

# Space Station Electromagnetic Techniques

## International Space Station

Revision C

May 31, 1996



**NASDA**

National Space Development  
Agency of Japan



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**INTERNATIONAL SPACE STATION PROGRAM  
SPACE STATION ELECTROMAGNETIC TECHNIQUES**

**MAY 31, 1996**

## **PREFACE**

The Space Station Electromagnetic Test Techniques document establishes techniques to be used for the measurement and determination of the electromagnetic interference characteristics (emission and susceptibility) of electrical, electronic, and electromechanical equipment and subsystems. This document contains an introduction and paragraphs describing test requirements, test procedures, and documentation. The contents of this document are intended to be consistent with the requirements of SSP 30243 (Space Station Alpha Requirements for Electromagnetic Effects) and SSP 30237 (Electromagnetic Emission and Susceptibility Requirements for Electromagnetic Compatibility). The Space Station Electromagnetic Techniques document shall be implemented on SSP contracts. This document is under the control of the Space Station Control Board.

**INTERNATIONAL SPACE STATION PROGRAM OFFICE**

**SPACE STATION ELECTROMAGNETIC TECHNIQUES**

**MAY 31, 1996**

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Reference SSP 50019 Joint Management Plan and  
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**INTERNATIONAL SPACE STATION PROGRAM  
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**LIST OF CHANGES**

**MAY 31, 1996**

All changes to paragraphs, tables, and figures in this document are shown below:

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000008 R1	6-3-94	Revision B	All
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## **1.0 INTRODUCTION**

### **1.1 PURPOSE**

This requirements document establishes techniques to be used for the measurement and determination of the electromagnetic interference EMI characteristics (emission and susceptibility) of electrical, electronic, and electromechanical equipment and subsystems as required by SSP 30237, Space Station Electromagnetic Emission and Susceptibility Requirements for Electromagnetic Compatibility.

### **1.2 APPLICATION**

Unless otherwise specified, the test requirements and methods contained in this document are invoked by SSP 30237. Section 3.0 herein contains the measurement procedures to be used in determining compliance with the emission and susceptibility requirements of SSP 30237. The test procedures are for the entire specified frequency range. Certain equipment or subsystems may not require testing at all frequencies. Exemption to specific frequencies shall be identified and justified in the Electromagnetic Effects Control Plan (SS-VE-055).

### **1.3 BACKGROUND**

The test procedure requirements contained in this document are based on MIL-STD-462, Electromagnetic Interference Characteristics, Measurement of, but represents a rewrite for specific application to the International Space Station Program (SSP).

### **1.4 UNITS**

Symbols, units, and physical constants used in this document are in accordance with the International System of Units as described in MIL-STD-463A, Definition and System of Units, Electromagnetic Interference and Electromagnetic Compatibility Technology.

### **1.5 EMISSION AND SUSCEPTIBILITY DESIGNATIONS**

The test methods contained in this document are designated by an alphanumeric identification scheme. Each method is identified by a two-letter combination followed by a two-digit number.

- Conducted Emission tests are designated by “CE—”.
- Radiated Emission tests are designated by “RE—”.
- Conducted Susceptibility tests are designated by “CS—”.
- Radiated Susceptibility tests are designated by “RS—”.
- Leakage Emission tests are designated by “LE—”.

## **1.6 PRECEDENCE**

SSP 41000, System Specification for the Space Station defines the design and performance requirements for the SSP and invokes SSP 30243, Space Station Electromagnetic. In the event of any conflict between SSP 30243, SSP 30237 and this document, SSP 30243 shall take precedence.

## 2.0 DOCUMENTS

The following documents are applicable to the extent specified in this document. For Space Station documents, the term “Current Issue” is shown in place of the specific date and issue when the document is under Space Station Control Board control.

<b>DOCUMENT NO.</b>	<b>TITLE</b>
SSP 30237 Rev. C Reference	Space Station Electromagnetic Emission and Susceptibility Requirements for Electromagnetic Compatibility Paragraphs 1.1, 1.2, 1.6 3.0, 3.1.1.1, 3.1.1.5.3, 3.1.2.3.5, 3.2.2.1.4, 3.2.2.3.5, 3.2.2.3.6, 3.2.3.1.5.3, 3.2.4.1.4.1, 3.2.4.1.4.2, 3.2.4.2.2
SSP 30242 Rev. D Reference	Space Station Cable/Wire Design and Control Requirements for Electromagnetic Compatibility Paragraph 3.3.4.1.4.2
SSP 30243 Rev. D Reference	Space Station Requirements for Electromagnetic Compatibility Paragraph 1.6
SSP 30482 Rev. B Reference	Volume 1 Electrical Power Specifications and Standards: EPS Electrical Performance Specifications Paragraph 3.1.1.3
MIL–STD–45662 Rev. A (08 August 88) Reference	Calibration Systems Requirements Paragraph 3.2.2.3.4
MIL–STD–463 Rev. A (19 September 88) Reference	Definitions And System of Units, Electromagnetic Interference and Electromagnetic Compatibility Technology Paragraph 1.4
MIL–STD–462 (1 May 70) Reference	Electromagnetic Interference Characteristics, Notice 2, Measurement of Paragraph 1.3

### **3.0 REQUIREMENTS**

The test techniques and procedures contained in this requirements document shall be used in demonstrating compliance with emission and susceptibility requirements of SSP 30237. The test levels and test limits are defined in SSP 30237.

#### **3.1 GENERAL REQUIREMENTS**

##### **3.1.1 TEST CONDITIONS**

###### **3.1.1.1 AMBIENT ELECTROMAGNETIC LEVELS**

Conducted and radiated ambient levels shall be at least 6 decibels (dB) below the applicable limits of SSP 30237. Ambient conditions shall be determined prior to the beginning of measurements on the energized Equipment Under Test (EUT).

###### **3.1.1.2 GROUND PLANE**

A solid plate copper or brass ground plane shall be used. It shall have a minimum thickness of 0.25 millimeter (mm) for copper or 0.63 mm for brass and be 2.25 square meters (m) or larger in area with the smaller side no less than 76 centimeters (cm) in length. When testing is performed in a shielded enclosure, the ground plane shall be bonded to the shielded room such that the direct current (dc) bonding resistance shall not exceed 2.5 milliohms. In addition, the bonds shall be placed at distances no greater than 90-cm apart. For large equipment mounted on a metal test stand, the test stand shall be considered a part of the ground plane for testing purposes and shall be bonded accordingly.

###### **3.1.1.3 POWER SUPPLY CHARACTERISTICS**

Power supplies for test samples requiring a power source for its operation and not supplied as part of the equipment shall have characteristics and tolerances within the limits of SSP 30482, Volume 1.

###### **3.1.1.4 RADIO FREQUENCY ABSORBER MATERIAL**

Radio Frequency (RF) absorber material may be used in shielded enclosures to reduce reflections from the surfaces of the enclosure to the measurement antennas for non-stirred mode tests only. Any use of RF absorber material shall be documented in the test report.

### 3.1.1.5 TEST SITE

#### 3.1.1.5.1 SHIELDED ENCLOSURES

Shielded enclosures shall be of sufficient size to adequately accept the EUT without sacrificing test accuracy or requiring deviation from the methods specified herein. The characteristics of shielded enclosures shall be defined in the EMI Test Plan.

#### 3.1.1.5.2 OPEN FIELD SITES

Open field sites may be used when sufficiently large screen rooms are not available or when the nature of the equipment tested precludes their usage. The ambient requirements of this document shall be observed to the maximum extent possible. Techniques to mitigate the effects of ambient levels that exceed the specified levels of SSP 30237 shall be detailed in the EMI Test Plan.

#### 3.1.1.5.3 TEST SITE ATMOSPHERIC CONDITIONS

Testing shall be performed under the following atmospheric conditions where possible:

- Temperature: 15 to 35 degrees Celsius
- Pressure: 610 to 780 mm Mercury
- Relative Humidity: 20 to 80 percent of Saturation.

### 3.1.2 MEASURING EQUIPMENT

This section describes the test equipment used in the test methods contained in this requirements document.

#### 3.1.2.1 TEST ANTENNAS

Antennas used in performing radiated emission and susceptibility tests shall be documented. Receive antenna factors and methods used to establish radiated susceptibility environments shall be detailed in the test procedure and the EMI Test Plan. The following antenna characteristics are recommended:

FREQUENCY RANGE	TEST	ANTENNA CHARACTERISTICS
14kHz–30MHz	RE02	Electrically short high impedance electric field probe, vertically polarized. Traditionally the 41” rod with active or passive matching to 50 ohms.

<b>FREQUENCY RANGE</b>	<b>TEST</b>	<b>ANTENNA CHARACTERISTICS</b>
14kHz–30MHz	RS03	The parallel plate (and numerous modifications), long wire, and E–field generator are available and listed in order of preference. The E–field generator should be reserved for the case in which the EUT is too large for other methods.
30MHz–200MHz	RE02 RS03	Dipole–like antennas. Typical antenna used in this band has been the MIL–STD–461 biconical. Care should be taken in the antenna selection to ascertain that the balun does an adequate job of matching the low frequency high antenna impedance of 50 ohms.
200MHz–1GHz	RE02 RS03	The traditional logconical and the logperiodic are available. The double ridge horn should be avoided, since the gain increases drastically with frequency.
1GHz–10GHz	RE03	RE02 Broadband (ridged) or standard gain horns. Logconicals are also available
10GHz–	RE02 RS03	20–dB standard gain horns.

### **3.1.2.2 TEST ANTENNA COUNTERPOISE (MONOPOLE)**

The following requirements shall be used when rod antennas that require a counterpoise are used. The test antenna counterpoise shall be referenced to the same ground reference used for the (EMI) meter. For measurements in shielded enclosures, the counterpoise shall be bonded to the reference ground plane. The bond strap shall be a solid metal sheet having the same width as the counterpoise, welded along the entire edge at the points of contact. Alternatively, the counterpoise shall be clamped and/or soldered to the ground plane in two places. If desired, the counterpoise may be configured so that one dimension is of adequate length to reach the equipment ground plane. For outdoor measurements, the counterpoise and interference analyzer shall be referenced to a good Earth ground.

### **3.1.2.3 USE OF MEASURING EQUIPMENT**

All laboratory equipment shall be operated as prescribed by the applicable instruction manuals unless otherwise specified herein. This requirements document shall take precedence in the event of conflict with instruction manuals or other documents issued by industry or other government agencies unless identified in an approved EMI Test Plan. For test repeatability, all test parameters used to configure the test shall be recorded in the EMI Test Plan and the EMI Test Report. These parameters shall include measurement bandwidths, video bandwidths, sweep speeds, etc.

### **3.1.2.3.1 GROUNDING OF MEASURING EQUIPMENT**

To avoid false data that may be introduced by ground loops test equipment shall be referenced to the same ground as the EUT. An equipment safety ground shall be maintained at all times, but for a specific test the ground power line may be broken by means of an isolated transformer or isolation connectors. To avoid high frequency ground loops, test receivers for tests above 30 MHz shall be placed outside the test chamber.

### **3.1.2.3.2 EQUIPMENT WARM-UP TIME**

Prior to performing tests, the measuring equipment shall be switched on for a period of time adequate to allow parameter stabilization. If the operation manual does not specify a specific warm-up time, the minimum warm-up period shall be one hour.

### **3.1.2.3.3 MEASURING EQUIPMENT CALIBRATION**

Measuring instruments and accessories used in determining compliance with this requirements document shall be calibrated under an approved program in accordance with MIL-STD-45662A, Calibration Systems Requirements.

### **3.1.2.3.4 MEASUREMENT ACCURACY**

Test equipment shall be capable of measuring to within the following accuracy:

- 2% for frequency
- 3 dB for amplitude.

In the event that an above-specification signal emission is found in any of the specific frequency and amplitude ranges above 100 MHz listed in SSP 30237, the frequency of the offending signal shall be determined to an accuracy of 0.002%.

### **3.1.2.3.5 MEASUREMENT BANDWIDTHS**

The measuring instrument bandwidth shall be less than one third the lowest tuned frequency in the range for narrowband and less than one half the lowest tuned frequency for optional broadband measurements. Optional broadband measurements should be made using bandwidths approximately ten times the narrowband bandwidth.

### **3.1.2.4 MEASUREMENT ANTENNA POSITION**

#### **3.1.2.4.1 EQUIPMENT UNDER TEST EVALUATION**

The following face probing technique shall be applicable only to large, rack mounted EUTs. EUTs mounted on a ground plane arranged with their interconnecting cables in accordance with the requirements of this document need not be probed. Whenever possible, each EUT shall be mounted so as to have the face with the most connectors facing the measurement antenna. Each face of the EUT shall be probed with a loop or other suitable sensor to determine the localized area producing maximum emission or susceptibility. Probing shall be performed at frequencies known or calculated to represent worst case interference; if no such information is available, probing shall be performed at no fewer points than one frequency for every two octaves over the frequency range of test. The face exhibiting worst case characteristics in any octave or band, provided that band is not less than two octaves, shall face the test antenna for that portion of the frequency scan. Automatic scan techniques may be used to scan all sides.

#### **3.1.2.4.2 LOCATION**

When performing radiated emission and susceptibility tests, no points of the antennas shall be less than 30 cm from the floor and ceiling and 1 m from the walls of the shielded enclosure or obstruction.

#### **3.1.2.4.3 LINEARLY POLARIZED ANTENNAS**

For radiated emission measurements above 30 megahertz (MHz), linearly polarized antennas shall be positioned to measure the vertical and horizontal components of the emission. For radiated susceptibility measurements above 30 MHz, linearly polarized test antennas shall be positioned so as to generate vertical and horizontal fields.

### **3.1.3 PULSED CONTINUOUS WAVE REQUIREMENTS**

The following guidelines govern the requirements for pulsed continuous wave interference:

- Narrowband limits shall be used
- Bandwidth correction factors shall not be used.

### **3.1.4 ARRANGEMENT AND OPERATION OF EQUIPMENT UNDER TEST**

#### **3.1.4.1 CONTROL ADJUSTMENT**

For a representative set of modes of operation, controls on the EUT shall be operated and adjusted as prescribed in the instruction manual or as required by the equipment specification to obtain optimum performance. For susceptibility tests, the most susceptible modes shall be

selected. For emission tests, the most noisy modes shall be selected. Specific mode selection criteria and software used to operate the EUT shall be documented per the requirements of SSP 30243.

#### **3.1.4.2 SIGNAL INPUTS**

Actual or simulated signal inputs and software required to activate, utilize, or operate a representative set of circuits shall be used during emission and susceptibility testing.

#### **3.1.4.3 EQUIPMENT UNDER TEST ARRANGEMENT**

Interconnecting cable assemblies and supporting structures shall simulate actual installation and usage. Shielded leads used in the test setup shall be the same as specified in approved installation drawings. Diagrams of the cables which interconnect the EUTs shall be documented. Cables and equipment shall not be interposed between the EUT cables and the measurement antennas. When testing within a shielded enclosure, one face of the box comprising the EUT shall be located within 10 cm from the ground plane edge nearest the measurement antenna. All leads and cables shall be located within 10 cm from the ground plane edge nearest the measurement antenna and shall be supported at least 5 cm above the ground plane on non-conductive spacers. Power cable configuration shall simulate actual installation with minimum breakout for use with current probes near feed through capacitors.

#### **3.1.4.4 BONDING AND GROUNDING OF EQUIPMENT UNDER TEST**

Bonding of the EUT for tests shall be in accordance with the approved installation drawings for the equipment. When bonding straps are required to complete the test setup, they shall be the same as those specified in the installation drawings. Portable equipment shall be grounded by the third wire of the power cable. Physical isolation of the portable equipment chassis from structure shall be required for testing. Bonding provisions used for all testing shall be documented in the EMI Test Report.

##### **3.1.4.4.1 SHOCK AND VIBRATION ISOLATORS**

If the EUT is mounted on a base with shock or vibration isolators in the operational installation, the test setup shall include such mounting provisions. Bonding hardware and application for the EUT shall be identical to the approved installation drawing. If no provisions for bond straps are made on the installation drawings, then no bond straps shall be used during testing.

##### **3.1.4.4.2 EXTERNAL GROUND TERMINAL**

When an external terminal is provided for a ground connection on the EUT, this terminal shall be connected to the ground plane. The conductor used for the connection shall be of similar

dimensions and material to that shown on installation drawings, i.e., length, width, thickness, and diameter.

#### **3.1.4.5 LOADS**

The EUT shall be loaded with the full mechanical and electrical load or equivalent for which it is designed. If worst case EMI conditions exist at a reduced load, the tests shall include the reduced level loads as well as the full load. This requirement specifically includes electrical loading of the contacts of mechanisms which are designed to control electrical loads even though such loads are physically separate from the EUT. Operation of voltage regulators and other circuits that function intermittently shall be required during testing. The loads used shall simulate the impedance of the actual load. Mechanical devices shall also be operated under load. The EUT shall be actuated by the same means as in the installation. As an example, if a solenoid is actuated by a silicon controlled rectifier, a toggle switch shall not be used to operate the solenoid for the test.

#### **3.1.4.6 SOURCE AND LOADS FOR COMMUNICATIONS–ELECTRONICS EQUIPMENT**

All RF outputs of communications electronics equipment shall be terminated with shielded dummy loads as appropriate for the EUT and the test being performed, to produce maximum normal output. At the frequencies of concern, the Voltage Standing Wave Ratio of resistive dummy loads, attenuators, directional couplers, samplers, power dividers, and the internal output impedance of standard signal generators shall be no greater than:

- Transmitter loads; 1.5:1
- All other dummy loads and pads; 1.3:1
- Standard signal generators; 1.3:1.

The use of standard signal generators shall be defined in the equipment list of the test procedure.

### **3.2 SPECIFIC TEST PROCEDURES AND TECHNIQUES**

#### **3.2.1 CONDUCTED EMISSIONS**

##### **3.2.1.1 CE01, CONDUCTED EMISSIONS**

Direct current power, low frequency, 30 Hz to 15 kHz.

###### **3.2.1.1.1 APPLICABILITY**

The test method for CE01 shall be applicable for measuring narrowband conducted emissions in the frequency range between 30 Hz and 15 kHz on the following types of leads:

- dc leads which obtain power from, or provide power to other equipment, distribution panels or subsystems.

#### **3.2.1.1.2 TEST EQUIPMENT**

The test equipment shall include the following:

- Current probe
- Electromagnetic interference analyzer with a narrowband capability
- 10-microfarad feed-through capacitors.

#### **3.2.1.1.3 TEST SETUP**

The test setup shall be as shown in Figure 3-1.

#### **3.2.1.1.4 TEST PROCEDURE**

Measurements shall be taken with the interference analyzer bandwidth as specified in this document.

#### **3.2.1.1.5 DATA**

Emissions greater than 20 dB below the specified limits shall be logged and reported in the test report. In cases where the noise floor and ambient are not 20 dB below specified level, only those emissions above the noise floor/ambient are required to be recorded.

#### **3.2.1.2 CE03, CONDUCTED EMISSIONS**

Direct current power leads, 15 kHz to 50 MHz.

##### **3.2.1.2.1 APPLICABILITY**

The test method for CE03 shall be applicable for measuring narrowband conducted emissions in the frequency range between 15 kHz and 50 MHz on the following types of leads:

- dc leads which obtain power from other sources or provide power to other equipment, distribution panels or subsystems.

Interconnecting leads and cables between equipment that form a subsystem from the same supplier are exempt if the units are tested together.

### **3.2.1.2.2 TEST EQUIPMENT**

The test equipment shall include the following:

- Current probe
- Matching transformer
- if required between current probe and the interference meter to allow the measuring system to meet the sensitivity requirements needed to perform the test
- Interference analyzer
- Isolation transformer for interference analyzer as required.

### **3.2.1.2.3 TEST SETUP**

The test setup shall be as shown in Figure 3–1.

### **3.2.1.2.4 TEST PROCEDURE**

Measurements shall be taken with the interference analyzer bandwidth as specified in this document.

### **3.2.1.2.5 DATA**

Emissions greater than 20 dB below the specified limits shall be logged and reported in the test report. In cases where the noise floor and ambient are not 20 dB below specified level, only those emissions above the noise floor/ambient are required to be recorded.

### **3.2.1.2.6 CE03 NOTES**

The EUT and EMI instrumentation shall derive their power requirements from separate phases of the ac power source, if possible. The purpose of this requirement is to provide isolation between the EUT and measurement instrumentation through the enclosure power line filters. CAUTION: The instrumentation shall be properly grounded before applying ac power to prevent potential shock hazard to personnel.

### **3.2.1.3 CE07, CONDUCTED EMISSIONS**

Direct current power leads, spikes, time domain.

#### **3.2.1.3.1 APPLICABILITY**

The purpose of this test method is to measure in the time domain, the load induced effect on dc power quality caused by cycling the EUT power and operating modes. This method is

applicable for measuring time domain spikes occurring when loads are energized in a discrete manner from secondary power (example: remote power controller). Measurement shall be made line-to-line. The requirement for turn-off transients is applicable only when the power switch is contained within the EUT (as opposed to a remotely located power switch or circuit breaker).

#### **3.2.1.3.2 TEST EQUIPMENT**

The test equipment shall include the following:

- Line Impedance Stabilization Network (LISN) as shown in Figure 3-3
- Oscilloscope
- Switch
- Recording Device
- Triggering Device.

#### **3.2.1.3.3 TEST SETUP**

The setup shall be as shown in Figure 3-4. The measurement shall be made line-to-line, with oscilloscope probes connected between each line to be measured and each of the two channels of the oscilloscope, with the second channel inverted and added to the first channel. The probes shall be attached to the energized line impedance stabilization network, with the switch to the EUT open. The measurement is made when the switch is closed. Prior to making a line to line measurement as described above, it is necessary to match the gain of the two oscilloscope channels within some tolerance. The tolerance required is what is necessary to reduce common mode “residues” to a level that will not affect test results.

#### **3.2.1.3.4 TEST PROCEDURE**

With the test setup of Figure 3-4, cycle the power to the EUT on/off and exercise all the appropriate internal EUT mode switches. Record the voltage transients. Compare against the appropriate transient specification.

#### **3.2.1.3.5 CE07 NOTES**

A LISN shall be inserted in each pair of lines tested. See Figure 3-3. The series resistance shall be based on the final installation dc resistance of the Space Station Power Distribution System (PDS) between the DC-to-DC Converter Unit (DDCU) and the start of the dedicated feeders to the installed EUT. The oscilloscope shall provide a minimum single event bandwidth of 20 MHz, effective resolution of 8 bits (for a digital oscilloscope). The oscilloscope shall have a two channel capability, with the ADD and INVERT modes available, again with a 20-MHz single event bandwidth. If the EUT is cycled on/off by a controlled remote switch or breaker, then this function shall be provided for in the test setup. A mercury (Hg) relay switch or equivalent which is not a source of significant transient effects shall be used. The triggering device is

critical to a successful test. Triggering shall be provided such that, as a minimum, 90% of the leading edge of the transient waveform can be viewed.

### **3.2.2 CONDUCTED SUSCEPTIBILITY**

#### **3.2.2.1 CS01, CONDUCTED SUSCEPTIBILITY**

Direct current power leads, 30 Hz to 50 kHz.

##### **3.2.2.1.1 APPLICABILITY**

The test method for CS01 shall be applicable for determining susceptibility of equipment and subsystems to electrical energy appearing on dc power leads.

##### **3.2.2.1.2 TEST EQUIPMENT**

The equipment shall consist of the following:

- Signal generator capable of providing the required test frequencies
- Audio power amplifier of 50 watts (W) or greater with output impedance less than or equal to 2.0 ohms and capable of delivering 50 W into a 0.5-ohm resistive load connected across the isolation transformer secondary
- Oscilloscope, voltmeter
- Isolation transformer
- A 100-microfarad capacitor may be required as a shunt to dc power source impedance if difficulty is encountered in obtaining the required test voltage.

##### **3.2.2.1.3 TEST SETUP**

The test setup shall be as shown in Figure 3-5. Appropriate monitoring devices shall be connected to EUT outputs.

##### **3.2.2.1.4 TEST PROCEDURE**

The signal generator shall be tuned through the required frequency range with the power amplifier output adjusted to the level specified in SSP 30237. The equipment shall be monitored for:

- Malfunction
- Degradation of performance
- Deviation of parameters beyond tolerances indicated in the equipment specification.

#### **3.2.2.1.4.1 SUSCEPTIBILITY**

When an EUT susceptibility is noted, the output level shall be decreased to determine the susceptibility threshold level. This value shall be recorded. The requirement is also met when the audio power source, adjusted to dissipate 50 W in a 0.5-ohm load, can not develop the required voltage at the EUT power input terminals, and the EUT is not susceptible to the output of the signal source.

#### **3.2.2.1.4.2 SUPPLY VOLTAGE**

The required nominal supply voltage applied to the EUT shall be measured and maintained within specified tolerances during the test.

#### **3.2.2.2 CS02, CONDUCTED SUSCEPTIBILITY**

Direct current power leads, 50 kHz to 50 MHz.

##### **3.2.2.2.1 APPLICABILITY**

The test method for CS02 shall be applicable for determining susceptibility of equipment and subsystems to electrical energy appearing on dc power leads including power returns and which are not grounded internally to the equipment or subsystem.

##### **3.2.2.2.2 TEST EQUIPMENT**

The test equipment shall consist of the following:

- Signal Source: a 50-ohm output impedance source capable of generating 1 volt (V) rms. and/or 1 W output, minimum, into a 50-ohm load
- LISN as specified in Figure 3-3
- Voltmeter, oscilloscope, or interference analyzer
- Coupling capacitor: The capacitor shall be used to isolate the power line frequencies from the signal source and shall have an RF impedance of 5 ohms or less, over the frequency range of the test. The capacitor may be changed during the test to maintain the impedance.

##### **3.2.2.2.3 TEST SETUP**

The general test setup shall be as shown in Figure 3-6.

##### **3.2.2.2.4 TEST PROCEDURE**

- The coupling capacitor and voltmeter, oscilloscope, or interference analyzer shall be connected within 30 cm of the termination to the EUT

- The test signal shall be applied to each power lead
- When testing equipment using single point grounds (dc power input leads isolated within the EUT), the test signal shall be applied between each power lead or ground return lead and the ground plane
- The voltage across the injection terminal to ground of the EUT shall be measured and recorded
- If the EUT is susceptible to the applicable limit level, then the signal source output shall be decreased to determine and record the threshold of susceptibility.

### **3.2.2.3 CS06, CONDUCTED SUSCEPTIBILITY**

Spikes, power leads.

#### **3.2.2.3.1 PURPOSE**

The test method for CS06 shall be used to determine equipment susceptibility to spike interference on power leads, including grounds and returns which are not grounded internally to the equipment or subsystem.

#### **3.2.2.3.2 APPLICABILITY**

CS06 shall be applicable to equipment and subsystem power leads, including grounds which are not grounded internally to the equipment or subsystem.

#### **3.2.2.3.3 TEST EQUIPMENT**

The test equipment shall consist of the following:

- Spike Generator
- Capacitor as required
- Oscilloscope.

#### **3.2.2.3.4 TEST SETUP**

The test setup shall be as shown in Figure 3–7 and Figure 3–8.

#### **3.2.2.3.5 TEST PROCEDURE**

Test procedures for testing equipment with dc leads shall be as follows:

- The EUT and test instrumentation shall be connected as shown in Figure 3–7 or Figure 3–8.

- Either a series or shunt test method may be used.
- The applied spike amplitude, rise time, and duration, as measured by the oscilloscope across the input terminals of the EUT, shall follow the typical wave shape and amplitude as specified in SSP 30237. The applied spike shall be developed across a non-inductive 5-ohm resistor and then applied to the EUT.
- Repetitive (6 to 10 pulses per second) spikes, both positive and negative, shall be applied to the EUT ungrounded input lines for a period not less than 2 minutes in duration. On equipment employing gated circuitry, the spike shall be triggered to occur within the time frame of the gate.
- If susceptibility occurs, then its threshold level, repetition rate, and time of occurrence on circuit gates shall be determined and recorded.

#### **3.2.2.3.6 CS06 NOTES**

The spike generator shall have the following characteristics:

- Pulse width of 10 and 0.15 microsecond
- Pulse repetition rate of 3 to 10 pulses per second
- Voltage output as required by SSP 30237
- Output control
- Adequate transformer current capacity commensurate with line being tested
- External synchronization capability
- External trigger capability
- Capacitor may be used to protect dc power source. Any oscilloscope with 10-MHz bandwidth or greater and sweep rates greater than 10 times the pulse rate shall be acceptable.
- Output impedance 2 ohms or less for 0.15-microsecond transient and 1 ohm for 10-microsecond transient.

### **3.2.3 RADIATED EMISSIONS**

#### **3.2.3.1 RE02, RADIATED EMISSIONS**

Electric field, 14 kHz to 20 GHz (narrowband).

##### **3.2.3.1.1 APPLICABILITY**

The test method for RE02 shall be applicable for the measurement of radiated emissions from all equipment and subsystems, cables (including control, pulse, IF, power and antenna transmission lines), and interconnecting wiring of the equipment and subsystem; for narrowband emissions, it

applies at the fundamental frequencies and all spurious emissions including harmonics, but does not apply for radiation from antennas.

#### **3.2.3.1.2 TEST FREQUENCY RANGE**

The test frequency range shall be as follows:

- Narrowband Emissions
- 14 kHz to 20 GHz.

#### **3.2.3.1.3 TEST EQUIPMENT**

The test equipment shall be as follows:

- Test antennas
- Interference analyzer (set in peak mode).

#### **3.2.3.1.4 TEST SETUP**

The basic test setups shall be as shown in Figures 3–9 and 3–10. EUT antenna terminals, if any, shall be connected to shielded dummy loads.

##### **3.2.3.1.4.1 NON-PORTABLE EQUIPMENT**

Non-portable equipment is permanently connected either physically or electrically to a vehicle, system, or installation. It shall be tested in accordance with the setup shown in Figure 3–9.

##### **3.2.3.1.4.2 PORTABLE EQUIPMENT**

Portable equipment, including manpack operable equipment and test equipment, shall be tested in accordance with the setup shown in Figure 3–10.

##### **3.2.3.1.4.3 EQUIPMENT CLASSIFIED BOTH PORTABLE AND NON-PORTABLE**

Equipment falling into both the non-portable and portable categories shall be tested both ways.

#### **3.2.3.1.5 TEST PROCEDURE**

##### **3.2.3.1.5.1 LOCATE MAXIMUM RADIATION**

The EUT shall be probed as indicated in paragraph 3.1.2.4.1 to locate the points of maximum radiation from the EUT.

### **3.2.3.1.5.2 ANTENNAS**

The test antennas shall be selected and positioned as stated in paragraph 3.1.2.4 at a test distance of 1 m. In the frequency range of 30 MHz to 20 GHz, linearly polarized antennas shall be positioned so as to make both vertical and horizontal measurements. If a rod antenna with a counterpoise is used, then the counterpoise of a 41-inch rod antenna shall be bonded in accordance with the requirements of this document.

### **3.2.3.1.5.3 RE02 NOTES**

RE02 shall be measured in peak detector mode.

## **3.2.4 RADIATED SUSCEPTIBILITY**

### **3.2.4.1 RS02, RADIATED SUSCEPTIBILITY**

Magnetic induction field.

#### **3.2.4.1.1 APPLICABILITY**

The test method for RS02 shall be applicable for the determination of the susceptibility of cable connected equipment to short duration, fast risetime induction fields electromagnetically coupled into the equipment through the wiring connecting equipment.

#### **3.2.4.1.2 TEST EQUIPMENT**

The test equipment shall consist of the following:

- Spike generators as specified in Method CS06 of this document
- A dual channel oscilloscope having a 10-MHz bandwidth.

#### **3.2.4.1.3 TEST SETUP**

The test setup shall be as indicated in Figure 3–11. The cable under test (CUT) shall be stressed by taping an insulated AWG#12 (or larger) size wire (coupling wire) to each CUT in the test setup, parallel to the CUT, running the entire length of the bundle to 15 cm from each end connector. The portions of the test wire not taped to the CUT shall be well removed from the CUT in order to couple the maximum flux into the CUT. In some cases where it is known that the Space Station installed cable will be significantly longer than the CUT, it may be desired to simulate stressing of the installed length by multiple parallel wraps of the test wire such that the meter turns product of the test wire taped to the CUT is numerically equal to the length (in meters) of the installed cable. In such cases, it is important that the portions of the test wire not adjacent to the CUT be not only removed from the vicinity of the CUT, but also that each layer

of the wrap be removed from adjacent layers to limit inductance which can cause an inability to provide sufficient current to perform the test. For the same reason, it is important to have a controlled test wire configuration so that the calibrated current is unchanged for the duration of the test.

#### **3.2.4.1.4 TEST PROCEDURE**

##### **3.2.4.1.4.1 SPIKES**

Two spike signals, both positive and negative, shall be impressed at a rate of 400 Hz or at the maximum rate at which the waveforms and amplitudes specified in SSP 30237 can be achieved. The waveforms and amplitudes of the spike signals shall be measured across a non-inductive 10-ohm resistor. The measurement device shall be an oscilloscope, configured to read differentially across the resistor. That is, two probes shall be used to connect at the resistor terminals, and one channel's input shall be subtracted from the other (oscilloscope in ADD and INVERT modes).

##### **3.2.4.1.4.2 EQUIPMENT UNDER TEST PERFORMANCE**

The EUT shall be monitored for susceptibility. The monitoring period shall be sufficient to check all modes of the EUT for susceptibility. The susceptibility criteria as well as the appropriate monitoring period shall be defined in the approved test plan. Thresholds of susceptibility shall be determined and recorded where susceptibility is noted. Because the interference signals coupled into the CUT are functions of both currents in the test wire and the separation of the test wire from the CUT, the threshold of susceptibility shall be specified two ways. First, the spike amplitude shall be diminished until the threshold is reached. That spike amplitude shall be recorded. Secondly, the amplitude and waveform specified in SSP 30237 shall be re-established, and the test wire shall be removed a small distance from the CUT. The test shall be rerun to determine the threshold of susceptibility for the separation of test wire and CUT. If the CUT is comprised of many bundle classes, the most sensitive bundle class in the CUT shall be used to determine the separation.

##### **3.2.4.1.5 RS02 NOTES**

Power input and output leads are exempt from this test. It is not intended that individual wires be tested but rather that wire bundles configured per Space Station installation drawings be tested. CUTs which have a diameter greater than 1 cm shall have the test wire sequentially placed at different locations around the periphery of the CUT in order to assure that all wires are adequately stressed. Alternately, to more quickly complete the test, an extra wire may be laid up parallel to the CUT, on the opposite side of the CUT from the first wire, for CUTs of greater than 1-cm diameter. Each such extra wire shall have currents driven into it at separate times. Current carrying wires shall be kept 15 cm away from cable connectors. All cables shall be at least 5 cm above the ground.

### **3.2.4.2 RS03, RADIATED SUSCEPTIBILITY**

Electric Field, 14 kHz to 20 GHz.

#### **3.2.4.2.1 APPLICABILITY**

The test method for RS03 shall be used to determine equipment and subsystem susceptibility in the presence of an electric field.

#### **3.2.4.2.2 TEST EQUIPMENT**

The test equipment shall consist of the following:

- A signal source capable of generating electric fields and frequencies specified in SSP 30237
- An interference analyzer to measure test field strengths
- Antennas as specified in paragraph 3.2.2.1
- An output monitor to monitor performance of the EUT.

#### **3.2.4.2.3 TEST SETUP AND PROCEDURES**

##### **3.2.4.2.3.1 PLACEMENT OF ANTENNAS**

The test setup shall be as required by the general testing requirements of this document for placement of antennas.

##### **3.2.4.2.3.2 TEST SIGNALS**

Test signals shall consist of two categories. These categories are based on standard test frequencies and frequencies at amplitudes that are defined by the Space Station design.

##### **3.2.4.2.3.3 TEST SIGNAL LEVELS**

The test signal levels shall be as specified in SSP 30237. The test signal shall be established at the mounting location of the EUT. The field strengths shall be verified as required. Standard test frequencies shall consist of a frequency sweep from 14 kHz to 200 MHz at 5 V/m, 200 MHz to 8 GHz at 60 V/m and 8GHz to 10 GHz at 20 V/m. The Station defined frequencies are 2.2 GHz at 161 V/m, 8.5 GHz at 79 V/m and 14.8 – 15.2 GHz at 250 V/m.

##### **3.2.4.2.3.4 SIGNAL MODULATION**

Signal modulation for Station derived frequencies shall be defined by the tier 1 contractor and both the type of modulation and percentage of modulation, if applicable, shall be documented.

The tier 1 contractor shall also define the signal modulation characteristics for the standard test frequencies. The minimum criteria for the signal modulation of the standard test frequencies shall be as defined in this document.

#### **3.2.4.2.3.5 ANTENNA SELECTION**

Fields shall be generated, as required, with signal sources and antenna that provide the required field strength. Longwire antennas or parallel strip line antennas may be used if they are applicable and desired.

#### **3.2.4.2.3.6 FIELD STRENGTH CALIBRATION**

The specified field strength shall be established prior to the actual testing by placing a field measuring antenna at the same distance and in the same relative location as the EUT and by adjusting the signal level applied to the transmitting antenna until the required field intensity is indicated. The voltage or power at the input terminals of the transmitting antenna required to establish the specified field shall be monitored and recorded. When performing this calibration in a shielded enclosure, the measurement antenna shall be placed in either the exact location that the EUT will occupy or shall be in a position which simulates exactly the geometry of the EUT location with respect to distances to reflective surfaces. This calibration may be used for all subsequent testing provided that either the data were taken in a reflective free area or the same shielded enclosure EUT location was used.

#### **3.2.4.2.3.7 LARGE EQUIPMENT UNDER TEST**

When a large EUT will be immersed in a field, the transmitting antenna shall be placed at a distance sufficient to allow the entire EUT to fall within the 3-dB beamwidth of the transmitted field. If this is not feasible because of either difficulty in generating the required field at the greater distance or the nature of the antenna radiation characteristics, then the EUT may be tested in segments where each segment is equal in dimension to the 6-dB beamwidth of the antenna radiation characteristic. For a whip transmitting antenna, the horizontal segments shall have length no greater than those given by the following equation:

$$L = 2 [R d - (d/2)^2]^{1/2},$$

where R is the test distance and d is the EUT width measured along a line forming a right angle with the face of the EUT which is directed toward the transmitting antenna.

#### **3.2.4.2.3.8 SUSCEPTIBILITY DETERMINATION**

The signal generators shall be tuned through the required frequency ranges with the power output adjusted to provide the fields specified in SSP 30237. The equipment shall be monitored for evidences of susceptibility:

- Malfunction

- Degradation of performance
- Deviation of parameters beyond tolerances indicated in the EUT specification at frequencies where susceptibility is encountered, the threshold of susceptibility shall be determined. All pertinent data shall be recorded.

#### **3.2.4.2.3.9 MINIMUM CRITERIA FOR SIGNAL MODULATION**

Test signals shall be modulated according to the following minimum criteria for testing performed using the standard test frequencies.

##### **3.2.4.2.3.9.1 EQUIPMENT UNDER TEST WITH AUDIO CHANNELS/RECEIVERS**

- Amplitude modulation (AM) Receivers: Modulate 50 percent with 1000-Hz sinewave.
- Frequency modulation (FM) Receivers: When monitoring signal to noise ratio, modulate with 1000-Hz sinewave using 10-kHz deviation. When monitoring receiver quieting, use no modulation.
- Single Side Band Receivers: Use no modulation.
- Other Equipment: Same as for AM receivers.

##### **3.2.4.2.3.9.2 EQUIPMENT UNDER TEST WITH VIDEO CHANNELS OTHER THAN RECEIVERS**

Modulate 90 to 100 percent with pulse of duration 2 per bandwidth and repetition rate equal to bandwidth/1000 where bandwidth is the video bandwidth.

##### **3.2.4.2.3.9.3 DIGITAL EQUIPMENT**

Use pulse modulation with pulse duration and repetition rates equal to that used in the equipment.

##### **3.2.4.2.3.9.4 NON-TUNED EQUIPMENT**

Amplitude modulate 50 percent with 1000-Hz sinewave.

### **3.2.5 LEAKAGE EMISSIONS**

#### **3.2.5.1 LE01, LEAKAGE EMISSIONS, POWER USER LEAKAGE CURRENT**

##### **3.2.5.1.1 APPLICABILITY**

The test method for LE01 shall only be applicable to equipment and subsystems that use ac power.

##### **3.2.5.1.2 TEST EQUIPMENT**

The test equipment shall be as follows:

- ac power source
- A current meter capable of measuring 10 percent, minimum, of the test limit current at the frequency of the power source
- An insulator/isolator of dimensions sufficient to limit the capacitance between the chassis and the ground plane to 10 picofarads maximum and the resistance between the chassis and the ground plane to  $10^6$  ohms dc, minimum.

##### **3.2.5.1.3 TEST SETUP**

The test setup shall be as shown in Figure 3–12 or equivalent.

##### **3.2.5.1.4 TEST PROCEDURE**

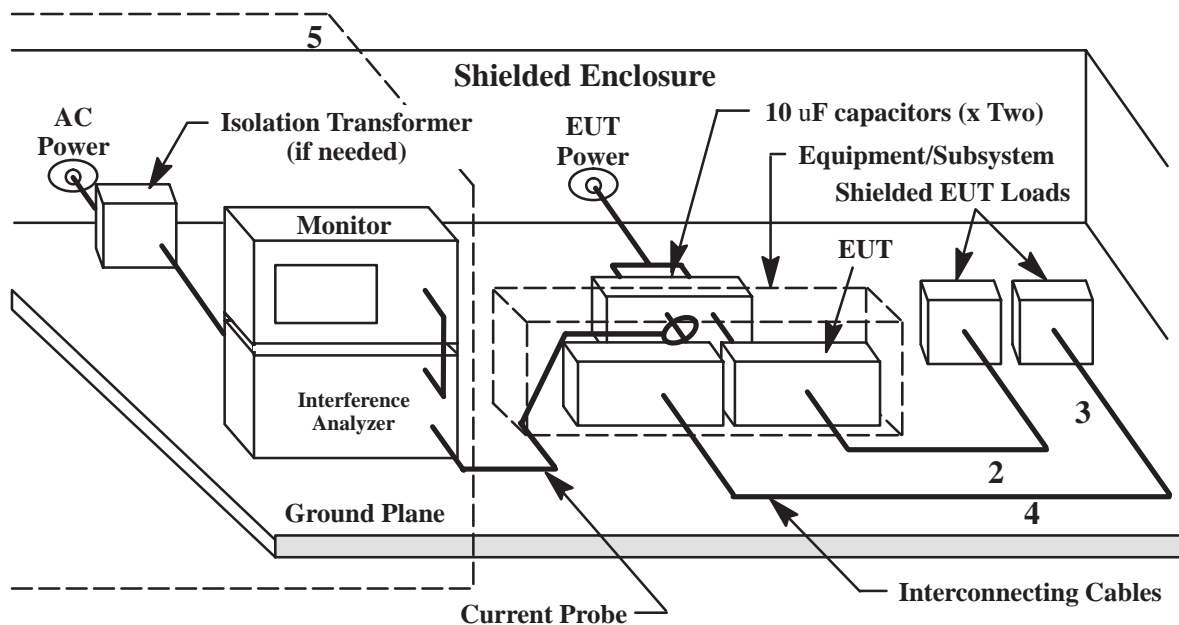
The EUT shall be electrically energized and operated as specified in its operating manual. While the EUT is operating, the leakage current at the power frequency shall be measured and recorded. The EUT shall be tested for each mode of operation.

##### **3.2.5.1.5 LEAKAGE CURRENT LIMIT**

The power frequency leakage current shall not exceed the value specified in SSP 30237.

### **3.3 DOCUMENTATION**

Documentation shall conform to the requirements of SSP 30243.

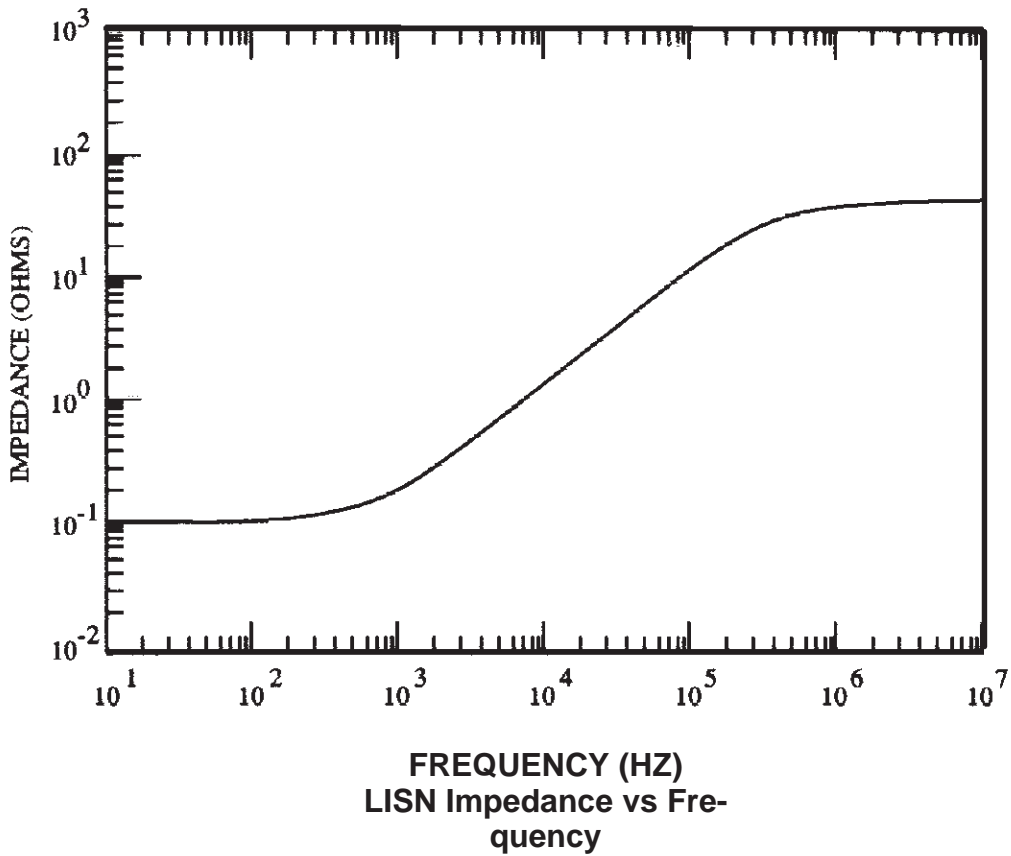


Notes:

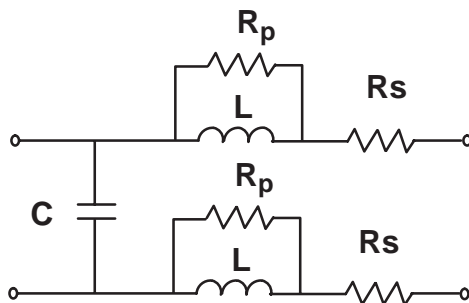
1. Shielded enclosure is bonded to ground plane every 90 cm or less.
2. Cable bundles are separated by at least 5 cm.
3. Cables are placed at least 5 cm above ground plane.
4. Cables and leads are placed within 10 cm of edge of ground plane.
5. May be located in a different room.
6. The 10 uF capacitors are not applicable to CE03.

**FIGURE 3-1 TYPICAL TEST SETUP FOR MEASURING CONDUCTED EMISSIONS ON DC POWER LINES OR INTERCONNECTING LEADS (CE01 AND CE03)**

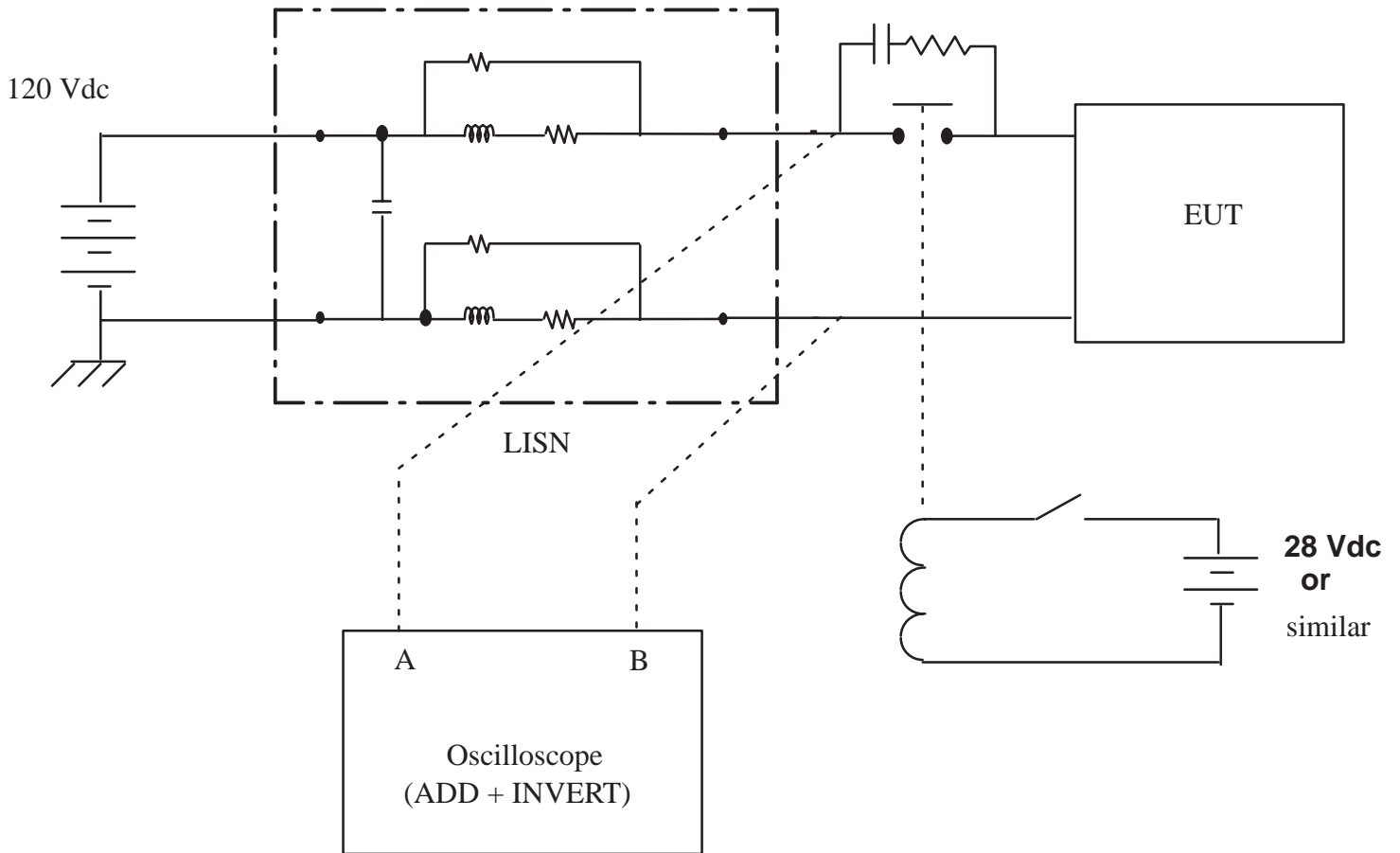
- L = 10  $\mu$ H
- R<sub>p</sub> = 25 ohms
- R<sub>s</sub> = 0.05 ohms
- C = 5000  $\mu$ F for energy storage. May be more or less, purpose is to provide stiff voltage at LISN input.



**Schematic:**



**Figure 3-3 LISN FOR CE07 MEASUREMENTS**



**NOTE:** Hg switch or relay should be filtered to reduce effects of arcing. Capacitor reduces arcing on turn-off, resistor reduces effect on turn-on (due to capacitor).

FIGURE 3-4 CE07 TEST SETUP

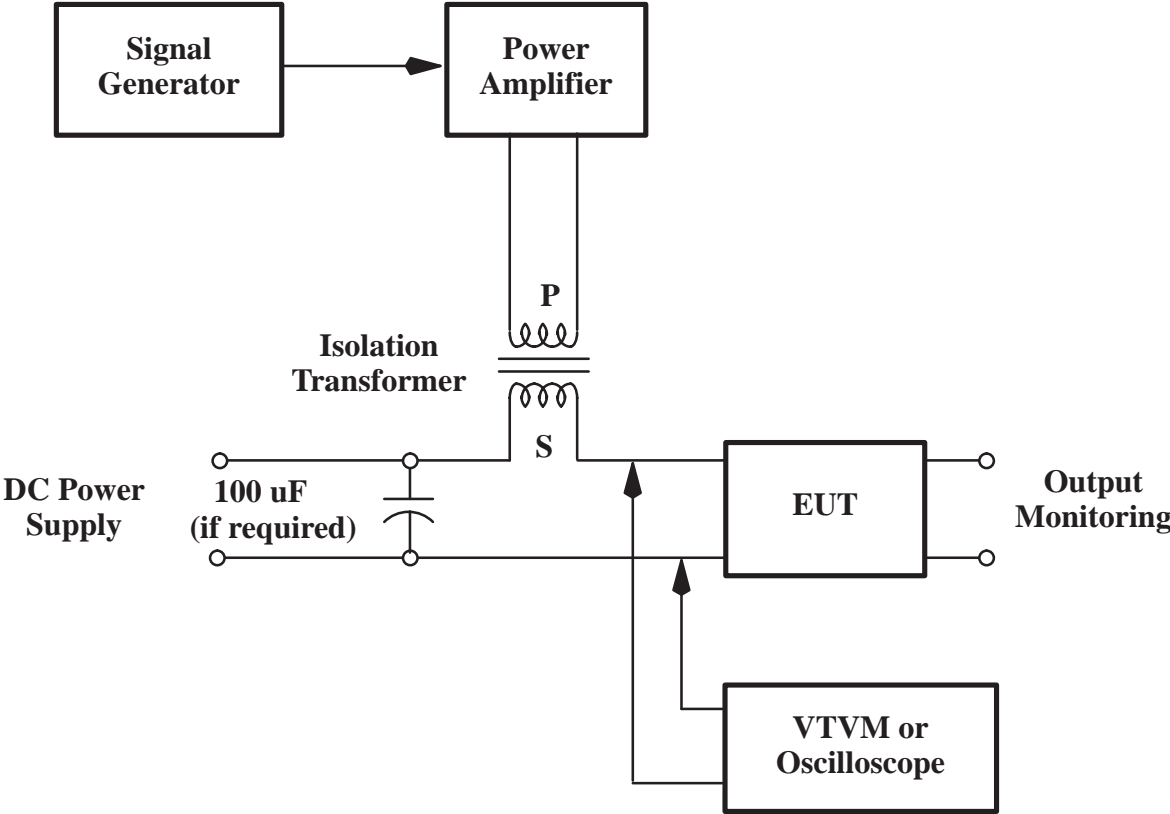
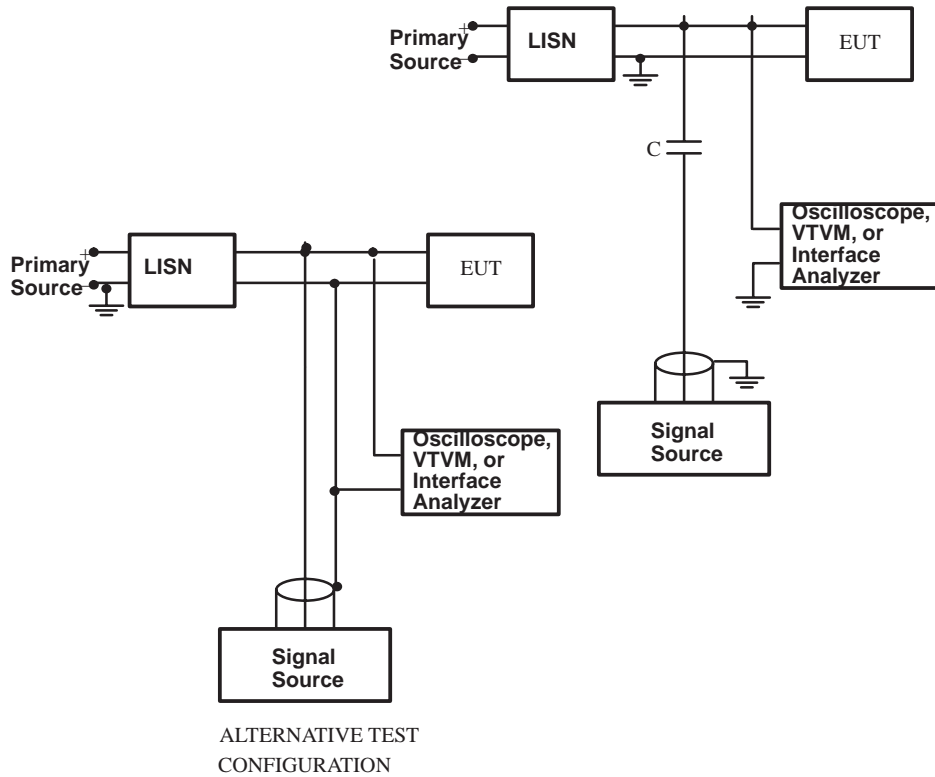
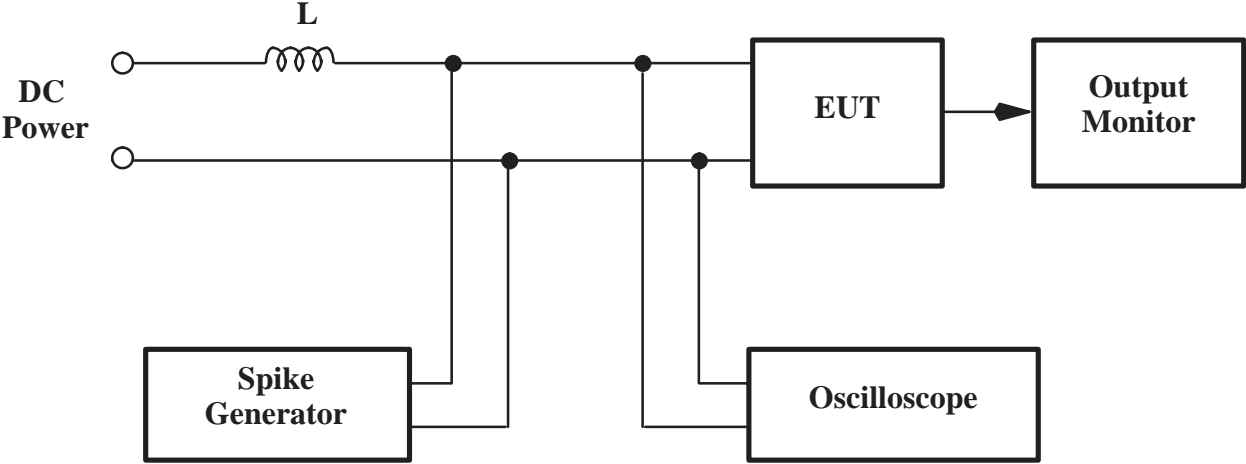


FIGURE 3-5 CONDUCTED SUSCEPTIBILITY, 30 Hz TO 50 kHz TYPICAL TEST SETUP (CS01)



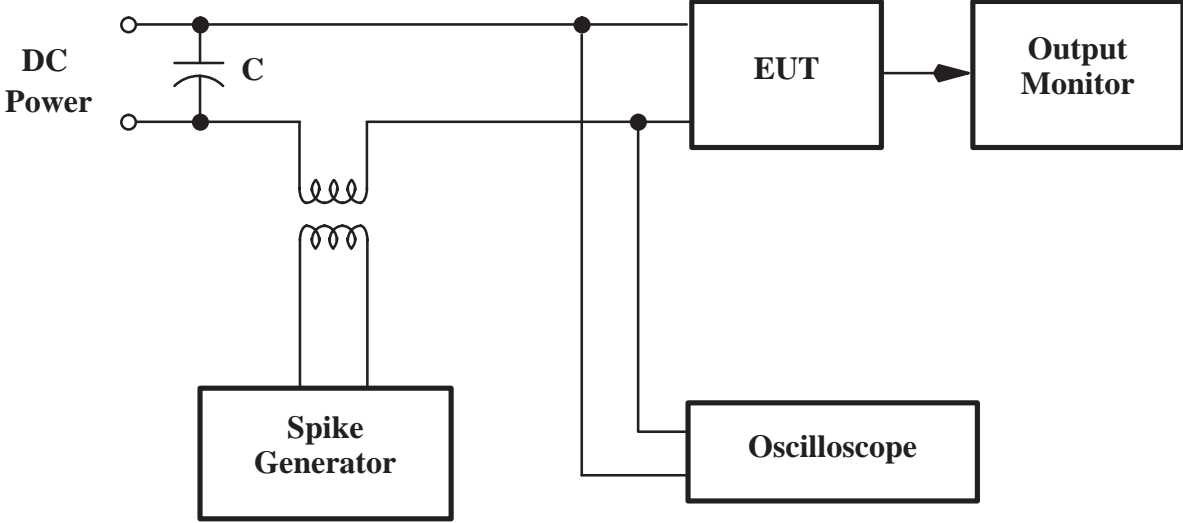
1. The value of C shall be chosen such that  $X_c < 5$  ohms over the test frequencies
2. Connect the coupling capacitor and the VTVM, Oscilloscope, or Interference Analyzer, within 5 cm of the termination to the EUT
3. Alternative test configuration is to float the Signal Source and Oscilloscope and move the ground to the negative lead on the Primary side of the LISN

**FIGURE 3-6 CONDUCTED SUSCEPTIBILITY, 50 kHz TO 50 MHz TYPICAL TEST SETUP (CS02)**



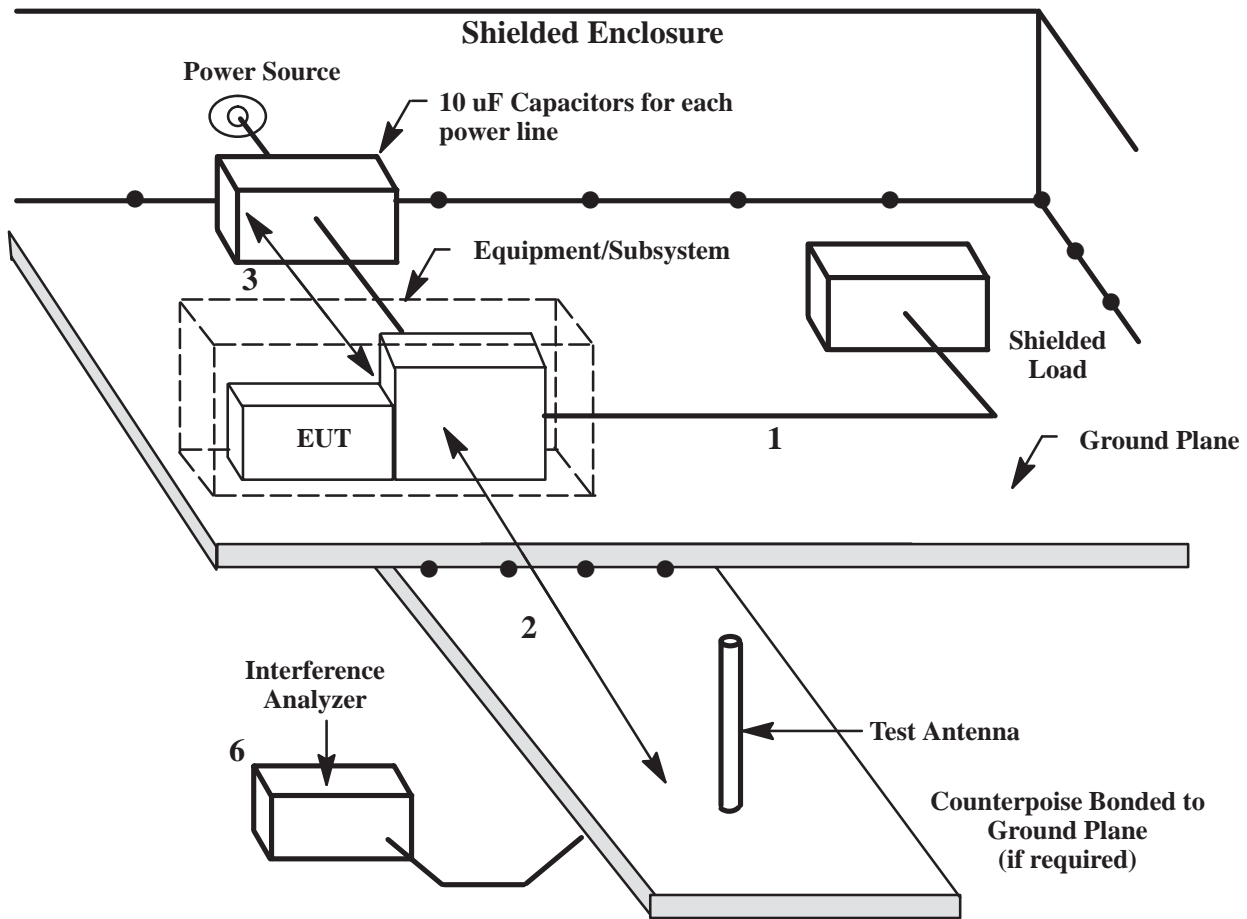
Note: L = 20 microhenries (optional)

**FIGURE 3-7 CONDUCTED SUSCEPTIBILITY, SPIKE PARALLEL INJECTION TEST SETUP (CS06)**



Note: Capacitor may be used to protect the DC power supply.

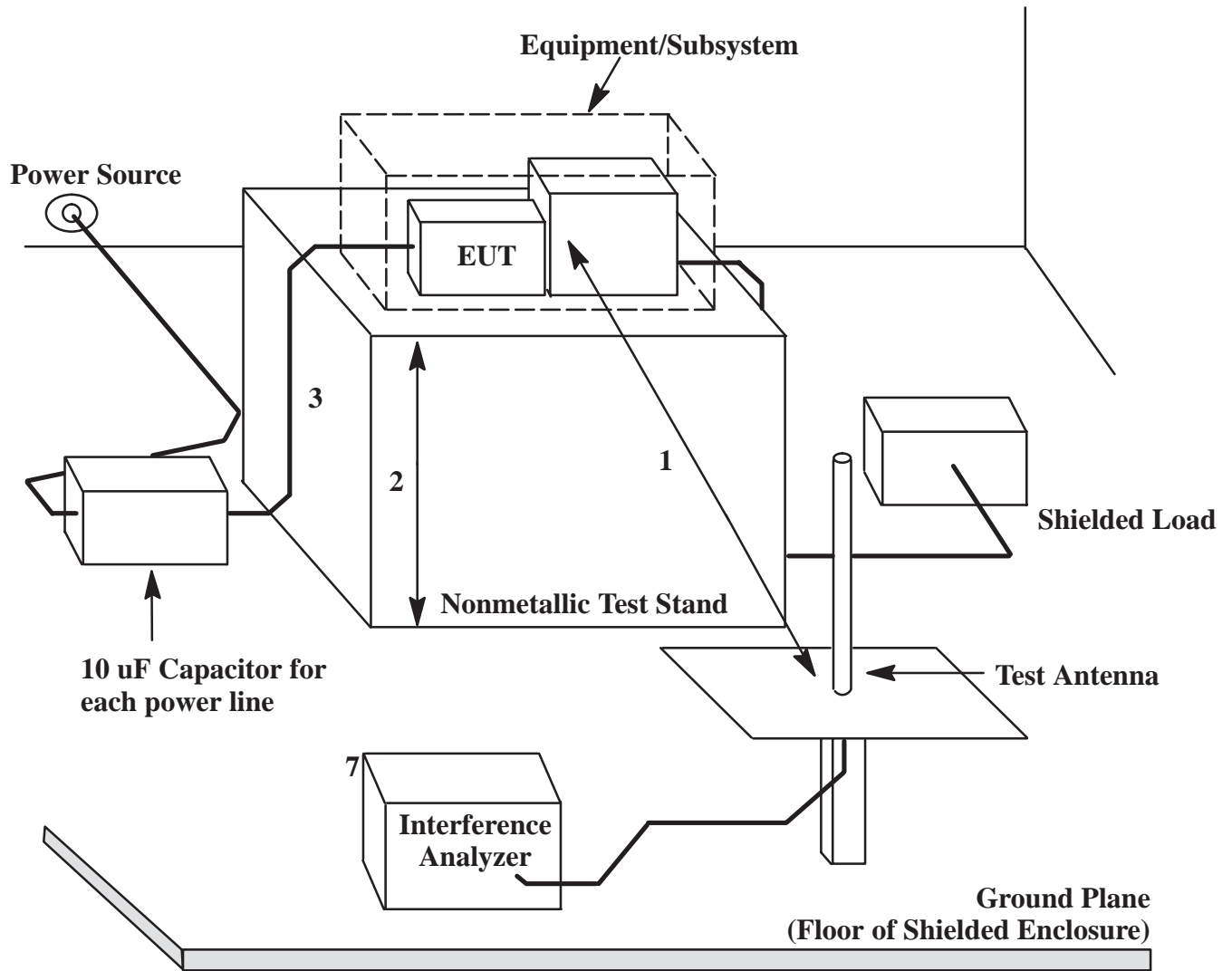
**FIGURE 3–8 CONDUCTED SUSCEPTIBILITY, SPIKE SERIES INJECTION TEST SETUP (CS06)**



Notes:

1. Cables are placed at least 5 cm above ground plane.
2. Requirement at 1 meter.
3. Input power leads are greater than two meters and less than three meters in length.
4. If the test sample is comprised of more than one unit, interconnecting cable lengths of at least 2 meters shall be exposed to the test antenna except for deliverable cables whose length is less than 2 meters.
5. Matching network is mounted below counterpoise.
6. For measurements above 30 MHz, the interference analyzer shall be placed outside the shielded enclosure.

**FIGURE 3-9 TYPICAL TEST SETUP FOR RADIATED MEASUREMENTS (RE02)**



Notes:

1. Required at 1 meter.
2. Typically 1 meter.
3. Power leads are greater than 2 meters and less than 3 meters in length.
4. Height of test antenna shall be located for maximum pickup.
5. Only the test sample and the Interference Analyzer shall be connected to the enclosure power.
6. Matching network is mounted below the counterpoise.
7. For measurements above 30 MHz, the interference analyzer shall be placed outside the shielded enclosure.

**FIGURE 3-10 TYPICAL TEST SETUP FOR RADIATED MEASUREMENTS ON PORTABLE EQUIPMENT (RE02)**

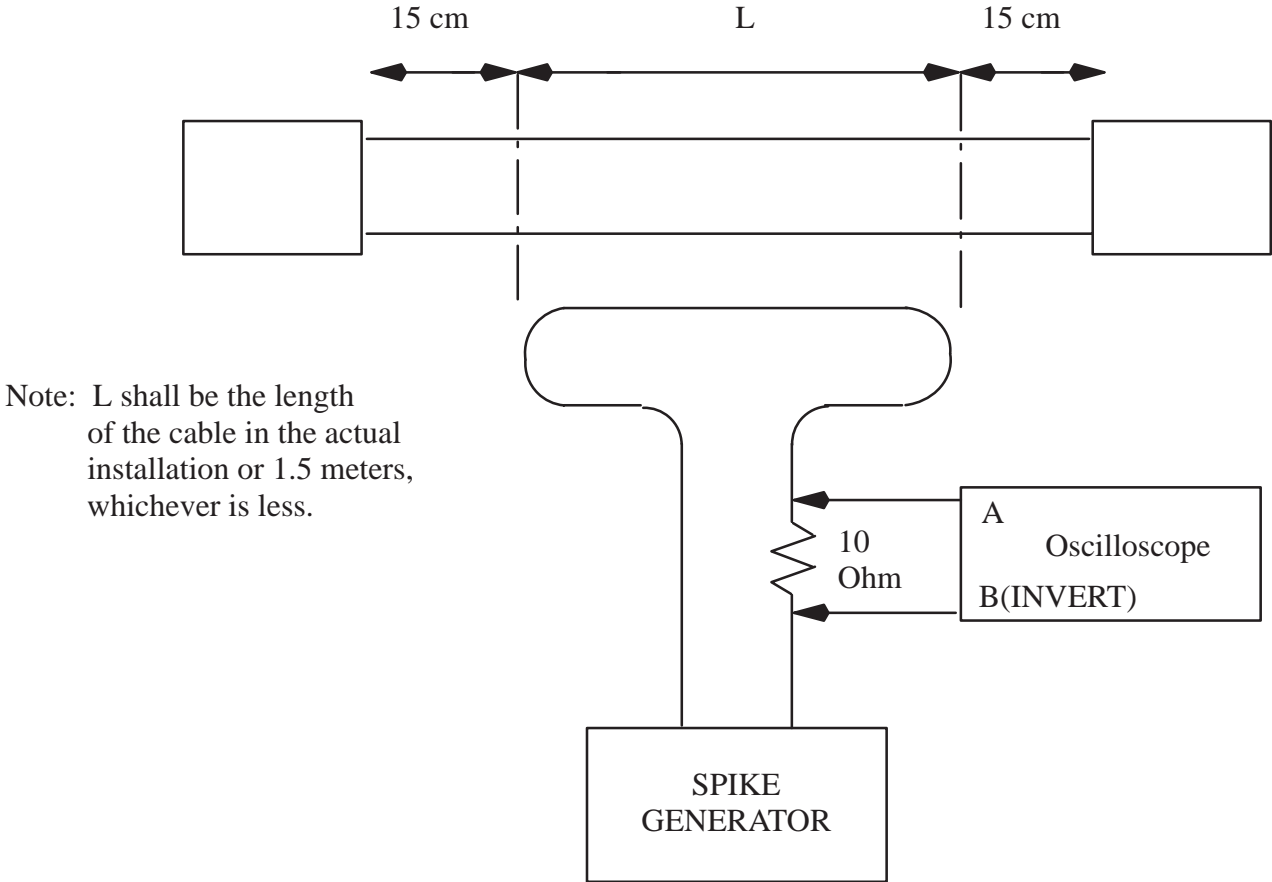


FIGURE 3-11 RS02 CABLE TEST SETUP

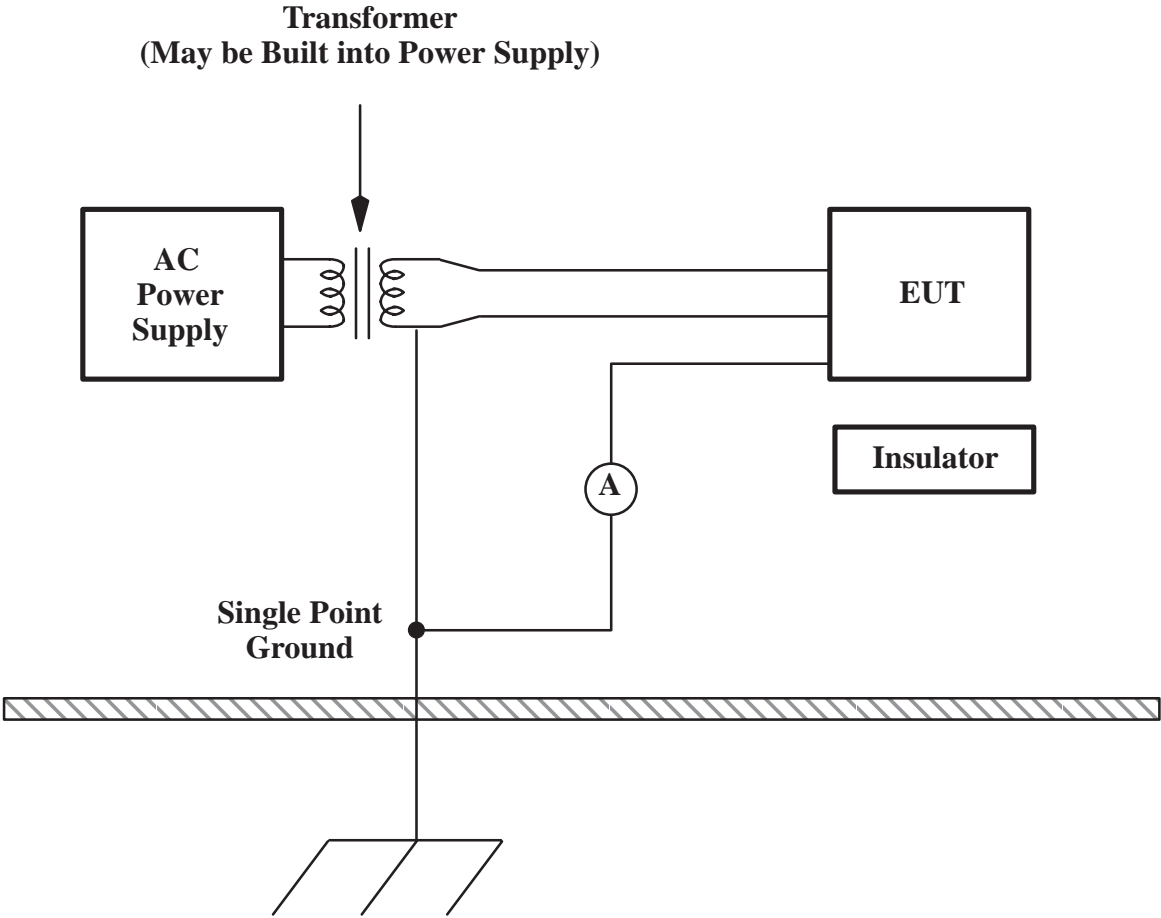


FIGURE 3-12 TYPICAL TEST SETUP, POWER USER LEAKAGE CURRENT (LE01)

#### **4.0 QUALITY ASSURANCE PROVISIONS**

All quality assurance provisions shall be in accordance with the Space Station Program Quality Assurance Program Requirements as specified in SSP 41000.

#### **4.1 RESPONSIBILITY FOR INSPECTION**

Unless otherwise specified, the supplier is responsible for the performance of all inspection requirements. Except as otherwise specified, the supplier may use his own facilities or any other commercial laboratory acceptable to National Aeronautics and Space Administration (NASA or responsible IP agencies). NASA or IP agencies reserves the right to perform any of the inspections set forth in this requirements document where such inspections are deemed necessary to assure supplies and/or services conform with prescribed requirements.

**APPENDIX A ABBREVIATIONS AND ACRONYMS**

A	Amp
ac	Alternating Current
AM	Amplitude Modulation
BB	Broadband
cm	Centimeter
CRT	Cathode-Ray Tube
CUT	Cable Under Test
dB	Decibel
dBm	Decibel Relative to One Milliwatt
dBW	Decibel Relative to One Watt
dc	Direct Current
DDCU	DC to DC Converter Unit
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EUT	Equipment Under Test
F	Farad
FM	Frequency Modulation
GHz	Gigahertz
Hg	Mercury
Hz	Hertz
IF	Intermediate Frequency
in	inch
kHz	kilohertz
kW	kilowatt

LISN	Line Impedance Stabilization Network
m	Meter
MHz	megahertz
mm	Millimeter
NASA	National Aeronautics and Space Administration
NB	Narrowband
PDS	Power Distribution System
RF	Radio Frequency
rms	Root Mean Square
SG1	Signal Generator 1
SG2	Signal Generator 2
SSP	Space Station Program
$\mu$	Micro
V	Volt
W	Watt

## **APPENDIX B GLOSSARY**

### **COMMUNICATIONS – ELECTRONICS EQUIPMENT**

Any equipment which transmits, emits, or receives signals, writing, images, sounds or information of any nature by wire, radio, visual, or other electromagnetic means.

### **EQUIPMENT**

Any electrical, electronic, or electromechanical device or collection of devices intended to operate as a single unit and to perform a single function. As used herein, equipment includes but is not limited to the following: receivers, transmitters, transponders, power supplies, hand tools, processors, test apparatus, and test instruments.

### **SUBSYSTEM**

A collection of equipment designed and integrated to perform a single function where in any equipment within the subsystem is not required to function as an individual equipment.

### **SYSTEM**

A collection of equipment, subsystems, skills, and techniques capable of performing or supporting an operational role. A complete system includes related facilities, equipment, subsystems, materials, services, and personnel required for its operation to the degree that it can be considered self-sufficient within its operational environment.