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SURFACE VEHICLE STANDARD

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(R) ELECTROMAGNETIC COMPATIBILITY MEASUREMENT PROCEDURE FOR VEHICLE COMPONENTS—IMMUNITY TO RADIATED ELECTROMAGNETIC FIELDS, 10 kHz TO 500 MHz—TRI-PLATE LINE METHOD

1. ***Scope***—This procedure covers the recommended testing techniques for the determination of electric field immunity of an automotive electronic device. This technique uses a Tri-Plate Line (TPL) from 10 kHz to 500 MHz and is limited to components which have a maximum height of equal to or less than 1/3 the height between the driven element and the outer, grounded plates.

A Tri-Plate Line is a variation of a TEM cell design which is constructed without sides to the cell. The TPL sets up a region of uniform electric and magnetic fields between the center septum and the top and bottom grounded plates.

One advantage to the use of the TPL as opposed to a TEM cell is that the construction permits large devices to be placed within the cell with their associated cables attached without special feed through ports or adapters as required for a TEM cell. The lack of sides which would be found in a TEM cell permits easy routing of the cables to and from the Equipment under test (EUT).

The TPL does not have a serious problem with fields reflected from the side walls as does the TEM cell due to the lack of side walls. This permits its use to frequencies above twice the normal useful frequency for a TEM cell of the same physical size.

However, the lack of side walls also means that the TPL must be used within a shielded room to prevent radiation from the TPL from interfering with nearby electronic devices. The possibility of room resonances and reflected waves distorting the measurements must not be ignored. This is discussed in greater detail in the body of this document.

CAUTION—Hazardous voltages and fields exist on and near the Tri-Plate Line when the equipment is energized. Test personnel should ensure that no one is in the test chamber during a test.

2. ***References***—For general references, see SAE J1113/1.

2.1 **Applicable Publication**—The following publications form a part of this specification to the extent specified herein. Unless otherwise specified, the latest issue of SAE publications shall apply.

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

SAE J1113/1—Electromagnetic Compatibility Measurement Procedures and Limits for Vehicle

Components (Except Aircraft) (60 Hz to 18 GHz)

2.1.2 OTHER PUBLICATIONS

M.V. Schneider, "Micro Striplines for Microwave Integrated Circuits," Systems Technical Journal 48 #5, May-June 1969

3. ***Definitions***—For general definitions, see SAE J1113/1.

4. ***Test Equipment***—The test apparatus shall consist of the following:

4.1 **Signal Source**—Any signal source and power amplifier capable of supplying adequate RF power, both modulated and unmodulated, to develop the immunity levels specified in the test plan shall be used, provided the following requirements are met:

a. Residual FM shall be less than 10 Hz
b. Frequency resolution shall be less than 100 Hz
c. Harmonics and spurious outputs shall not be more than –20 dB referred to the fundamental power

4.2 In-line directional coupler and an RF wattmeter capable of measuring net power up to the maximum power and frequency in use

4.3 **Field Strength Meter**—A RF field strength meter capable of measuring 200 V/m up to 500 MHz. This instrument is to be used during calibration. Please refer to Appendix A.

4.4 Theory and construction of the TPL is contained in Appendix B.

5. ***Test Set Up***

CAUTION—Hazardous voltages and fields exist on and near the Tri-Plate Line when the equipment is energized. Test personnel should ensure that no one is in the test chamber during a test.

5.1 Test set up should be as shown in Figures 1 and 2.

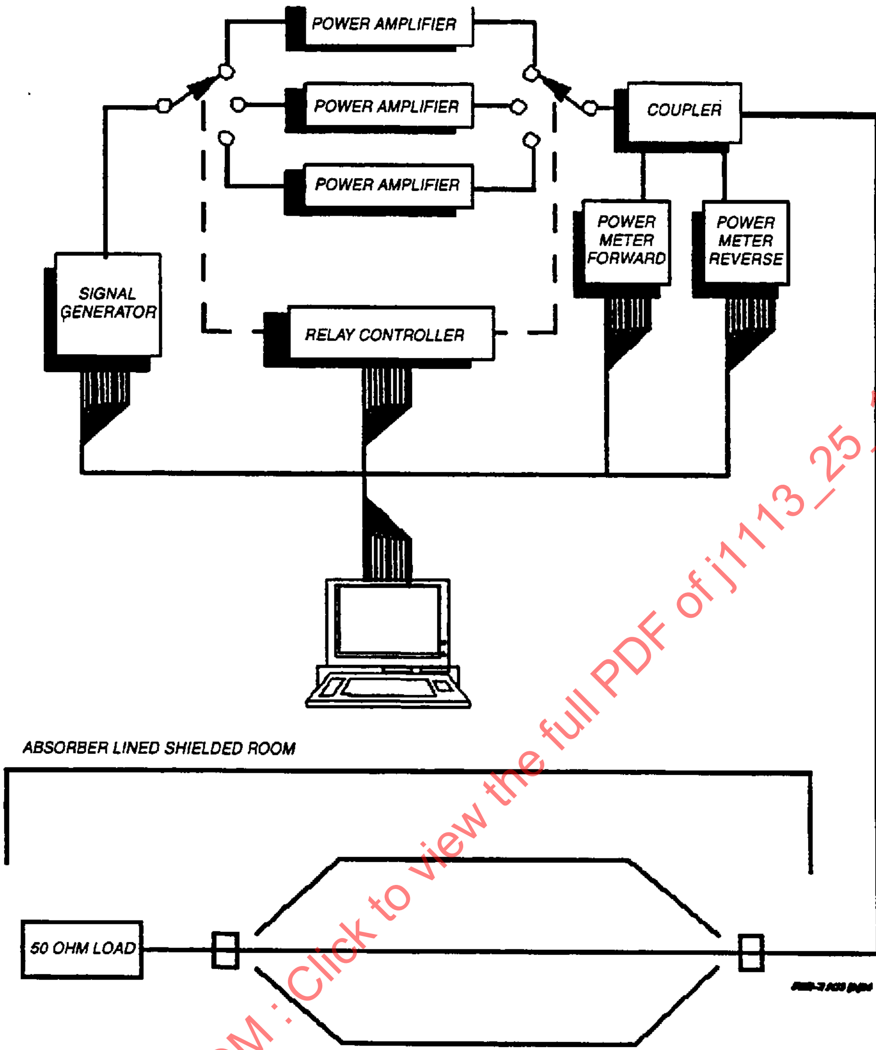
5.2 The EUT and its wire harness should be placed on a nonconductive fixture in the center of the TPL, parallel to its major axis, supported midway between the septum and the outer plate. This nonconductive fixture shall be constructed of material with a very low dielectric constant (e.g., foamed polystyrene or equivalent, $E_R \leq 1.4$.

The physical height of the EUT should not exceed 1/3 of the height of the distance between the ground plane and active conductor. Note that the primary function of the fixture is to lock the positions of the harness and EUT to ensure the most repeatable results and should be constructed with this in mind.

When peripheral devices are used for operating or monitoring the equipment under test, they should be the original vehicle devices, if possible. The peripheral devices are placed on the ground plane, and electrically/mechanically bonded to it as in the vehicle application.

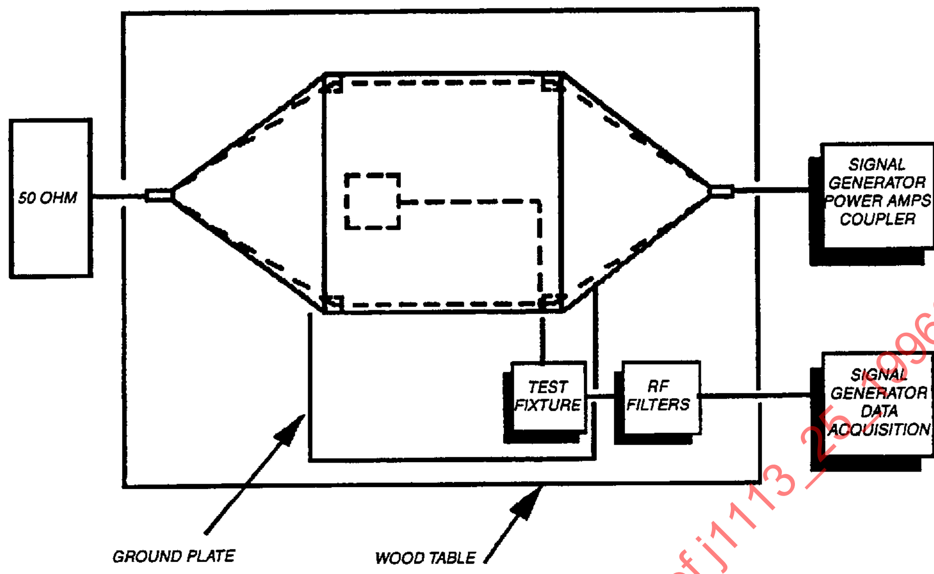
The remaining peripheral devices can be installed in three ways depending on their size and inherent RF immunity.

a. Outside of the shielded testing chamber
b. Shielded and filtered, in the shielded testing chamber
c. In the case of exclusively passive periphery (resistors, capacitors, coils, ferrites, mechanical switches, etc.) or radiation resistant periphery, unshielded, and unfiltered in the shielded testing chamber

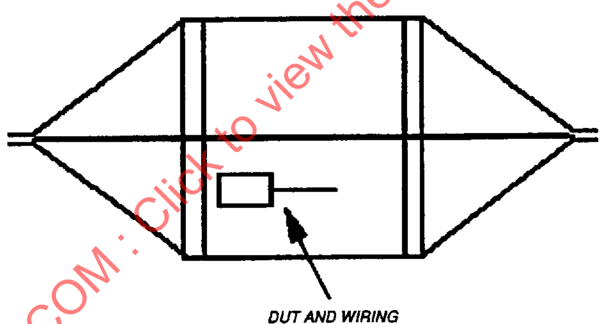


TRI-PLATE LINE TEST CONFIGURATION

FIGURE 1—TEST CONFIGURATION



TRI-PLATE WITHIN ABSORBER LINED SHIELDED ROOM



TRI-PLATE LINE TEST CONFIGURATION

FIGURE 2—TEST CONFIGURATION OVERVIEW

Leads fed through the wall of the shielded testing chamber shall be equipped with adequate RF filters at the wall. This prevents these leads from emitting strong radiation outside of the testing chamber, and possibly influencing the external measuring system, or causing other interferences.

5.3 When the equipment under test with a metal housing and a peripheral device used for the measurement are electrically connected directly to the vehicle mass (by screws, rivets, etc.), both shall be connected to the ground plane by a low inductance connections.

When the EUT is not electrically connected directly to the vehicle mass, both shall be placed on an insulating support. This insulating support shall be constructed of material with a very low dielectric constant (e.g., linen based phenolic, foamed polystyrene, or equivalent, $E_R \leq 1.4$) and shall have the same height as the insulating support on which the wire harness is installed.

The power supply shall be equipped with an adequate filter to prevent overloading the front end regulator by induced RF current. The impedance of this filter, as seen from the EUT, shall correspond to the vehicle power supply system impedance as close as possible.

6. ***Test Procedure***—Three test configurations are feasible; exposure of both the harness and EUT together, exposure of the wiring harness alone or exposure of the EUT alone.

6.1 **Exposure of Both the EUT and its Wiring Harness**—Both the EUT and its harness may be exposed simultaneously to the field of the Tri-Plate Line. (This is the preferred test configuration.) The EUT is placed under the Tri-Plate Line with the attached cable harness running the length of the Tri-Plate Line and exiting at 90 degrees to the septum to maximize induction into the wiring harness. Care must be taken to ensure that the physical size of the EUT does not exceed one-third of the height under the Tri-Plate Line as this may distort the test field.

6.2 **Exposure of the EUT Alone**—When it is desired to determine EUT immunity directly, the EUT may be placed under the Tri-Plate Line with the attached cable harness exiting immediately at 90 degrees to the septum of the Tri-Plate Line to minimize induction into the wiring harness. Care must be taken to ensure that the physical size of the EUT does not exceed one-third of the height under the Tri-Plate Line as this may distort the test field.

NOTE—This requires special agreement between the users.

6.3 **Exposure of Wiring Harness Alone**—The RF fields induced in the harness couple into the EUT using the harness wiring as 'antennas' for the received signal. Expose as much of the harness as can be easily extended under the Tri-Plate Line septum without doubling or folding back the harness on itself.

NOTE—This requires special agreement between the users.

6.4 Fields should be generated as required in the test plan. Information on methods of determining the field strength within the TPL is provided in Appendix A.

6.5 The TPL should be excited according to the frequency and modulation information contained in SAE J1113/1.

7. ***Test Severity Levels***

7.1 A full description and discussion of the Function Performance Status Classification including Test Severity Levels are given in SAE J1113/1 Appendix C. Please review it prior to using the suggested Test Severity Levels presented in Appendix C.

8. ***Notes and Special Considerations***

8.1 For most designs of a TPL, the field strengthis uniform (±3 dB) along the length of its parallel section.

8.2 If the EUT occupies a significant portion of the volume between the active conductor and the ground plate, the test field will be perturbed resulting in a stronger field than that indicated by the measured net power.

8.3 Since the RF field is not fully contained , the test must be performed in a shielded room with the generating and monitoring equipment outside the room. Energy radiated from the TPL into the shielded room will create standing wave patterns which may affect the net field strength about the test object and/or cable harness. These standing waves will be quite noticeable at frequencies where the shielded room dimensions support a cavity resonance.

Caution must be exercised to ensure that resonance effects do not influence the test results obtained with this test method. This effect can be reduced significantly by installing RF absorbing panels between the TPL and the walls. These panels absorb the energy radiated from the TPL and reduce the influence of reflections from the walls of the shielded room and dampen the cavity resonance effects.

8.4 **Marginal Indicia**—The change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions have been made to the previous issue of the report. An (R) symbol to the left of the document title indicates a complete revision of the report.

PREPARED BY THE SAE EMI STANDARDS AND TEST METHODS COMMITTEE

APPENDIX A

TRI-PLATE LINE FIELD CALCULATION

A.1 The field intensity between the driven element of the TPL and its grounded surfaces is a function of the TPL impedance and the net power into the TPL as given by Equation A1:

$$E_v = \frac{\sqrt{Pwr \times Z}}{h} \quad \text{(Eq. A1)}$$

where:

Ev is defined as the field between septum and grounded plates of the TPL in Volts/meter
Pwr is defined as the net RF power into the 50 Ω line feeding the TPL
Z is defined as the characteristic impedance of the TPL (see Appendix C)
h is defined as the plate separation between the ground plates and the active conductor of the TPL (meters)

At low frequencies, a small field RF probe may be used to verify the calculated calibration curve between the net RF power into the TPL and the field in the uniform field region at frequencies below which the wavelength $\lambda \leq 2L$, where L is defined as the length of the TPL.

The position of the field probe should be as close as possible to the middle of the empty TPL (no harness or EUT in place) and referenced to the longitudinal and transverse axes under the septum of the TPL.

As an alternative to direct measurement of the impressed field, a calibration sweep with an empty TPL (no harness or EUT) based upon the RMS value of the field can provide field information which will be valid for all modulations and will not be influenced by reflections from a harness or a EUT.

If the TPL is set up carefully so as to minimize reflections and maintain the system VSWR at ≤1.4:1, then only the forward power into the directional coupler needs to be measured to determine field strength. A sample plot of TPL field strength for one design is shown in Figure A1.

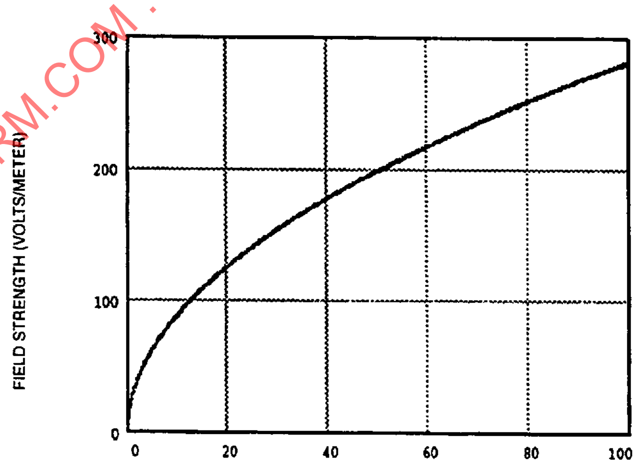


FIGURE A1—FIELD STRENGTH AS A FUNCTION OF FORWARD POWER

APPENDIX B (INFORMATIVE) TRI-PLATE LINE CONSTRUCTION

B.1 The construction of a Tri-Plate Line is shown in Figure B1. The ratio of W to h determines the characterisitc impedance Z according to Equations B1 and B2:

$$Z = \frac{30 \cdot \pi}{\sqrt{er}\left[\dfrac{\frac{w}{b}}{\left(1-\frac{t}{b}\right)} + \dfrac{c}{0.0885 \cdot er}\right]} \qquad \text{(Eq. B1)}$$

where:

w is the active conductor width
π is approximately equal to 3.14159
b is the full cell height
t is the active conductor thickness
h is defined as b/2
C is the fringing capacitance
er is the relative dielectric constant of air

and

$$C = \left[\frac{0.0885 \cdot er}{\pi} \cdot \left[\frac{2}{1-\frac{t}{b}} \cdot \left(1n\left(\frac{1}{1-\frac{t}{b}} + 1\right)\right)\right] - \left[\frac{1}{\left(1-\frac{t}{b}\right)} - 1\right] \cdot 1n\left[\left[\frac{1}{\left(1-\frac{t}{b}\right)^2}\right] - 1\right]\right] \qquad \text{(Eq. B2)}$$

Given a specific example such as:

a. TPL width—W = 500 mm
b. Cell height—b = 600 mm

Equations B1 and B2 give an impedance of: $Z = 71.58\ \Omega$