Error Control in Radiated Emission Measurements", EMC Technology, Vol. 1, No. 4, October 1982, pp 38–47
8. E. L. Bronaugh and W. H. McGinnis, "Whole-Vehicle Electromagnetic Susceptibility Tests in Open-Area Test Sites: Applying SAE J1338", SAE Paper 830606, SAE, 400 Commonwealth Drive, Warrendale, PA 15096 (Feb. 1983)
9. F. J. Nichols and L. H. Hemming, "Recommendations and Design Guides for the Selection and Use of RF Shielded Anechoic Chambers in the 30-1,000 MHz Frequency Range", "IEEE International Symposium on Electromagnetic Compatibility, Boulder, Colorado, August 18–20, 1981, pp 457–464
10. A. A. Smith, R. F. German, J. B. Pate, "Calculation of Site Attenuation from Antenna Factors", IEEE Transactions on Electromagnetic Compatibility, Vol. EMC-24, No. 3, (Aug. 1982) pp 301–316
11. A. A. Smith, "Standard-Site Method of Determining Antenna Factors", IEEE Transactions on Electromagnetic Compatibility, Vol. EMC-24, No. 3, (Aug. 1982) pp 316–322.
12. R. F. German, "Comparison of Semi-Anechoic Chamber and Open-Field Site Attenuation Measurements", IEEE International Symposium on Electromagnetic Compatibility, Santa Clara, CA, (Sept. 8–10, 1982) pp 260–265
13. S. D. Bloom, "Correlation and Calibration of Anechoic Chambers", IEEE National Symposium on Electromagnetic Compatibility, San Antonio, TX, (April 24–26, 1984) pp 21–25
14. L. Farber and D. H. Chapman, "Antenna Factors Determined in an Absorber-Lined Shielded Enclosure", IEEE National Symposium on Electromagnetic Compatibility, San Antonio, TX, (April 24–26, 1984) pp 1–7
15. E. L. Bronaugh and D. R. Kerns, "Rod Antennas for High-Strength Radiated Susceptibility Tests from VLF and HF", IEEE International Symposium on Electromagnetic Compatibility, San Diego, CA, (Oct. 9–11, 1979) pp 413–416
16. J. B. Pate, "Potential Measurement Errors Due to Mutual Coupling Between Dipole Antennas and Radio Frequency Absorbing Material in Close Proximity", IEEE National Symposium on Electromagnetic Compatibility, San Antonio, TX, (April 24–26, 1984) pp 13–19

3. **Measurement Philosophy**—The design objective of an anechoic chamber is to create an indoor electromagnetic compatibility testing facility which simulates open field testing without the weather and Federal Communications Commission radiation constraints. Typical chambers have absorbing material lining as many surfaces in the chamber as possible to minimize reflections and resonances. The design objective is to reduce the reflectivity in the test area to -10dB or less.

The test consists of generating radiated electromagnetic fields by using antenna sets with rf sources capable of producing the desired field strengths over the range of test frequencies. Typically the fields are monitored with small probes to ensure proper leveling. To reduce testing error, the vehicle under test is usually monitored by optical couplers.

4. **Apparatus**—Typical test apparatus consists of the following:

- a. **Anechoic Chamber**: The size, shape, and construction of an anechoic chamber can vary considerably, Figure 3 or Figure 2. The chamber shape is a function of the types of tests to be performed, the size of vehicle to be tested and the frequency range to be covered. Basically, an anechoic chamber consists of a shielded room with absorbing material mounted on its internal surfaces. The minimum size of the room is determined by the size of the test region needed, the size of the transmitting antennas and the clearances needed between the absorber, antennas, and the largest vehicle that is to be tested. To create the test region (quiet zone), the absorber, antenna systems, and chamber shape are selected to reduce the amount of extraneous energy in the test region below a minimum value which will give the desired measurement accuracy. Since the performance of absorber is a function of its construction (thickness, shape, material, etc.) and the angle of incident energy, the determination of the optimum location and construction of the absorber in an anechoic chamber to meet the reflectivity requirements is a complex process.

The use of scale models can greatly reduce both the cost and time involved in establishing an acceptable design. In addition, the model may reveal room resonances which are not predicted by a theoretical study. The test area in the chamber may have a dynamometer and/or a vehicle turntable. Additional guidelines for designing an anechoic chamber are available in reference (9). Specific design requirements and construction details for an anechoic chamber are available (1), (2), (3). For typical anechoic chamber specification, see the Appendix.

- b. Signal Sources: Any commercially available signal source and power amplifier, as required, capable of supplying adequate power, (modulated and unmodulated) to develop the susceptibility levels specified in the test plan may be used. Typically for the lower MHz bands, these power levels range from 10,000 watts for five meter test distances to 2,000 watts for one meter. For the GHz bands, these powers drop to 100 or 200 watts. The harmonic and spurious outputs from the rf source should be less than -20dB referred to the fundamental. Specific tests and frequencies near the band edges of the generators may require additional harmonic suppression with appropriate filter prior to final amplification. The frequency accuracy of the signal generators shall be within $\pm 2\%$, if a frequency counter is not used.
- c. Signal Samplers and Monitor Tees: As required by frequency and rf voltage monitoring equipment.
- d. Power Monitoring Equipment: Commercially available power meters and directional couplers capable of measuring the maximum generated powers given in (a) over the frequency range of 20 MHz to 18 GHz. Several different meters will be required. To protect the generators in the high frequency band, the power meters and couplers must be able to measure VSWR. Electric field probes may be used over most of the frequency range as an option if due care is exercised, see section 4c.
- e. Frequency Counter: Frequency counters capable of measuring frequencies from 20 MHz to 18 GHz or an equivalent frequency determination built into the rf signal sources. If a frequency counter is not used, the frequency accuracy of the rf signal sources shall be within $\pm 2\%$.
- f. Antenna Sets: Any commercial available antenna set including high power baluns which is capable of radiating the specified field strengths at the specified distance with power available. A typical set consists of several horn or parabolic antennas, a log periodic, and a biconical dipole.¹ For the 20 MHz to 150 MHz band, specialized antennas may be needed. Reference (15) outlines the construction of a high power rod antenna which could be used in the lower part of this band.
- g. EUT Monitor: Test equipment, hardened to the test power levels, required to monitor the operation of the equipment under test (EUT) coupled to the control center by commercially available fiber optic links or high resistance leads.
- h. System Controller: If desired, process controllers or small computers compatible with the IEEE 488 Bus can be used to control the testing and test equipment.

5. Test Setup Procedure—Anechoic chamber susceptibility measurement techniques have been described in detail in several papers(4), (1), (2). The setup and measurement procedure is summarized below.

- a. Typical test setups are shown in Figs. 3a and 3b.
- b. The vehicle may be placed in the chamber centered with respect to the width and length, or placed in the chamber's "quiet zone" if the chamber is so designed. The test area may contain a dynamometer and/or a turntable. The surface under the vehicle may be conducting or absorptive depending on the test plan and facility capabilities.

If direct comparisons between the anechoic chamber and an open field site are desired, a conducting floor in the anechoic chamber may be needed since the open field site has a reflective ground plane.

1. High power balun is especially needed for this antenna.

- c. The determination of the field strength at the vehicle can be done several ways. Field probes placed near the vehicle can be used to measure the field directly. Measurement of the forward RF power into the antenna set and use of the antenna factors to calculate the field strength can be used. Measurement of the field at test area, without the vehicle present, with a field probe in conjunction with the forward rf power necessary to maintain the field level is another. These and others can be used exclusively or in combination. Each method has its uncertainties.

Field probes, if used, should not perturb the field, therefore, they should be electrically small and electrically isolated. The transmission lines from the probes should be either very high resistance lines or fiber optic links. Placement of the probe is critical to reducing measurement errors. If the probe is placed near a discontinuity, such as a sharp bend or corner of the vehicle, or near a resonant cable or component, the resulting measurement could be in error by a substantial amount. Unless otherwise specified by the probe's manufacturer, the probe should be placed parallel to the generated field above an approximately flat surface. For additional information on the use of field probes, see reference (8). If the field strength is determined by the use of antenna factors, the vehicle should be in the antenna's far field¹ and the site attenuation must be known over the frequency band. Details of determining both site attenuation and errors associated with antenna factors are given in several sources (10, 11, 12, 13, 14, 16). In particular, Pate(16) reported errors of greater than 1.5dB in the antenna factor if a dipole antenna is placed closer than 0.2 of a wave length from the absorber and if a biconical antenna is closer than 2 m.

If the field strength is determined by the use of either the antenna factor or a field probe in the absence of the vehicle, a potentially large error can be caused by the vehicle interacting with the transmitting antenna. To minimize this error, both the forward and reflected powers should be monitored and the transmitter adjusted for the same net power (forward less reflected) to the antenna both before and after the vehicle is placed in the test area. Discussions of additional errors in generating a "known field" are given in references (5), (6), (7). J1338 and reference (8) further discuss establishing the test field.

- d. The EUT should be operated as required in the test plan by actuators which have a minimum effect on the EUT i.e., plastic blocks on the accelerator, pneumatic actuators with plastic tubes. Connections to equipment monitoring for electromagnetic interference reactions of the EUT may be accomplished by using fiber optics, or by high resistance leads. Other types of leads may be used but require extreme care to minimize interactions. The orientation, length, and location of the latter leads must be carefully documented to assure repeatability of the test results.
- e. Because of the multiple power amplifiers and antennas required, the vehicle is generally scanned in bands over the test frequency range of 20 MHz to 18 GHz. Since some EUT's may have relatively slow thermal and/or electrical time constants or long cycle times, the sweep rate or dwell time (depending on the frequency generation equipment) must be compatible with reaction/interaction times of the EUT to the test field. This reaction has two parts: 1) the time required for the EUT to respond to a given frequency and 2) the frequency band width over which the response can occur. The latter quantity can be used to define a "Q" of the response in the normal manner (i.e. $Q = F/B$ where B is the -3dB band width and F is the center frequency). Typical values for this Q range from about 2 to 40.

If the response is the result of a resonant circuit which is not affected by other vehicle conditions, then the response time (T_r) can be approximated by $T_r \approx 0.3F$ and the maximum scan speed (SS_m) by $SS_m \leq 1.73 (F/Q)^2$.

1. For antennas less than a wave length (λ), the far field begins at $\lambda/2\pi$. For antennas with electrically large apertures, it begins at d^2/λ where d is the largest dimension of the antenna.

If, however, the response can only occur during part of an electrical system cycle (i.e., while an engine controller is sampling an external sensor), the response time is hard to predict and the scan speed or dwell time must be much slower than SSm. If a field probe is used to level the field during testing, the system will require time to stabilize at each frequency. This stabilization time may be the limiting factor to the scanning time.

For step frequency systems, great care is needed in selecting the frequency steps. In general, the maximum step should be less than B/2 to assure that all responses are found. In addition, all known clock frequencies, and any other specified in the test plan should be tested. Care, however, should be exercised during their testing to prevent irreversible damage to the EUT which would render continued testing meaningless and require costly repairs.

To minimize potential confusion caused by generator harmonics, each generator band may be scanned from the high frequency to the low. If harmonic responses are recorded which are still ambiguous, high power, low pass filters and notch filters can be used to resolve the ambiguity.

6. Test Procedure

- a. Place the vehicle in the test area and operate it according to the test plan.
- b. With the transmitting antenna in the horizontal plane and the signal unmodulated, scan the first band with the field strength set at the minimum acceptance level noting any susceptibility responses.
- c. Repeat (b) in increasing stepped field strengths until the maximum test level is reached. If a system is caused to be inoperable and does not return to normal function after the field is removed before the maximum test level is reached, the band of frequencies over which this occurs may have to be deleted during the higher power level scans to complete the testing.
- d. Repeat (b) and (c) with the signal modulated as required in the test plan.
- e. Repeat (b), (c), and (d), for each of the frequency bands and vehicle orientations specified in the test plan. Because of the narrow beam width of the high frequency antennas, the number of vehicle positions should increase with frequency to ensure complete coverage. For further guidance see reference (8) and J1338.
- f. If desired, the threshold susceptibility level and center frequency can be found. Select the mid frequency of each response band and slowly increase the transmitted power until a response is seen. Then vary the frequency slightly maintaining constant power to ensure the lowest response level is monitored.

7. **Notes**—If required in the equipment specification or approved test plan, the test signals (20 MHz-18GHz) can be modulated. The modulation frequency and type should be based upon an engineering analysis of the EUT's estimated susceptibility characteristics and the characteristics of signals in the vehicle's environment. If these characteristics are unknown, the following guidelines are suggested:

- a. EUT's with audio channels/receivers ¹
 AM receivers: Modulate 30% with 1000-Hz tone.
 FM receivers: When monitoring signal-to-noise ratio, modulate with 1000-Hz signal using 10-kHz deviation. When monitoring receiver quieting, use no modulation.
 Other equipment: Same as for AM receivers.

1. There are several industry standards for the performance of radio receivers that may be helpful for determining the modulation to be used on the susceptibility test signal. Two of them are IEEE 185 and EIA RS-204-A, others may be more appropriate for certain equipment.