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**Electromagnetic
Susceptibility
Measurement
Procedures for
Vehicle Components
(Except Aircraft)**

SAE Recommended Practice
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Ø ELECTROMAGNETIC SUSCEPTIBILITY MEASUREMENT PROCEDURES
FOR VEHICLE COMPONENTS (EXCEPT AIRCRAFT)

1. INTRODUCTION:

1.1 Scope: This SAE Recommended Practice establishes uniform laboratory measurement techniques for the determination of the susceptibility to undesired electromagnetic sources of electrical, electronic, and electromechanical ground-vehicle components. It is intended as a guide toward standard practice, but may be subject to frequent change to keep pace with experience and technical advances, and this should be kept in mind when considering its use.

1.2 Measurement Philosophy: The need for measurement of the susceptibility of vehicle electronic components to electromagnetic sources has become more essential as more electronic components are introduced into motor vehicles. Electronic and electrical equipment may be susceptible to performance anomalies when subjected to electromagnetic sources, either of a transient or steady-state nature.

Electromagnetic interference (EMI) may be transient, intermittent, or continuous in nature arising from sources such as transmitters or other equipment located either on board or adjacent to the vehicle, or from component parts of the vehicle ignition or electrical power systems.

This recommended practice sets forth uniform procedures for establishing the susceptibility levels of individual vehicle components. It does not set limits on levels of EM energy in which vehicle components must perform; however, suggestions for developing functional performance status classifications for immunity are given in Appendix B.

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1.2 (Continued):

A direct method of specifying the EM energy environment limits is to measure the actual fields, voltages, current, and impedances around the component or system of interest under all hazardous conditions. This will, of course, require a large enough sample of installations to determine possible variations. Some example data showing fields exists in NBS Technical Note 1014, "Electromagnetic Interference (EMI) Radiative Measurements for Automotive Applications."

It is recommended that a statistically valid number of components be tested using procedures adopted as standard by the testing organization. For destructive testing, such as transients on the power leads of Section 4, consult a handbook on statistical methods for details of the Karber method or the Bruceton (stair-step) method of sensitivity measurements. These methods eliminate the effects of cumulative degradation which often occurs during destructive testing.

It is suggested that only those portions of this recommended practice which are critical to the particular use of the component under test be applied, rather than subject the component to the provisions of the entire document. Thus, if the particular component under test is known to be susceptible mainly to transients, but otherwise well protected against conducted and radiated EMI, then only Section 4 need be applied. Or, if susceptibility to radiated energy is known to be a primary cause of malfunctions, then only Sections 6 through 9 need be applied.

Caution must be exercised in many portions of this procedure where high voltages or intense fields may be present.

ANSI and OSHA standards should be consulted concerning applicable limits on field exposure. For near field power density calculations, refer to paragraph 1.3.7.

1.3 Definitions and Terminology: The following definitions apply to the terms indicated as they are used in this recommended practice:

- 1.3.1 Ambient Level: Those levels of radiated and conducted signal and noise existing at a specified test location and time when the test sample is in operation. Atmospherics, interference from other sources, and circuit noise or other interference generated within the measuring set compose the ambient level.
- 1.3.2 Conducted Emission: Desired or undesired electromagnetic energy which is propagated along a conductor.
- 1.3.3 Electromagnetic Compatibility (EMC): Is the condition that enables equipment, subsystems, and systems (electronic, chemical, biological, etc.) to function without degradation from electromagnetic sources and without degrading the electromagnetic environment; that is, it is the condition which allows the coexistence of different electromagnetic sources without significant change in performance of any one in the presence of any or all of the other.

- 1.3.4 Emission: Electromagnetic energy propagated from a source by radiation or conduction.
- 1.3.5 Equipment Under Test (EUT): The device or system whose susceptibility is being checked.
- 1.3.6 Field Decay (Voltage): The exponentially decaying negative voltage transient such as developed by an automotive alternator when the field excitation is suddenly removed, as when the ignition switch is turned off.
- 1.3.7 Field Strength: The term field strength shall be applied to either the electric or the magnetic component of the field, and may be expressed as V/m or A/m. When measurements are made in the far field and in free space, the power density in W/m^2 may be obtained from field strengths approximately as $(V/m)^2/377$ or $(A/m)^2 \times 377$. When measurements are made in the near field and in free space, both the complex electric and magnetic vector components of the field must be fully defined. Power density may then be obtained by use of the Poynting vector.
- 1.3.8 Ground Plane: A metal sheet or plate used as a common unipotential reference point for circuit returns and electrical or signal potential.
- 1.3.9 Load Dump (Voltage): The exponentially decaying positive voltage transient developed by an automotive alternator when disconnected, suddenly from its load, while operating without a storage battery or with a discharged storage battery. Removal of the load, the resulting transient, or both in combination are commonly referred to as alternator load dump.
- 1.3.10 Radiated Emission: Radiation - and induction-field components in space. (For the purpose of this document, induction fields are classed together with radiation fields.)
- 1.3.11 Spurious Emission: Any unintentional electromagnetic emission from a device.
- 1.3.12 Susceptibility: The characteristic of an object that results in undesirable responses when subjected to electromagnetic energy.
- 1.3.13 Test Plan: The specific document that details all tests and limits for the particular device in question.
2. CONDUCTED SUSCEPTIBILITY, 30 HZ TO 250 KHZ - ALL INPUT AND OUTPUT LEADS INCLUDING POWER:
- 2.1 Purpose: This section covers the requirements for determining the susceptibility characteristics of automotive electronic equipment, sub-systems, and systems to EM energy injected onto all leads. This test may be used over the frequency range of 30 Hz to 250 kHz.

2.2 Measurement Philosophy: For the frequency range of this test, the impedances seen by the signal, load and power supply leads are generally known and can be treated as lumped constants. In this test, a wide range audio voltage source is coupled through a transformer to each specified pin of the EUT. The signal source impedance must be low in comparison to the impedance of the circuit being tested. Experience has shown that a signal source impedance of 0.5 ohms maximum is adequate for the test. The EUT should be connected so it will operate in its normal manner. Actual loads and sources should be used where appropriate or may be simulated. A capacitor shunt element should be used on a specific lead, if a large percentage of the test signal does not appear across the signal, load or power supply lead relative to ground. (See Fig. 1.)

2.3 Grounding and Shielding: For the stated frequency range there are no special grounding and shielding requirements. However, the requirements of paragraph 3.3 may be utilized here, if expedient.

2.4 Apparatus: To utilize the full frequency range of this test, the apparatus shall be as follows:

- (a) Audio Oscillator: 30 Hz to 250 kHz.
- (b) Audio Power Amplifier: 50 W or greater with output impedance equal to, or less than, 2.0Ω (capable of delivering 50 W into a 0.5Ω resistive load connected across an isolation-transformer secondary). 30 Hz to 250 kHz
- (c) Isolation transformer: 4:1 impedance ratio; secondary as connected shall be capable of handling the current flow without saturating the core. 30 Hz to 250 kHz
- (d) Measuring Instrument: Oscilloscope, Voltmeter, or EMI Meter.
- (e) Power Supply: The power supply used for this test shall have the equivalent of 100 μ f (min) capacitor across the output terminals.
- (f) Capacitor: A 100 μ f capacitor may be used to shunt the source end of the isolation transformer to ground, if difficulty is encountered in obtaining sufficient test voltage.

2.5 Test Setup and Procedures: The test setup is shown in Fig. 1.

- (a) The system power supply voltage shall be set as specified in the test plan.
- (b) The audio oscillator shall be tuned through the required frequency range (30 Hz to 250 kHz).
- (c) The injected voltage level shall be progressively increased toward the level specified in the test plan. Alternatively, the test voltage may be held at a specified test level and, if an effect on the EUT is detected, the test voltage reduced to determine the threshold.

2.5 (Continued):

- (d) The EUT shall be monitored for (1) malfunction, (2) degradation of performance, or (3) deviation of parameters beyond tolerances indicated in the equipment specification or the test plan.
- (e) The effects resulting from the injection of electromagnetic energy, the frequency and the threshold level shall be recorded.

2.6 Notes:

- 2.6.1 The upper frequency limit for items 2.4a, 2.4b, and 2.4c can be reduced in accordance with the user's frequency range requirements.
- 2.6.2 It is recognized that other types of equipment can produce equivalent signals, for example, a Power Oscillator can replace the oscillator and amplifier; a Power Operational Amplifier can replace the amplifier and power supply, etc.
- 2.6.3 The following procedure can be used to verify the signal source impedance at the isolation transformer secondary terminals.
 - (a) Set a voltage level at the primary terminals and measure the open circuit secondary voltage (V_{oc})
 - (b) Connect a known load R_L across the secondary and measure the closed-circuit secondary voltage (V_{cc})
 - (c) The impedance shall be calculated as follows:

$$Z = \frac{R_L (V_{oc} - V_{cc})}{V_{cc}} (\Omega)$$

- (d) Repeat the above procedure at one frequency per decade from 30 Hz to 250 kHz (including 30 Hz and 250 kHz).
 - (e) The measured impedance shall be less than, or equal to 0.5Ω .

3. CONDUCTED SUSCEPTIBILITY, 50 KHZ TO 100 MHZ - ALL INPUT AND OUTPUT LEADS, INCLUDING POWER:

- 3.1 Purpose: This section covers the requirements for determining the susceptibility characteristics from 50 kHz to 100 MHz of automotive electronic equipment, subsystems, and systems to EMI injected onto all input leads, including signal and power.
- 3.2 Measurement Philosophy: Power-source RF impedance seen by a given type of electronic equipment depends upon this varying impedance and would render susceptibility measurements meaningless unless the impedance is also measured or controlled. In order to compare measurements made at various locations, powerline RF impedance seen by the equipment shall be controlled by line-impedance stabilization networks. The EUT should be connected so it will operate in its normal manner. Actual loads and sources should be used where appropriate or may be simulated.

3.3 Grounding and Shielding: To achieve uniform measurement conditions at radio frequencies requires that certain grounding practices be followed. Ground requirements are that EUT, LISNs, and terminating loads:

- (a) be placed on a metallic ground plane having the following minimum dimensions:
 - 1. Thickness: 1.5 mm (0.060 in) aluminum, copper, or brass sheet.
 - 2. Length: 1 m or underneath entire equipment plus 0.5 m whichever is larger.
 - 3. Width: width of equipment plus 0.25 m on each side.
- (b) be bonded to the ground plane as in its intended installation.
- (c) not otherwise be grounded, unless required in installation instructions. The line-impedance stabilization networks shall be bonded to the ground plane as close as possible to the EUT ground. No shielding is to be used other than that called out in installation instructions.

3.4 Power Input Lead Test:

3.4.1 Apparatus:

- (a) Signal Source: A 50 Ω output-impedance source with an output of 100 V or greater into a matched load.
- (b) One of the following to measure RF voltage:
 - 1. Calibrated Oscilloscope
 - 2. High Impedance RF Voltmeter
 - 3. EMI Meter
 - 4. Spectrum Analyzer
- (c) Line-Impedance Stabilization Networks (LISN's): as specified in Figs. 2 and 3 with 50 Ω resistive RF terminations. (See Appendix A for suggestion of construction details.) When using a LISN, caution should be exercised to avoid load-current limiting due to series inductance in the LISN. This limiting may occur when loads switch between high and low impedance states. Use of a LISN may then result in increased susceptibility.
- (d) Test-Source Injection Networks illustrated in Fig. 4.
- (e) Power Supply: DC.

3.4.2 Test Setup and Procedure: The test setup is shown in Fig. 5. The procedure is as follows:

- (a) Each control and signal lead shall be loaded with a termination impedance. At these frequencies, however, the impedance as seen by the control and signal leads may no longer be determined by the system designer, due to uncontrollable stray impedances. It may be possible to simulate these impedances with a simple capacitor and inductor added to the actual leads if the frequency in MHz does not greatly exceed $300/20\pi\ell$ where the ℓ is the characteristic lead length in meters. Above that frequency, the test designer should design the test plan and setup to given uniform results.
- (b) The EUT shall be connected as shown in Fig. 5, observing the grounding and shielding requirements of paragraph 3.3.
- (c) Signal sources and measuring instrumentation shall be connected to an LISN through test-source injection networks. Care shall be exercised to insure sufficiently short leads on the injection networks and LISN's to minimize loss of signal due to series inductance and shunt capacitance. A current probe on the injection lead right next to the EUT can be used to monitor the signal. For signal-source and measuring-instrument impedance equal to $50\ \Omega$, use the signal-injection network of Fig. 4A. For a signal-source impedance of $50\ \Omega$ and a high-impedance measuring instrument, use the signal-injection network of Fig. 4B. Note the corresponding attenuation factors.
- (d) Increase the level of the test signal while continuously scanning through the required frequency range (50 kHz - 100 MHz). Tests shall be conducted at not less than three frequencies per octave representing the maximum susceptibilities within that octave. Monitor the equipment under test for: (1) malfunction, (2) degradation of performance, or (3) deviation of parameters beyond tolerances indicated in the equipment specification or approved test plan (see paragraph 3.6). Record the highest level before degradation was observed.
- (e) See paragraph 2.5(c).

3.5 All Leads Except Power:

3.5.1 Apparatus:

- (a) Signal Sources: as for powerline measurements.
- (b) Measuring Instruments: as for powerline measurements.
- (c) Test Source Injection Networks: see Fig. 4.

3.5.2 Test Setup and Procedure:

- (a) Test setup is shown in Fig. 6. Note that the LISN remains in the powerline circuit and its RF injection terminal is loaded with $50\ \Omega$.
- (b) Each control and signal terminal not under test is loaded with its terminating impedance and test signals are injected into the test terminal as indicated in Fig. 6. At these frequencies, however, the impedances seen by control and signal leads may no longer be determined by the system designer. It may be possible to simulate the stray impedance as described in paragraph 3.4.2(a). Care shall be exercised to insure sufficiently short leads on the injection networks and LISN's to minimize loss of signal due to series inductance and shunt capacity. A current probe on the injection lead right next to the EUT can be used to monitor the signal.
- (c) Increase the level while continuously scanning through the required frequency range (50 kHz - 100 MHz). Tests shall be conducted at not less than three frequencies per octave representing the maximum susceptibilities within that octave. Monitor the EUT for: (1) malfunction, (2) degradation of performance, or (3) deviation of parameters beyond tolerances indicated in the equipment specification or approved test plan. (See paragraph 3.6.) The values at which these occur shall be recorded.

3.6 Notes:

- (a) Each LISN shall be tested over the range for which it is designed. The impedance should be within 20% of the curves in Figs. 2 and 3. If any discrepancies occur, then the network should be modified, for example, by adding ferrites to inductor leads to increase impedance at higher frequencies.
- (b) Unless otherwise required in the equipment specifications or approved test plan, the test signals shall be modulated according to the following rules:
 - 1. Test samples with audio channels/receivers.
 - AM Receivers: Modulate 30% with 1000 Hz tone.
 - FM Receivers: Modulate with 1000 Hz signal using 30% modulation.
 - SSB Receivers: Use no modulation.
 - Other Equipments: Same as for AM receivers.
 - 2. Test samples with video channels other than receivers. Modulate 90 - 100% with pulse of duration $2/BW$ and repetition rate equal to $BW/1000$, where BW is the video bandwidth (Hz).
 - 3. Digital Equipment: Use pulse modulation as appropriate with pulse duration and repetition rate set equal to that used in the equipment under test or associated with other known external pulse sources that may be operating in close proximity.
 - 4. Non-Tuned Equipment: Amplitude modulate 30% with 1000 Hz tone or as otherwise specified in the test plan.

4. CONDUCTED SUSCEPTIBILITY, TRANSIENTS, POWER LEADS 12 V PASSENGER CAR SYSTEMS:

- 4.1 Purpose: This section describes methods and apparatus to determine the capability of various electrical devices to withstand transients which normally occur in motor vehicles. Test apparatus specifications outlined in this section were developed for 12 V passenger cars. Similar specifications are being developed for 12 V trucks and 24 V vehicles.

Functional performance status classifications for immunity to transients are given in Appendix B. EUT performance requirements for each of the test pulses must be individually determined.

- 4.2 Measurement Philosophy: Installed equipment is powered from sources which contain, in addition to the desired electrical voltage, transients with peak values many times this value, caused by the release of stored energy during the operation of relay and other loads connected to the source and during start and turn off of vehicles. These tests are designed to determine the capability of equipment to withstand such transients. The tests may be made in the laboratory (bench tests) as well as on the vehicle. These tests are outlined in ISO/TR 7637, "Road Vehicles - Electrical Interference by Conduction and Coupling: Part 1, Vehicles with Nominal 12 V Supply Voltage - Electrical Transient Conduction Along Supply Lines Only." Bench test methods should give results which allow comparison between different laboratories and are intended to provide a basis for development of devices and systems. These tests may also be used later during production of these devices and systems.

These tests may not cover all types of transients which can occur in a vehicle. Therefore, the test pulses described in paragraph 4.3 are characteristic of typical pulses. To ensure proper operation of a vehicle in the electromagnetic environment, on-board testing must be performed in addition to bench testing.

4.3 Apparatus:

- (a) Pulse generators capable of generating the transient waveforms shown in Figs. 7A - 7H shall be adjustable up to the amplitudes indicated. The specification of rise time (T_r), duration (T), and internal resistance (R_i) represent fixed requirements unless otherwise specified.
- (b) Oscilloscope (preferably storage): for monitoring the pulse generator
 - band width: at least 100 MHz
 - writing speed: at least 100 cm/ μ s
 - input sensitivity: at least 5 mV/division

4.3 (Continued):

- (c) Voltage Probe: for use in conjunction with the oscilloscope.
attenuation - 100/1
maximum input voltage - at least 1 kV
input impedance as a function of the frequency, f :

f (MHz)	Z (k Ω)
1	40
10	4
100	0.40

maximum length of the probe cable - 3 m

maximum length of the ground cable - 0.13 m

Note: Any other cable lengths may influence the result of the measurement and should be stated in the test report.

- (d) Switch S: Use standard production switch for the respective EUT.
Current rating must be sufficient to handle the required loads.
- (e) Equipment, as may be required, to perform a functional test of the component following transient application.

4.4 Test Setup and Procedure:

- (a) Connect a known functional EUT as shown in Fig. 8.
- (b) Ensure that the ambient temperature and supply voltage V_s are maintained as required by the appropriate test specification.
- (c) Set up the pulse generator to provide the polarity, amplitude, and pulse duration as specified in the appropriate test specification.
- (d) Generate the test pulse.
- (e) Perform the appropriate functional test to determine whether failure has occurred and record results.

4.5 Notes:

- (a) In determining the susceptibility level, care must be exercised to eliminate the effects of cumulative deterioration such as dielectric "punch through" in semi-conductor devices.
- (b) When testing to a specified level, unnoticed failures may occur which may be detected only by running life-cycle tests and comparing the results of tested components against those of untested components.
- (c) Rise time requirements as specified in Figs. 7A - 7H represent a design objective. For short duration, high voltage pulse, some rise times may not be practical.

4.5 (Continued):

- (d) The ambient temperature during the test shall be 23 ± 5 °C.
- (e) Power leads should be separated from all other leads for these tests.

5. ELECTROSTATIC DISCHARGE:

- 5.1 Purpose: This section covers the requirements for determining the susceptibility of automotive electronic components/subsystems to Electrostatic Discharge (ESD).
- 5.2 Measurement Philosophy: Occupants in a vehicle can generate significant electrostatic potentials. Devices in the vehicle may fail when an electrostatic discharge occurs.

Electrostatic discharge simulator parameters for use in automotive applications are unique to the automotive environment and differ from values used in other applications.

5.3 Apparatus:

- (a) ESD Simulator characteristics:
 - Voltage Range: variable from 1 kV to 15 kV (negative and positive polarity)
 - Capacitor: 330 pF (+ 10%)
 - Inductor: $< 1 \mu\text{H}$
 - Resistance: 2000Ω (+ 10%)
 - Tip: standard (IEC) finger model electrode. (See IEC 801-2)

ESD simulators are commercially available. Appendix C defines a test method for evaluating the characteristics of the simulator to ensure the generation of accurate and reproducible discharge waveforms.

- (b) Conductive Bench Top, at least 1 m^2 .

5.4 Test Procedure:

- (a) The device shall be placed on a conductive-bench top as shown in Figs. 9A and 9B. All voltage supply pins should be connected to an appropriate power source. All ground pins should be connected together. The ground pins, bench top, ESD simulator, and power source shall be grounded together and to earth ground. All other pins shall be connected to simulate normal modes of operation.
- (b) The method of air discharge to a point shall be used to simulate a real world ESD event. The ESD simulator must be charged to the "test voltage" before approaching the EUT. Approach the EUT at a speed approximating a "normal" interface by a human finger (greater than 5 cm/s).

5.4 (Continued):

- (c) Twenty discharges shall be applied to specified test points at each voltage level; ten with positive polarity and ten with negative polarity. A minimum of five (5) s shall be maintained between pulse applications.

If significant variations are observed in the measurement data, twenty discharges may not be sufficient to obtain statistically significant results. If this is found to be the case, a larger number of discharges will be required.

- (d) During and after each level of testing, the device shall be measured for performance which may indicate failure to meet design requirements.

6. RADIATED SUSCEPTIBILITY, POWER LINE MAGNETIC FIELD 60 HZ TO 30 KHZ:

- 6.1 Purpose: This section covers the recommended testing technique for determining the susceptibility of automotive electronic modules, subsystems, and systems to magnetic fields generated by power transmission lines and generating stations.

- 6.2 Measurement Philosophy: Electronic systems may be affected when immersed in a magnetic field. These fields are found near high power transmission lines and power generating stations that generate magnetic fields. The fields consist of the fundamental (60 Hz signal) and its odd harmonics with amplitudes approaching those shown in Fig. 10. Consequently, devices in vehicles that are driven near these sources may be subjected to these fields.

6.3 Test Specification:

- (a) Lower frequency: 60 Hz.
- (b) Upper frequency: 30 kHz.
- (c) Magnetic flux density of Helmholtz coil - see Fig. 10.

- 6.4 Test Apparatus: The following section describes a typical test setup that could be used to generate a uniform magnetic field for the testing as illustrated in Fig. 11.

- (a) Helmholtz Coil: The radius of the coil will be determined by the size of the EUT. In order to obtain a uniform magnetic field (+ 10%), the relationship between the EUT and the coil is illustrated in Fig. 12. The coil should be capable of producing frequency dependent magnetic flux density of 160 dBpT at 60 Hz, decreasing at a rate of 12 dB/octave. For a pair of Helmholtz coils spaced one radius, the magnetic flux density at the center of the system is given by:

$$B = \mu_0 H = (8.991 \times 10^{-7} N I) / R \text{ (Teslas)},$$

where N is the number of turns on each coil, R is the coil radius in meters, and I is the coil current in amperes. The coils are connected in series so that the magnetic fields add.

6.4 (Continued):

Or, the unperturbed magnetic field at the center of the system is given by:

$$H = \frac{0.7155 \text{ N I}}{R} \quad (\text{A/m}),$$

The current carrying capability and turn ratio should be selected such that the test specification can be met. The coil should not have a self resonant frequency at or lower than the upper test frequency. Helmholtz coils can be purchased commercially.

- (b) Function generator capable of producing 60 Hz to 30 kHz.
- (c) Audio Power Amplifier: 60 Hz to 30 kHz (approximately 200 W). Should be capable of delivering power to the coil to generate the specified magnetic field intensity at various frequencies as shown in Fig. 10.
- (d) Current Monitor: 60 Hz to 30 kHz.
- (e) Magnetic Field Intensity Monitor: 60 Hz to 30 kHz. Should be capable of measuring the specified magnetic field intensity.

6.5 Test Setup and Procedure:

- (a) Connect the test setup according to Fig. 11 without the EUT.
- (b) Calibrate the system by generating the magnetic field, measuring the field using the intensity monitor and recording the current versus field values.
- (c) Place the operating EUT in the central region of the Helmholtz coil. (Note: The Helmholtz coil criteria should be met.) Generate the desired magnetic field levels in accordance with the calibration established in paragraph 6.5 (b).
- (d) Monitor the EUT and record the respective magnetic field intensity for: (1) malfunction, (2) degradation of performance, or (3) deviation of parameters beyond tolerances indicated in the EUT specifications and approved test plan.

- 6.6 Notes: Caution must be exercised when operating high power amplifiers to avoid hazards to personnel and instrumentation. Instrumentation in the near vicinity of the coils must be shielded to prevent interference from radiated fields. Care should be exercised not to operate the coils near large metal objects or inside a shielded enclosure.

7. RADIATED SUSCEPTIBILITY, 14 KHZ - 200 MHZ, ELECTRIC AND MAGNETIC FIELDS USING A TEM CELL:

- 7.1 Purpose: This section covers requirements for the determination, typically, of the electric-field susceptibility of equipment, subsystems, and systems (whose largest dimension is less than 15 cm) in the frequency range 14 kHz - 200 MHz using a TEM cell. However, since components of both the electric and magnetic fields are established in the TEM cell, the technique can be used for both electric and magnetic field susceptibility testing.
- 7.2 Measurement Philosophy: A TEM transmission cell is a rectangular adaptation of a coaxial line which sets up a region of uniform electric and magnetic fields in a traveling wave of essentially free-space impedance. The EUT is exposed to this electromagnetic source, but, typically, only the electric-field component is monitored. However, since components of both the electric and magnetic field are present, the exposure field can be calibrated in terms of either electric or magnetic field for either electric or magnetic field susceptibility testing.

This technique also prevents disturbance to equipment not under test since the RF field source and EUT are completely self-contained within the electromagnetic enclosure.

The TEM cell can be used to accurately generate absolute test fields when the EUT does not occupy an excessive portion of the test volume (see paragraph 7.5 c). It is especially useful for diagnostic testing to determine, for example; frequencies of EUT susceptibility, some indication of how interference is coupled into the EUT, and the relative improvement in EUT immunity resulting from efforts to reduce EUT susceptibility. It cannot be used to determine EUT susceptibility to absolute test field levels if the EUT includes long wire harnesses that must be exposed to the test field. Only relative tests can be performed for this situation. The TEM cell lends itself to broadband automated testing and to continuous, swept frequency testing over the complete frequency range covered by the single TEM mode operation of the cell. TEM cell limitations due to EUT size and cell multimoding are discussed in SAE J1448 JAN84 (see Ref. 8). An alternate measurement approach is the use of open field tests as outlined in the SAE J1338 JUN81 (see Ref. 9). This approach however, is limited to discrete frequencies.

7.3 Apparatus:

- (a) Signal Source: Any commercially available signal source, power amplifier, and general-purpose amplifier capable of supplying at least 100 W of modulated and unmodulated power to develop the susceptibility levels specified in the test plan shall be used. Frequency accuracy shall be within + 2%. Harmonics and spurious outputs shall not be more than - 30 dB referred to the fundamental power.
- (b) RF Voltmeter: A commercially available RF voltmeter capable of measuring 100 V over the frequency range 14 kHz - 200 MHz.