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SURFACE VEHICLE STANDARD

SAE J1113-25

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Submitted for recognition as an American National Standard

(R) Electromagnetic Compatibility Measurement Procedure for Vehicle Components—Immunity to Radiated Electromagnetic Fields, 10 KHz to 1000 MHz—Tri-Plate Line Method

1. ***Scope***—This procedure covers the recommended testing techniques for the determination of radiated immunity of an automotive electronic device. This technique uses a Tri-Plate Line (TPL) operating over a frequency range from 10 KHz to 1000 MHz. This technique 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, ground plates.

A TPL, a variation of a TEM cell design, is constructed without sides to the cell. The primary advantage to the use of the TPL as opposed to a TEM cell is that its 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 (DUT).

The TPL does not have a serious problem with fields reflected from the side walls as does with the TEM cell. This permits its use to frequencies above that of a TEM cell of the same physical size. Note that although the construction of the TPL limits generation of uniform electric and magnetic fields to frequencies below 500 MHz, experience has shown that the TPL may be used at frequencies up to 1 GHz and still provide reasonable and repeatable test results. This may only occur if the test setup requirements (i.e., DUT plus 1 meter of cable) and characterization procedures, delineated in this SAE Standard are followed.

The lack of side walls also means that the TPL must be used within an RF shielded enclosure to prevent RF energy, radiated from the TPL from interfering with near-by electronic devices. To prevent potential resonances and reflected waves within the shielded enclosure from distorting the fields produced within the TPL, the test chamber walls and ceiling must be lined with RF absorbing material. These issues are discussed in greater detail in the body of this document.

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

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

2.1 Applicable Publications—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)
SAE J1113-21—Road Vehicle—Electrical Disturbances by Narrowband Radiated Electromagnetic Energy—Component Test Methods—Part 21: Absorber-Lined Chamber
SAE J1812—Performance Status Classification for EMC Immunity Testing

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 dBc referred to the fundamental power

4.2 Power Measurement—In-line directional couplers and RF wattmeters capable of measuring forward, reflected, and TPL output power up to the maximum power and frequency in use.

4.3 Field Strength Meter—An RF field strength meter and a small, 3 axis isotropic field probe capable of measuring field strengths from 50 to 200 V/m up to 1000 MHz. This instrumentation shall be used during characterization. Please refer to Appendix A.

4.4 TPL Construction—Construction of the TPL is contained in Appendix B.

4.5 TPL 50 Ω Load—A 50 Ω load capable of handling the expected maximum power and frequency in use.

4.6 RF Shielded, Absorber-Lined Test Chamber—Since the TPL has no side walls, RF energy can radiate from the TPL into the open environment. For this reason, the TPL testing shall be performed in a shielded enclosure. To avoid standing wave patterns within the shielded enclosure, which may affect testing of the DUT, the room shall include RF absorber on the walls and ceiling. The absorber shall be selected to reduce the reflected E-field by 10 dB or greater in the vicinity of the TPL.

5. ***Test Setup***—Test setup should be as shown in Figures 1, 2, and 3.

5.1 TPL Location and Grounding in Test Chamber—Figure 1 illustrates the location of the TPL within the shielded, absorber-lined test chamber. The minimum distance between the open sides of the TPL and the absorber material shall be greater than 1 m. The minimum distance between the ends of the TPL and absorber material shall be greater than 0.5 m. The TPL ground plane shall be bonded to the shield room walls or floor via bonding straps, or via the braid of the coaxial feed and load cables if either cable is less than 2 m in length.

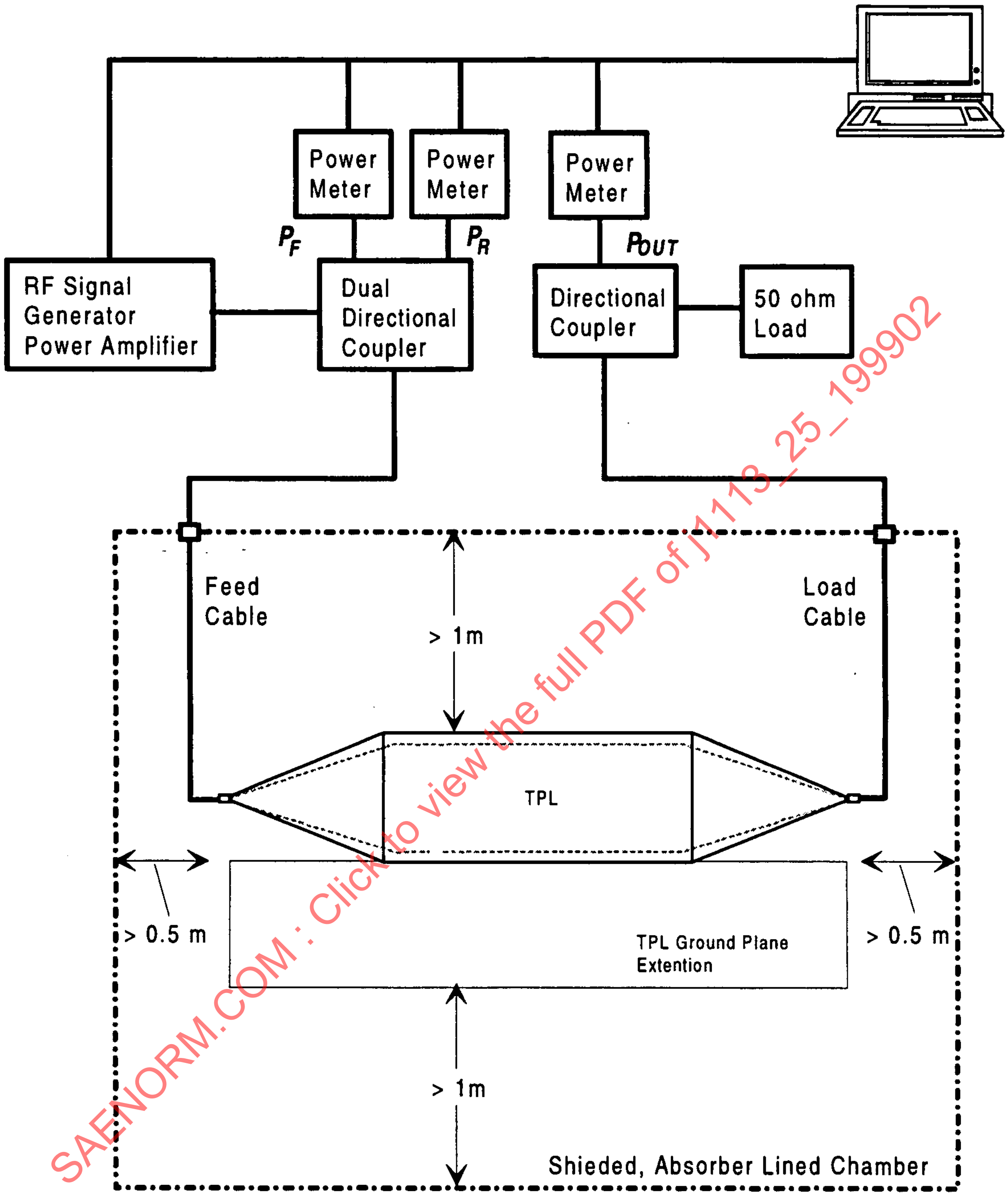

FIGURE 1—TPL TEST CONFIGURATION

5.2 **Non-Conductive Support Fixture**—The DUT 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 lower ground plate (i.e., 15 cm above the lower ground plate). Figure 2 illustrates this configuration. The nonconductive support fixture shall be constructed of material with a relative dielectric constant less than 1.4 up to 1000 MHz.

The fixture shall support the DUT's wire harness at a constant height above the TPL's lower ground plate over the harness's entire length between the DUT and Test Fixture. This requires the support fixture extend outside of the TPL to the Test Fixture (see Figure 2). The support fixture should also be designed to lock the positions of the DUT and its wire harness to ensure repeatable test results.

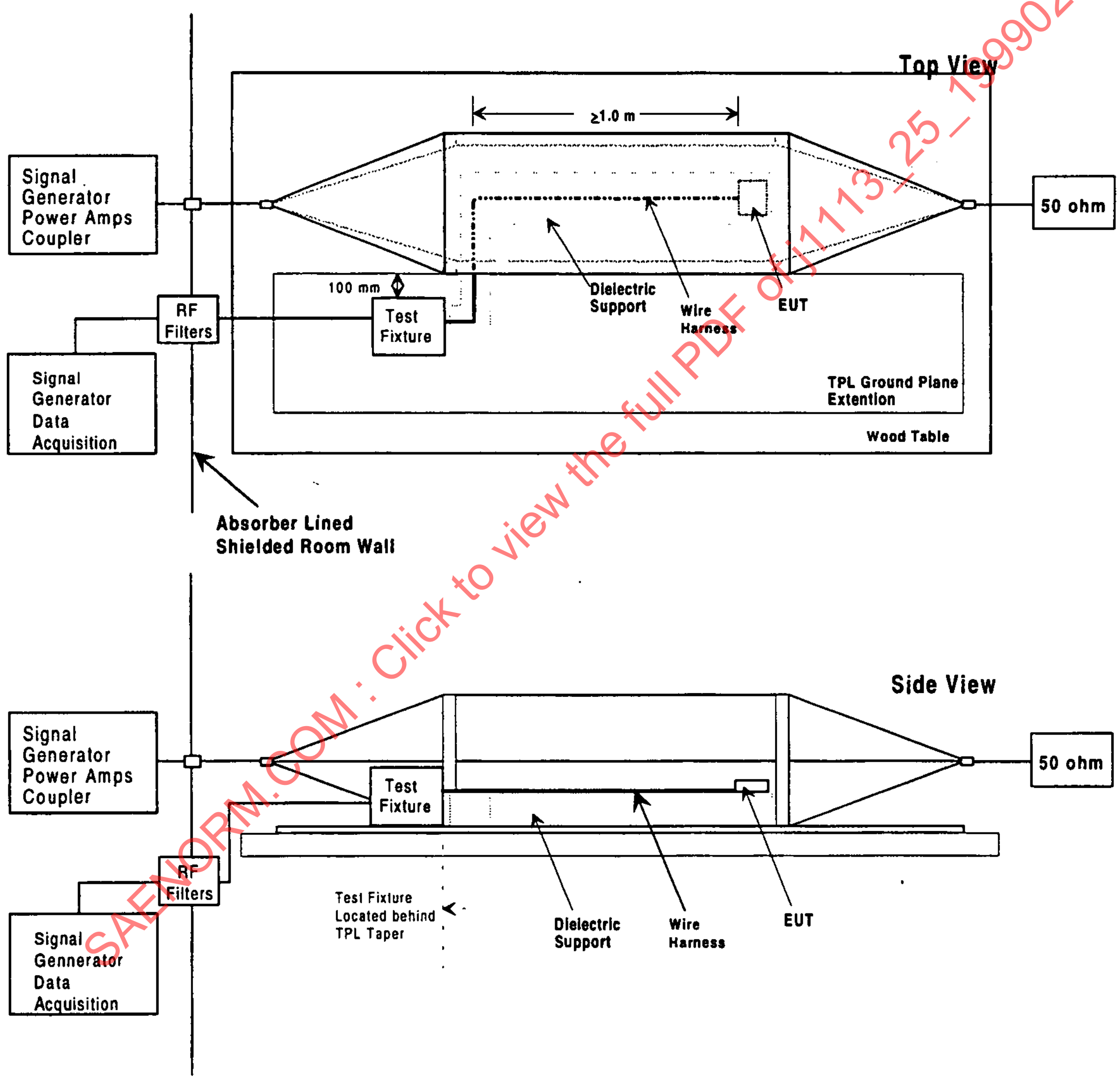

FIGURE 2—TPL TEST SETUP

5.3 DUT Wire Harness—The DUT wire harness shall be 2 m in total length with at least 1 m of harness lying along the longitudinal axis of the TPL (i.e., "exposed section") as illustrated in Figure 2. This section of the wire harness along with the DUT shall be centered between the TPL tapers. The remainder of the DUT's wire harness shall exit the TPL at 90 degrees with respect to the TPL's longitudinal axis. Details of the layout of the DUT and its wire harness shall be documented in the test plan.

The wire harness shall be constructed to connect the DUT directly to a shielded Test Fixture discussed as follows. All DUT circuits, including all power returns should be contained in this wire harness unless otherwise specified in the test plan.

5.4 Test Fixture—The Test Fixture is constructed to contain resistive and reactive loads that simulate other vehicle devices that normally connect to the DUT. In some cases, actual vehicle electronic devices may be used, however care should be taken to assure that they are immune to the radiated fields produced by the TPL which could adversely affect testing of the DUT. Effort should be made to locate all peripheral loads in a single test fixture such that the wire harness connects to a single location. Specific details of the test fixture design shall be included in the test plan.

The Test Fixture shall be located no closer than 100 mm to the nearest edge of the TPL and shall not extend beyond the TPL taper as illustrated in Figure 2. The Test Fixture metal enclosure shall be electrically bonded to the TPL ground plane.

5.5 Support Equipment—When peripheral equipment is required to support or monitor operation of the DUT, it may be impractical to contain it within the Test Fixture. In these situations, the support/diagnostic equipment should be located outside of the test chamber. If this approach is taken, the Test Fixture shall be used as the interface between the support equipment and the DUT. It is recommended that fiber optic media be used to facilitate these connections. If wire line connections are used, RF filtering shall be included within the Test Fixture to decouple this wiring from the DUT cable harness and to prevent conduction of RF currents back to the peripheral support equipment. RF filtering capacitance shall be terminated to the Test Fixture enclosure as illustrated in Figure 3. Additional RF filtering should also be considered at the bulkhead connection at the shield room wall to prevent stray coupling to the wiring which could affect the test results. Care should be taken to minimize the filter capacitance to avoid potential influence of the DUT test results. Details about the RF filters used (i.e., construction, performance, etc.) shall be included in the test plan. All signal lines connecting the Test Fixture to the peripheral support equipment should also be shielded to prevent stray coupling between the Test Fixture and where the cable harness exits the shielded enclosure.

5.6 DUT Maximum Dimensions—The physical height of the DUT shall not exceed 10 cm, which is one-third the separation between the TPL's septum and lower ground plate. If the DUT dimensions exceed 10 cm, it is recommended the DUT be tested using SAE J1113-21.

5.7 DUTs with Metal Enclosures—If the DUT has a metal enclosure and the enclosure is normally connected directly to the vehicle structure, the DUT enclosure shall be electrically/mechanically bonded to the TPL lower ground plate via methods similar or identical to that used in the vehicle (e.g., brackets, braided straps, etc.) If the DUT metal enclosure is not connected directly to the vehicle structure, it shall be placed directly on the non-conducting support fixture. DUT power return wiring shall be connected to the TPL ground plane via the test fixture as illustrated in Figure 3.

5.8 Power Supply—The power supply shall meet the requirements delineated in SAE J1113-1. The power supply shall also 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 DUT, shall correspond to the vehicle power supply system impedance as closely as possible. The power supply negative return shall be referenced (connected) to the TPL ground plane via the test fixture as illustrated in Figure 3.

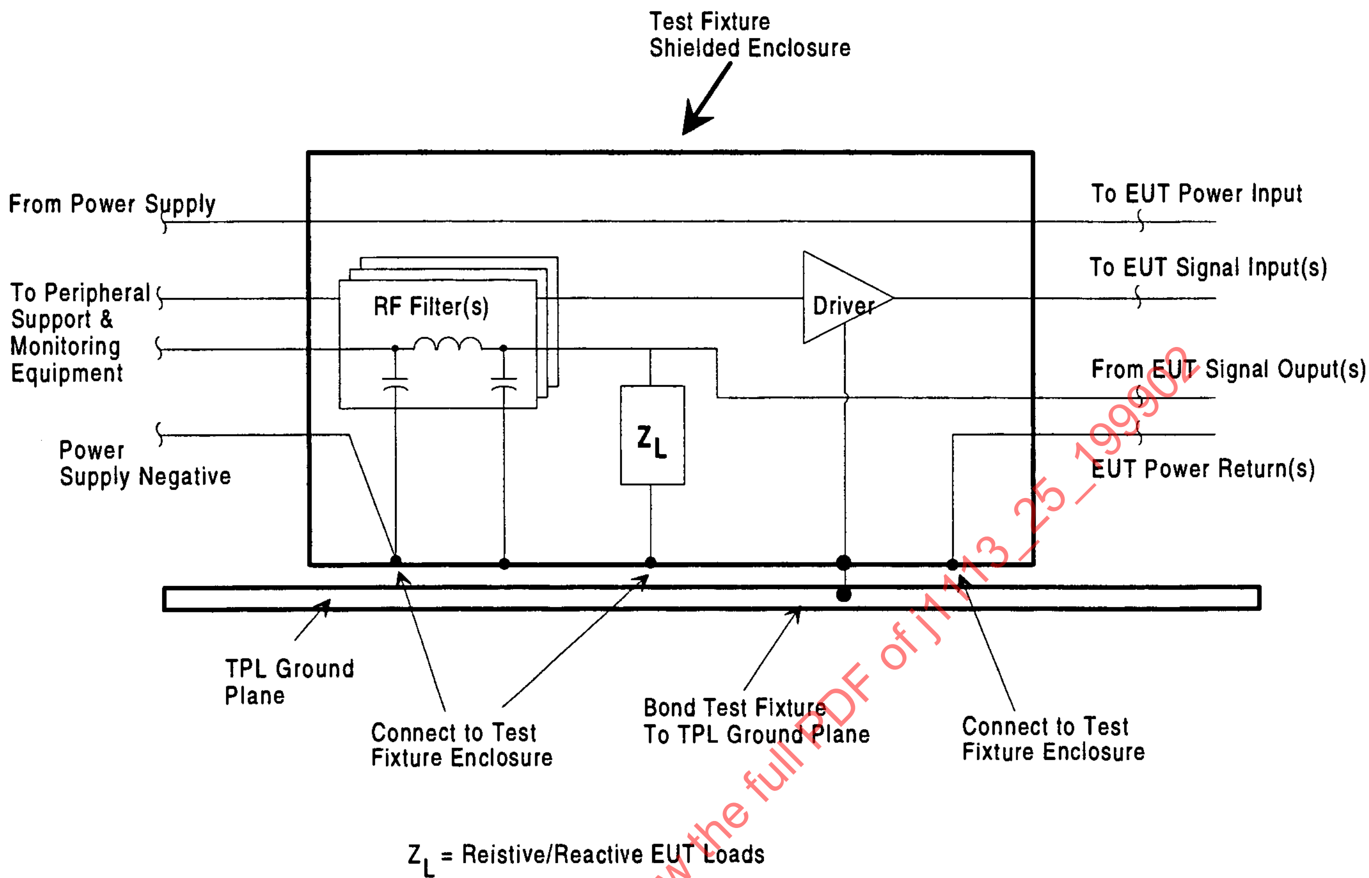

FIGURE 3—TEST FIXTURE CONFIGURATION

6. *Test Procedure*

6.1 Test Plan—Prior to performing any testing, a test plan shall be generated which describes the functional operating modes of the DUT, critical circuits, and applicable acceptance criteria.

6.2 TPL Characterization—The TPL shall be calibrated using the method described in Appendix A.

6.3 Test Conditions—Test conditions (i.e., test temperature, supply voltage, modulation, dwell time, frequency steps, etc.) shall be in accordance with 6.1 of SAE J1113-1.

6.4 DUT Monitoring—During testing, the DUT shall be monitored to verify its performance meets the acceptance criteria delineated in the test plan.

6.5 Test Severity Levels—A full description and discussion of the Function Performance Status Classification including Test Severity Levels are given in SAE J1113-1 Appendix A. Please review it prior to using either the Test Severity Levels presented in Appendix C or severity levels specified by the procuring activity.

6.6 Test Report—When required in the test plan, a test report shall be submitted detailing information regarding the test equipment, test set-up, DUT tested, DUT anomalies (acceptable or unacceptable), and any other relevant information regarding the test including any deviations from the original test plan along with an explanation of why they occurred.

7. Notes

7.1 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 COMMITTEE

APPENDIX A

TRI-PLATE LINE FIELD CHARACTERIZATION
(NORMATIVE)

A.1 During testing of the DUT, the field intensity generated between the septum and ground plates of the TPL is a function of the TPL impedance and the power delivered into the TPL as given by Equation A1:

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

where:

$E_v(f)$ is defined as the field between septum and grounded plates of the TPL in Volts/meter
$Z(f)$ is defined as the effective characteristic impedance of the TPL in ohms
h is defined as the separation between the septum and either of the ground plates of the TPL in meters
$P_{MID}(f)$ is defined as the Midpoint Power which is the average median power between the net power and output power defined by Equation A2.

$$P_{MID} = \frac{(P_{NET} + P_{out})}{2} \quad \text{(Eq. A2)}$$

where:

P_{NET} is the net RF power (in watts) into the TPL defined as: $P_F - P_R$
P_F is the forward RF power (in watts) into the 50 Ω coaxial line feeding the TPL
P_R is the reflected RF power (in watts) reflected at the interface between the 50 Ω coaxial line and the TPL
P_{OUT} is the RF power output from the TPL into a 50 Ω load

Field characterization requires that the TPL impedance Z(f) be determined. The following procedure shall be used.

a. At each test frequency (f), apply power to the empty TPL (no harness or DUT in place) and measure the field strength between the septum and lower ground plate of the TPL using a small RF field probe located at each of 5 positions as shown in Figure A1. Note the probe height above the TPL ground plate shall be the same as that specified for the DUT and its attached cable harness (i.e., 15 cm).
b. In addition to the 5 field strength measurements, record the forward, reflected, and output powers: $P_F(f)$, $P_R(f)$, $P_{OUT}(f)$.
c. Calculate the average field strength using Equation A3:

$$E_{AVG} = \frac{1}{5}\sum_{N=1}^{5} E_N \quad \text{(Eq. A3)}$$

where:

E_N is the field strength measured at each probe position shown in Figure A1

d. Calculate the midpoint power, $P_{MID}(f)$ using Equation A2.
e. Substituting E_{AVG} for E_V in Equation A1, along with $P_{MID}(f)$ from step d, solve for Z(f) shown in Equation A4:

$$Z(f) = h^2 \times \frac{E^2_{AVG}(f)}{P_{MID}(f)} \quad \text{(Eq. A4)}$$

f. Z(f) shall be determined at frequency steps no larger than those listed in Table 3 of SAE J1113-1.

The resulting array of Z(f) shall be used during testing of the DUT to determine the midpoint power required to achieve the required field strength $E_v(f)$.

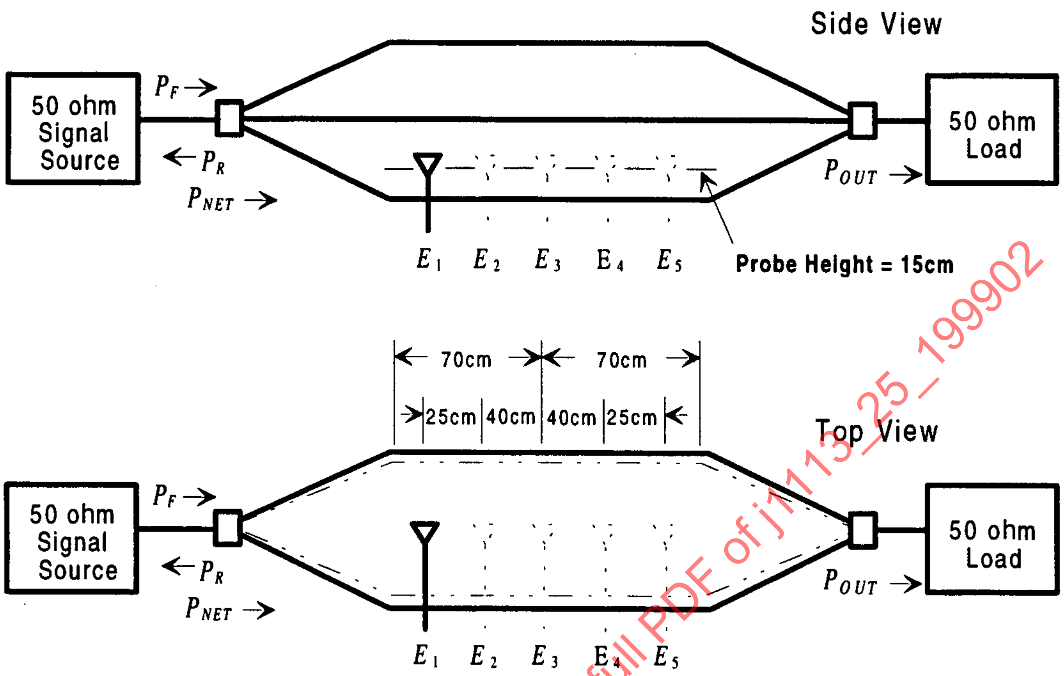

FIGURE A1—TRI-PLATE LINE CHARACTERIZATION SETUP