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Electromagnetic Susceptibility Measurements of Vehicle Components Using TEM Cells (14 kHz–200 MHz)— SAE J1448 JAN84

SAE Information Report
Approved January 1984

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ELECTROMAGNETIC SUSCEPTIBILITY MEASUREMENTS OF VEHICLE COMPONENTS USING TEM CELLS (14 kHz–200 MHz)— SAE J1448 JAN84

SAE Information Report

Report of the Electrical and Electronic Systems Technical Committee, approved January 1984

1. Purpose—This report covers requirements for the determination of 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 [1]. This report outlines a systematic approach, using a TEM cell, for evaluating the electromagnetic (EM) radiated susceptibility of electronic equipment. The purpose of the report is to provide guidelines, for those using TEM cells for performing EM susceptibility measurements, to improve the repeatability and, hence, the value of their test results. The report describes the test setup, details the step-by-step procedures to use in performing susceptibility measurements, and discusses pertinent information related to the range of application and limitations associated with the use of TEM cells.

2. Measurement Philosophy—A transverse electromagnetic (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 freespace impedance. The equipment under test (EUT) is exposed to this electromagnetic source, but only the electric-field component is monitored. 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. This technique is intended primarily for use in diagnostic testing to determine, for example, frequencies of EUT susceptibility, some indication of how electromagnetic interference (EMI) is coupled into the EUT, and the relative improvement in immunity that may result from efforts to reduce an EUT's susceptibility (that is, A-B measurements). It is not intended for use in determining EUT susceptibility to absolute test field levels if, for example, the EUT includes long wiring harnesses that must be exposed polarization matched to the test field.

3. Apparatus—The test apparatus shall consist of the following:

(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, provided the following requirements are met: Frequency accuracy shall be within $\pm 2\%$ and 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.

(c) **Termination**—One 100 W, $50\ \Omega$ load.

(d) **Frequency Counter**—A frequency counter capable of measuring frequencies up to 200 MHz.

(e) **TEM Transmission Cell**—A transverse electromagnetic transmission cell is shown in Figs. 1 and 2. Typical dimensions for cells are given in Table 1. The dimension for a cell suggested for use in the frequency range 14 kHz–200 MHz is underlined on the table.

(f) **Low-Pass Filter**—Cutoff at 200 MHz, with the signal down 60 dB at frequencies greater than 300 MHz.

(g) **Signal Samplers or Monitor Tees**—Frequency and rf-voltage monitoring equipment.

(h) **Monitors**—Required test equipment to monitor the operation of the test sample.

(i) **Dual Directional Coupler(s)**— -30 dB or greater coupling ratio, 10–200 MHz.

(j) **rf Power Meters with Sensors**—Capable of measuring rf power levels up to 100 mW at frequencies of 10–200 MHz.

(k) **Dual Channel xy Recorder**.

4. Test Setup—Figs. 3A and 3B show two block diagrams of systems using the TEM cell for susceptibility measurements. Fig. 3A is used for frequencies below 10 MHz and Fig. 3B is used for frequencies above 10 MHz. Both systems are configured for swept frequency testing; however, either system could be used for discrete frequency testing without the use of the xy recorder or a sweep-type generator.

The high-power generator generally consists of a variable frequency generator and high-power linear amplifier. Most of today's linear amplifiers have built-in protection circuits which protect them in the event the cell system becomes impedance mismatched. The low-pass filter is needed to keep unwanted higher frequency components (second, third, etc., harmonics) from being introduced into the cell. This is especially important if the harmonics or spurious frequencies are above the multimode or resonant frequency limit of the cell. A frequency counter is used to tell precisely at what frequency a failure occurs. This can be important if the signal generator frequency calibration is not sufficiently accurate since

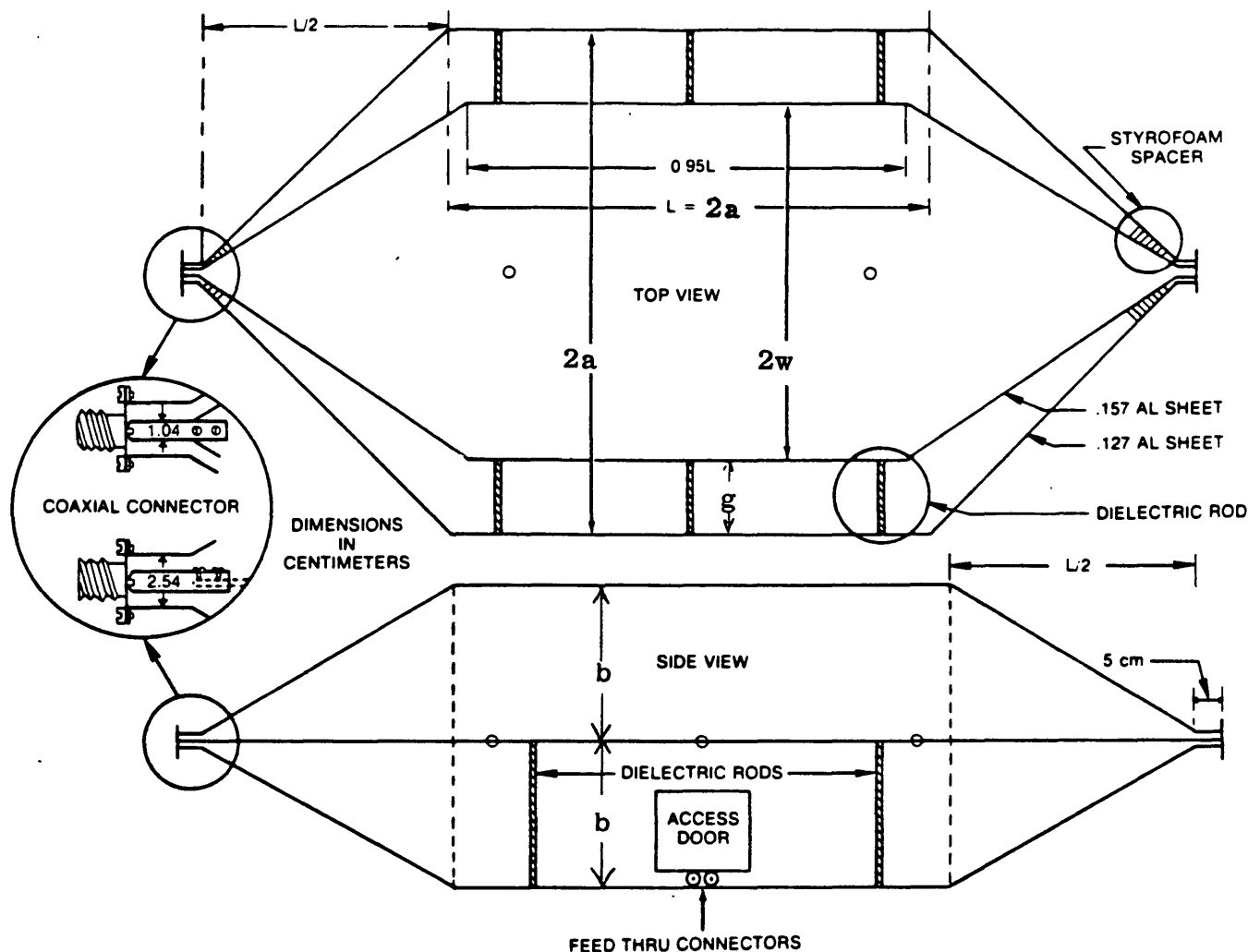


FIG. 1—DESIGN FOR RECTANGULAR TEM TRANSMISSION CELL

EUT susceptibility often is characterized by high Q -resonances which have very narrow frequency responses. The dual coupler and power meters are used to measure the incident and reflected power at the input of the cell. A test monitor is shown with the EUT and is used to determine failure of the EUT. A 50 Ω , high-power load is used to terminate the system.

The main difference between Figs. 3A and 3B is the use of an rf voltmeter with monitor tee in place of the directional coupler and power meters.

At frequencies below 10 MHz, the cell is electrically short (that is, much less than one wavelength), and accurate voltmeter measurements, which can be referred to the EUT location at the center of the cell, can be made.

Automated, interactive susceptibility measurements can be made by using a minicomputer controlled system as shown in Fig. 4. This system places the testing operation under control of the computer which progressively increases the test-field level in the cell at selected frequencies while monitoring the test-field level around the EUT and the performance of the EUT. If degradation occurs as determined from preestablished, programmed criteria, the computer can respond by limiting the test-field level to prevent damage to the EUT. The computer will also print out the susceptibility information according to software instruction and format.

5. Measurement Procedures—The following measurement procedures are suggested as a systematic approach for evaluating the EM radiated susceptibility of equipment using a TEM cell.

Step 1. Place the EUT inside the cell. Normally, the EUT is placed in one of two locations in the lower half space (below the septum) centered in the cell. The first location (location A) for placing the EUT is on the floor of the cell (Fig. 5), but insulated from it (unless grounding the EUT case to the cell is desired). This position is used to evaluate field-to-EUT case coupling by minimizing the exposure of the EUT's input/output leads and monitor leads to the test field as explained in Step 2. If the EUT is placed near the floor of the cell, the test field will be lower, relative to the field at the center (midway between the septum and floor) of the cell test zone—from 5 to 15% depending upon the cell form factor (width to height ratio). (That is, if a/b is 1.0, this correction factor is 0.85; if a/b is 1.5, this correction factor is 0.92; and if a/b is 1.67, the correction factor is 0.95).

The second common location (location B, Fig. 6) is halfway between the septum and cell bottom. The EUT is supported on dielectric material

EM SUSCEPTIBILITY TESTING

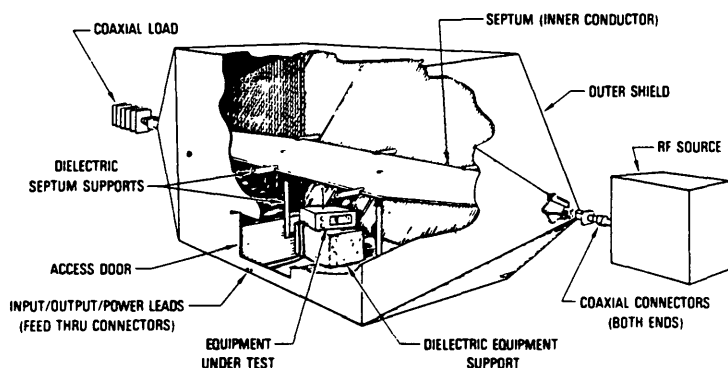


FIG. 2—CUT-AWAY VIEW OF TEM CELL BEING USED FOR EM SUSCEPTIBILITY TESTING. FIGURE SHOWS PLACEMENT OF EUT AND ASSOCIATED INPUT, OUTPUT, AND MONITORING LEADS INSIDE THE CELL