MILITARY STANDARD

ELECTROMAGNETIC INTERFERENCE
CHARACTERISTICS, MEASUREMENT OF

TO ALL HOLDERS OF MIL-STD-462:

1. THE FOLLOWING PAGES OF MIL-STD-462 HAVE BEEN REVISED AND SUPERSEDE THE PAGES LISTED:

NEW PAGE	DATE	SUPERSEDED PAGE	DATE
iii	31 July 1967	iii	Reprinted without change
iv	04 August 1986	iv	31 July 1967
9	31 July 1967	9	Reprinted without change
10	04 August 1986	10	31 July 1967
21/22	04 August 1986	21/22	31 July 1967
35	04 August 1986	35	31 July 1967
36	31 July 1967	36	Reprinted without change
36a	04 August 1986	new	
58e-58t	04 August 1986	new	
61	04 August 1986	61	31 July 1967
62	31 July 1967	62	Reprinted without change
63/64	04 August 1986	63/64	31 July 1967
87/88	04 August 1986	87/88	31 July 1967
95-100	04 August 1986	new	

2. RETAIN THIS NOTICE AND INSERT BEFORE TABLE OF CONTENTS.

3. Holders of MIL-STD-462 will verify that page changes and additions indicated above have been entered. This notice page will be retained as a check sheet. This issuance, together with appended pages, is a separate publication. Each notice is to be retained by stocking points until the military standard is completely revised.

4. Changes from previous issue. The margins of NOTICE 5 page changes are marked with asterisks to indicate where changes (additions, modifications, corrections) from the basic issue were made. This was done as a convenience only and the Government assumes no liability whatsoever for any inaccuracies in these notations. Bidders and contractors are cautioned to evaluate the requirements of this document based on the entire content of the basic issue irrespective of the marginal notations.

Preparing activity:
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(Project No. EMCS-N103)

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Navy - AS, OS, SH

AREA EMCS

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FIGURES

FIGURES-Continued

TABLES

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(1) Input attenuator, input gain, pulse stretcher, and high and low cutoff frequency controls shall be set to compensate for signal amplitude, shape, and frequency.
(2) Amplifier Mode - Set on normal linear signal.
(3) Slideback - Set to off (full counter clockwise).
(4) Sweep Video - Set to Sweep.
(5) Sweep rate trigger - Set to recur.
(6) Trigger - Set for desired sweep speed.
(7) Volume - Set for desired speaker volume.

(c) Sampling Pickup System.-The controls shall be set as follows:

(1) Probe.-Place the probe at desired point on the test sample to pick up sufficient synch signal.
(2) Amplifier H. P. Model 461A.-Set the gain control for a normal presentation on the oscilloscope. There shall be no clipping or distortion of the synch signal.

(d) Dual Beam Oscilloscope.-The controls shall be set as follows:

(1) Trigger- Set for external synch.
(2) Vertical Sensitivity controls - Set for normal presentation on A and B channels. There shall be no clipping or distortion of signals.
(3) Other controls - Set to compensate for signal amplitude, shape, and frequency.

4.2.8.2.2 Measurement Procedures.-Measurement procedures shall be as follows:

(a) Scan the full frequency range of the lowest tuning band of the EMI Meter for the frequency of maximum emission.
(b) Adjust the operating controls of EMI Meter, raster generator, dual beam oscilloscope, and signal sampling amplifier to produce the desired display on the dual beam oscilloscope.
(c) Adjust the trace on the dual beam oscilloscope so that the vertical sweeps are positioned symmetrically about the zero voltage reference axis.
(d) Reduce the channel A intensity on the oscilloscope to the fade-out point.
(e) Set the channel B intensity on the oscilloscope to a point where the brightness of the presentation does not obscure the raster presentation on channel A.
(f) Readjust the gain and attenuation controls of the EMI Meter, raster generator, sampling amplifier, and oscilloscope controls to obtain channel A and B waveforms which do not overload the video amplifiers.
(g) Adjust the sweep rate controls on the raster generator and oscilloscope for the desired frame rate.
(h) Correlated, repetitive interference pulses should appear as vertical columns of dots or solid vertical lines depending upon the sensitivity setting of the oscilloscope vertical amplifier. This is a means of separating the source interference signal from any high ambient random noise. The interference source signal is thus identified when this correlation is found between the monitor signal and the raster presentation.
(i) Adjust the channel A intensity control so that the correlated source interference signal is just visible.
(j) Turn off test sample.
(k) Place S1 and S2 in the measure position.
(l) Tune the signal generator to same frequency as the EMI meter.
(m) Place signal generator modulation control at 400 Hz 30 percent modulation.
(n) Without resetting operating controls of EMI meter, raster generator and oscilloscope, set the r.f. output of the signal generator so that the writing on the oscilloscope equals the intensity as in step (d).
(o) The induced voltage of the emission at the antenna shall equal the output voltage of the signal generator minus antenna injection network loss.

5. MEASUREMENT PROCEDURES

5.1 This section contains the measurement procedures to be used in determining compliance with the emission and susceptibility requirements of MIL-STD-461. The test procedures are applicable for the entire

specified frequency range; however, certain equipment or classes of equipment may not require testing throughout the complete measurement frequency range. These modifications are specified in MIL-STD-461.

* 5.2 Table I is an index of measurement procedures by method number, date, and title.

Table I. Index of Measurement Procedures

Method	Date	Title
CE01	31 July 1967	Conducted Emission, 30 Hz to 20 kHz, Power Leads
CE02	31 July 1967	Conducted Emission, 30 Hz to 20 kHz, Control and Signal Leads
CE03	31 July 1967	Conducted Emission, 20 kHz to 50 MHz, Power Leads
CE04	31 July 1967	Conducted Emission, 20 kHz to 50 MHz, Control and Signal Leads
CE05	31 July 1967	Conducted Emission, 30 Hz to 50 MHz, Inverse Filter Method
CE06	31 July 1967	Conducted Emission, 10 kHz to 12.4 GHz, Antenna Terminal
CS01	31 July 1967	Conducted Susceptibility, 30 Hz to 50 kHz, Power Lead
CS02	31 July 1967	Conducted Susceptibility, 50 kHz to 400 MHz, Power Lead
CS03	31 July 1967	Conducted Susceptibility, 30 Hz to 10 GHz, Intermodulation, Two Signal
CS04	31 July 1967	Conducted Susceptibility, 30 Hz to 10 GHz, Rejection of Undesired Signals at Input Terminals (2-Signal Generator Method)
CS05	31 July 1967	Conducted Susceptibility, 30 Hz to 10 GHz, Cross-Modulation
CS06	31 July 1967	Conducted Susceptibility, Spike, Power Leads
(T)CS07	31 July 1967	Conducted Susceptibility, Squelch Circuits
CS08	31 July 1967	Conducted Susceptibility, 30 Hz to 10 GHz, Rejection of Undesired Signals at Input Terminals (1-Signal Generator Method)
CS09	1 April 1980	Conducted Susceptibility, 60 Hz to 100 kHz, Structure Current (Common Mode Current)
CS10	4 August 1986	Conducted Susceptibility, Damped Sinusoidal Transients, Pins and Terminals, (Pin Injection), 10 kHz to 100 MHz
CS11	4 August 1986	Conducted Susceptibility, Damped Sinusoidal Transients, Cables, 10 kHz to 100 MHz
RE01	31 July 1967	Radiated Emission, 30 Hz to 30 kHz, Magnetic Field
RE02	31 July 1967	Radiated Emission, 14 kHz to 10 GHz, Electric Field
RE03	31 July 1967	Radiated Emission, Spurious and Harmonic Emissions, 10 kHz to 40 GHz
(T)RE04	31 July 1967	Radiated Emission, 20 Hz to 50 kHz, Magnetic Field
RE05	31 July 1967	Radiated Emission, 150 kHz to 1 GHz, Vehicles and Engine-Driven Equipment
RE06	31 July 1967	Radiated Emission, 14 kHz to 1 GHz, Overhead Power Lines
RS01	31 July 1967	Radiated Susceptibility, 30 Hz to 30 kHz, Magnetic Field
RS02	31 July 1967	Radiated Susceptibility, Magnetic Induction Fields
RS03	31 July 1967	Radiated Susceptibility, 14 kHz to 10 GHz, Electric Field
RS04	31 July 1967	Radiated Susceptibility, 14 kHz to 30 MHz
RS05	4 August 1986	Radiated Susceptibility, Electromagnetic Pulse Field, Transient

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METHOD CE03

CONDUCTED EMISSION, 20 kHz TO 50 MHz, POWER LEADS

* 1. Purpose.- This method is used for measuring conducted emissions on all power leads. This method is also applicable for testing to the UM04 and UM05 broadband conducted emissions requirements of MIL-STD-461.

2. Applicability.- This test method is applicable for measuring conducted emissions in the frequency range of 20 kHz to 50 MHz on a.c. and d.c. power input and output leads, including neutrals which are grounded externally to the equipment. Bonding straps need not be measured.

3. Apparatus.- The test apparatus shall include the following:

(a) Current Probes.

(b) Electromagnetic Interference Meter.

(c) Ten Microfarad Feed-Through Capacitor.

4. Test Procedure.- The test setup shall be as shown in Figure CE01-1. Conducted emissions shall be measured separately on each power lead.

* 5. Notes.

(a) Electric Generator Sets - No feed-through capacitors are required in the output power leads. Measurements shall be made near the output end of a 15 meter power cable terminated with the specified rated load(s). The cable shall be energized during no-load tests. The load bank may be shielded or located outside the test room.

(b) Portable Electric Hand Tools - The tool case shall be non-conductively separated from the metal ground plane by 1 meter. The EMI meter may be on a separate ground plane. Electric hand tools shall be tested at no load.

METHOD CS02

CONDUCTED SUSCEPTIBILITY, 50 kHz TO 400 MHz, POWER LEAD

1. Purpose.- This method is used to determine whether communication electronic equipment is susceptible to electromagnetic energy injected on its power leads.

2. Applicability.- This test method is applicable for all Class I equipment (see MIL-STD-461).

3. Apparatus.- The apparatus shall consist of the following:

(a) Signal Source.- A 50-ohm internal impedance and an output voltage of 7 volts to a matched load.

(b) 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 so as to maintain the impedance.

(c) VTVM, Oscilloscope, or EMI meter.

* 4. Test Setup and Procedure.- Test setup and procedures shall be as follows except that common mode coupling of a test signal shall be as shown in Figure CS02-2.

(a) Use the general test setup as shown in Figure CS02-1.

(b) Connect the coupling capacitor and VTVM, oscilloscope, or EMI meter within 5 cm of the termination to the test sample.

(c) Apply the test signal to each power lead.

(d) When testing equipment using single point grounds, apply the test signal between each power lead and the ground return, and also each power or ground return lead and the ground plane.

(e) Measure and record the voltage across the terminal of the test sample.

(f) If the test sample is susceptible to the applicable limit level, decrease the signal source output to determine and record the threshold of susceptibility.

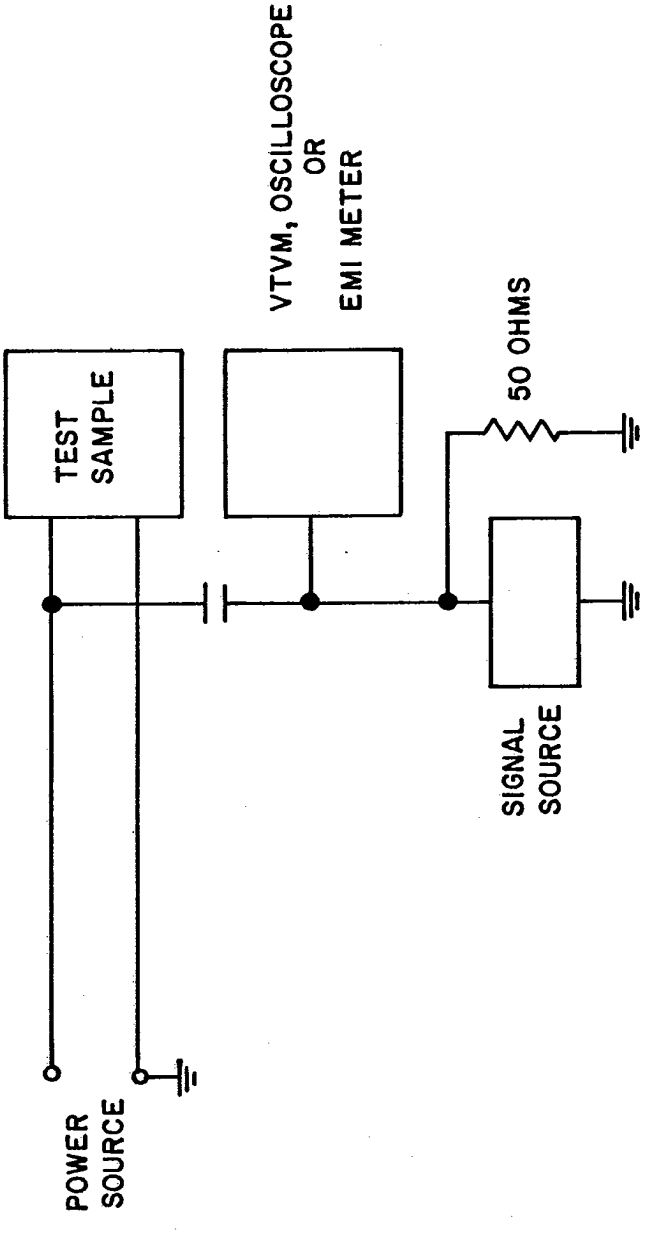
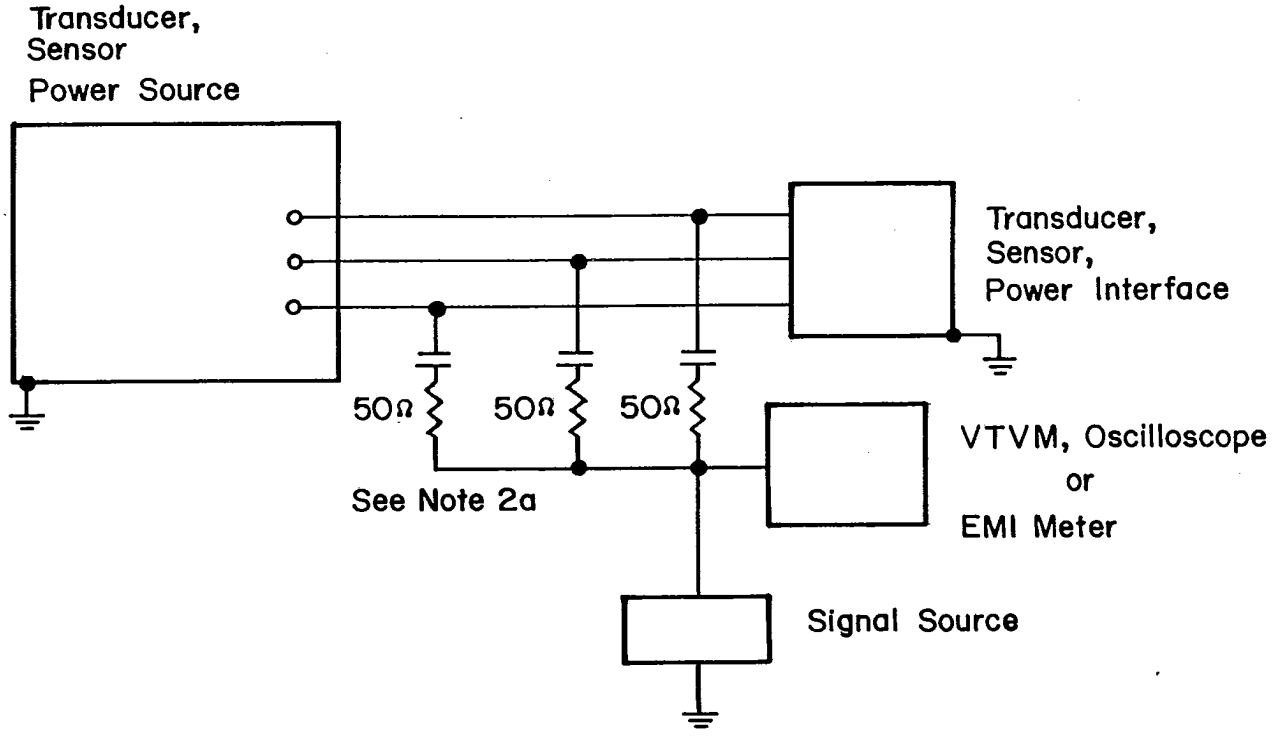


FIGURE CS02-1 — CONDUCTED SUSCEPTIBILITY 50 kHz TO 400 MHz



NOTES:

1. Signal Source. A 50 ohm internal impedance and an output voltage of 20 volts to a matched load.

2. Test Procedure. Use the test procedure in paragraph 4 except as follows:

   a. Up to three lines of an interface may be tested at the same time.

   b. The test need only be applied to one interface that is representative of similar interfaces.

FIGURE CS02-2 — CONDUCTED SUSCEPTIBILITY, 2 MHz TO 30 MHz, COMMON MODE COUPLING

METHOD CS10

CONDUCTED SUSCEPTIBILITY, DAMPED SINUSOIDAL TRANSIENTS, PINS AND TERMINALS (PIN INJECTION), 10 kHz to 100 MHz

1. Purpose.- This test method is used to determine equipment or subsystem susceptibility to damped sinusoidal transients.

2. Applicability.- This test is applicable for all interface pins and terminals of control leads, signal leads, power leads, and grounds and neutrals which are not grounded internally to the equipment or subsystem as specified in MIL-STD-461 or individual equipment specifications.

3. Apparatus.- The test apparatus shall consist of the following (See Table CS10-1):

(a) Damped Sinusoid Generator with the following characteristics:

(1)	Output	=	Peak voltage and current per applicable curve limit of MIL-STD-461 as measured across a 100 ohm load.
(2)	Output Control	=	Adjustable from 10 to 100 percent of limit.
(3)	Damping Factor, Q	=	15 $\pm$ 5.
(4)	Frequency Control	=	Adjustable over the 10 kHz to 100 MHz frequency range.
(5)	Pulse Repetition Rate	=	One pulse per second.
(6)	Output Impedance	=	100 ohms or less.
(7)	Synchronous Output	=	as appropriate.

(8) The damped sinusoid generator shall not interfere with normal operation of the test sample when the generator is connected (as specified in paragraph 4 below) but untriggered.

(b) Oscilloscope.- 100 MHz bandwidth minimum and 5 nanosecond per division minimum sweep rate.

(c) Coupling Device.- Either capacitive or inductive indirect injection devices shall be used, as specified in the approved EMI Test Plan (See paragraphs 5.5 and 5.6).

(d) Calibrating Load.- 100 ohm non-inductive resistor.

(e) Current Probe.- Electrostatically shielded probe with the following characteristics:

(1)	Transfer Impedance	=	0.5 ohm or more.
(2)	Frequency Response	=	3 dB points 10 kHz to 100 MHz.
(3)	Current Measuring Capability	=	per applicable limit of MIL-STD-461, 10 amperes maximum.
(4)	Output Impedance	=	50 ohm.

(f) LISN.- 5 µH Line Impedance Stabilization Network with connector terminated in 50 ohms.

(g) Interconnecting Test Cable/Breakout Box.- As specified in the approved EMI Test Plan.

(h) Isolation Transformer.- As appropriate.

(i) Filter/Isolator Device.- As appropriate.

(j) Scope Camera.- As appropriate.

4. Test Setup and Procedure.- The test setup and procedure shall be as follows:

(a) When testing leads, test sample and test instrumentation shall be as shown in Figure CS10-1.

(b) When testing an individual terminal, test sample and test instrumentation shall be as shown in Figure CS10-2. Multiple wire structures such as balanced leads, twisted pairs, shielded twisted pairs or triax shall be treated as a single wire and be tested simultaneously, as specified in Table CS10-2.

(c) The tests shall be performed at the following frequencies: .01, .1, 1, 10, 30 and 100 MHz. In addition, the test shall be performed at the test sample's critical frequencies, such as: local oscillator, I.F., power switching frequencies and harmonics, clock frequencies, bandpass frequencies, and as specified in the EMI Test Plan. The maximum test frequency shall not exceed 100 MHz.

(d) The generator output shall be calibrated at each test frequency prior to application of the test signal to the test sample. The generator output shall be calibrated using a 100 ohm load, as shown in Figure CS10-3.

(e) The test signal shall be applied to each interface pin or terminal of the test item sequentially. The common mode current measured by the oscilloscope shall follow the typical waveshape. The peak current level shall be adjusted to provide the specified current, but shall not exceed the precalibrated generator output level. The peak current obtained shall be recorded. The pin injected voltage shall be limited to the CS10 I_{max} x 100.

(f) A minimum of ten positive first half-cycle pulses, followed by ten negative first half-cycle pulses shall be applied at each frequency at all pertinent modes of operation of the test sample, as specified in the EMI Test Plan. The equipment shall also be tested in the power-off state.

(g) The pulse repetition rate shall be no greater than one pulse per second and no less than one pulse per minute.

(h) If any susceptibility, as defined in MIL-STD-461, is identified, determine and record the pin(s) under test, test frequency, threshold level, operation mode, and time occurrence (for logic circuitry) at which a failure or degradation occurred.

5.0 Notes.

5.1 Test sample, instrumentation, and termination box shall be grounded as installed in the operational system.

5.2 All cables shall be 5 cm above the ground.

5.3 Signal and control pins under test shall be terminated (either at the test sample instrumentation or termination box) with actual or dummy loads.

5.4 AC and primary DC powerlines shall be tested using line impedance stabilization networks.

5.5 The following coupling devices shall be used:

(a) Distributive capacitor (above 10 MHz) with $X_C \leq 100$ ohms.

(b) Current transformer, with single-turn secondary (10 khz to 10 MHz).

5.6 Alternate devices such as a discrete capacitor, diode, avalanche or Zener type diode, metal oxide varistor, or spark gap may be used, provided it is approved by the procuring activity.

5.7 Damping Factor.- The damping factor controls the sinusoid rate of decay. The damping factor satisfies the following equation:

$$Q = \frac{\pi (N-1)}{\text{Ln}\left(\frac{V_1}{V_N}\right)}$$

Q = Damping factor

N = Cycle number, e.g., 2, 3, 4, 5, ...

V_N = Peak voltage at Nth cycle

V_1 = Peak voltage at first cycle

Ln = Natural log

TABLE CS10-1

SUGGESTED TEST EQUIPMENT
FOR EMP TESTS CS10, CS11, and RS05

EQUIPMENT	MANUFACTURER	MODEL	FREQUENCY RANGE	TEST METHOD		
	NOTE: Equivalents may be used			CS10	CS11	RS05
Damped Sinusoid Generator	Elgal (Amplifier Research Corp.)	EM101A, Plus OSC Plug-in Units	10 kHz-100 MHz	X	X	
	R&B Enterprises	EMPS 461C	10 kHz-100 MHz	X	X	
LISN	Solar	6332-5-TS-100-N	DC-60 Hz	X	X	X
Capacitive Coupling Device	Elgal	COP-101	10 MHz-100 MHz	X	X	
	R&B Enterprises	CNC Series	10 MHz-100 MHz	X	X	
Current Probe	EG & G	SCP-1 LCP-1	12 kHz-140 MHz 13 kHz-100 MHz	X X	X X	
Inductive Coupling Device	Elgal	COP-101	10 kHz-10 MHz	X	X	
	R&B Enterprises	INC Series	10 kHz-100 MHz	X	X	
(Current Transformer)	EG & G	ICT-4	10 kHz-100 MHz	X	X	
	Fischer Custom Communications	F-110 (Core only)	10 kHz-10 MHz	X	X	
Calibration Networks	R&B Enterprises	CNC Series CNI Series	Cab. Coupling Inductive Coupling	X X	X X	
Direct Drive Network	R&B Enterprises	DCN Series	Direct Drive		X	
Parallel Plate Line	Elgal	EM102	t_r = 5 nsec t_d = 0.5 µsec			X
Transient Pulse Generator	Elgal	EM103	Transient			X
	Pulsar	FRP-125	Transient			X
D-DOT Sensor	EG & G	ACD-4, HSD-4	>1.1 GHz,>150 MHz			X
BALUN	EG & G	DMB-1	15 kHz-1000 MHz			X
Integrator	EG & G	RCI-1B	T.C. = 1 µsec			X
	Elgal	INT-1	T.C. = 1 µsec			X

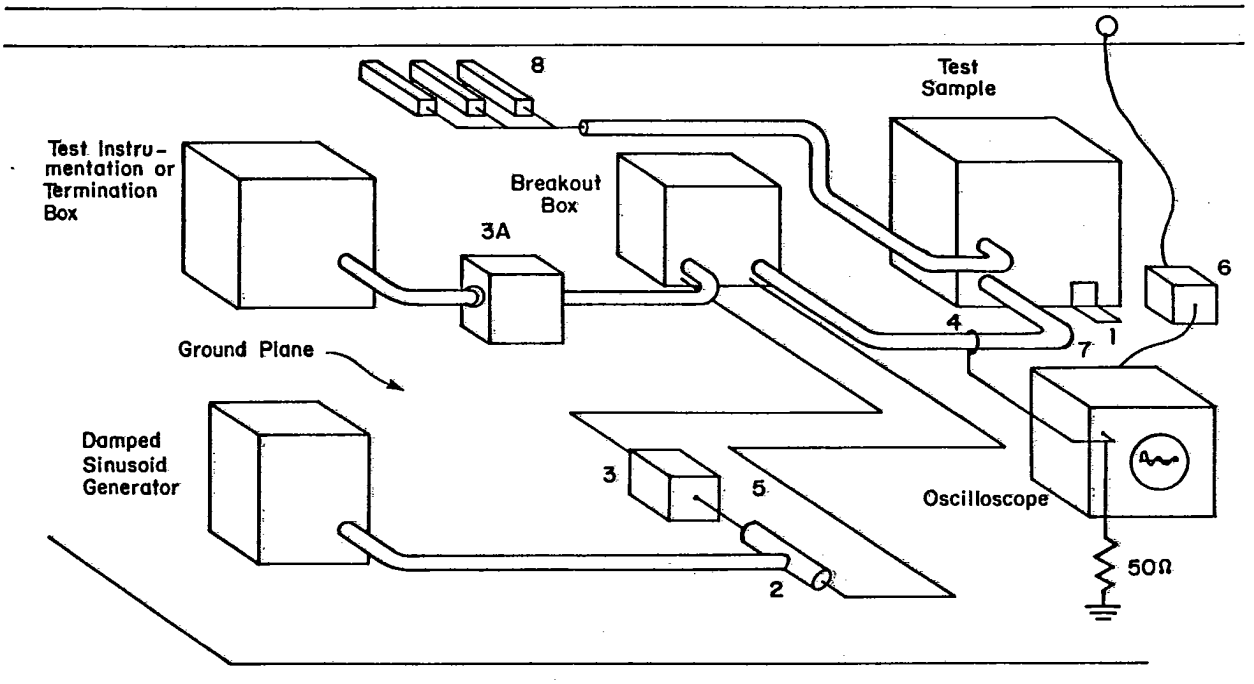
METHOD CS10
4 August 1986

TABLE CS10-2

WIRE COUPLING METHODS

WIRE TYPE	FREQUENCY RANGE	COUPLING	COMMENTS
I. Single Wire	10 kHz - 10 MHz Above 10 MHz	Inductive Capacitive	
II. Multiple Wire or Balanced Pair	10 kHz - 10 MHz Above 10 MHz	Inductive Capacitive	
III. Shielded Twisted Leads	10 kHz - 100 MHz 10 kHz - 10 MHz Above 10 MHz	Inductive Inductive Capacitive	Shield grounded at both ends Shield grounded at one end only
IV. Coax or Triax	10 kHz - 100 MHz 10 kHz - 10 MHz Above 10 MHz	Inductive Inductive Capacitive	Outer shield grounded at both ends Outer shield grounded at one end only

NOTE: 1. The 10 MHz cut-off frequency for inductive coupling is a guide. Inductive or capacitive coupling may be used for the entire 10 kHz - 100 MHz frequency range to achieve the current requirements.



NOTES:
1. The DC bond resistance between the ground plane and the test sample shall not exceed 2.5 milliohms.
2. Capacitive or inductive coupling device.
3. A filter or isolator should be used in order not to cause damage or interference to the test instrumentation. Alternatively, a common mode filter (3A) may be used.
4. Current probe $\leq$ 15 cm from test sample connector.
5. Lead under test. This lead shall be 10 AWG or larger and as short as possible. The maximum length of the lead shall not exceed 25 centimeters external to the coupling device.
6. Isolation transformer.
7. Cable between the test sample and the breakout box = 1 meter $\pm$ 0.1 m.
8. LISN terminated in 50 ohms.

FIGURE CS10-1 – TYPICAL TEST SETUP FOR LEADS, PIN INJECTION OF DAMPED SINUSOIDAL TRANSIENTS

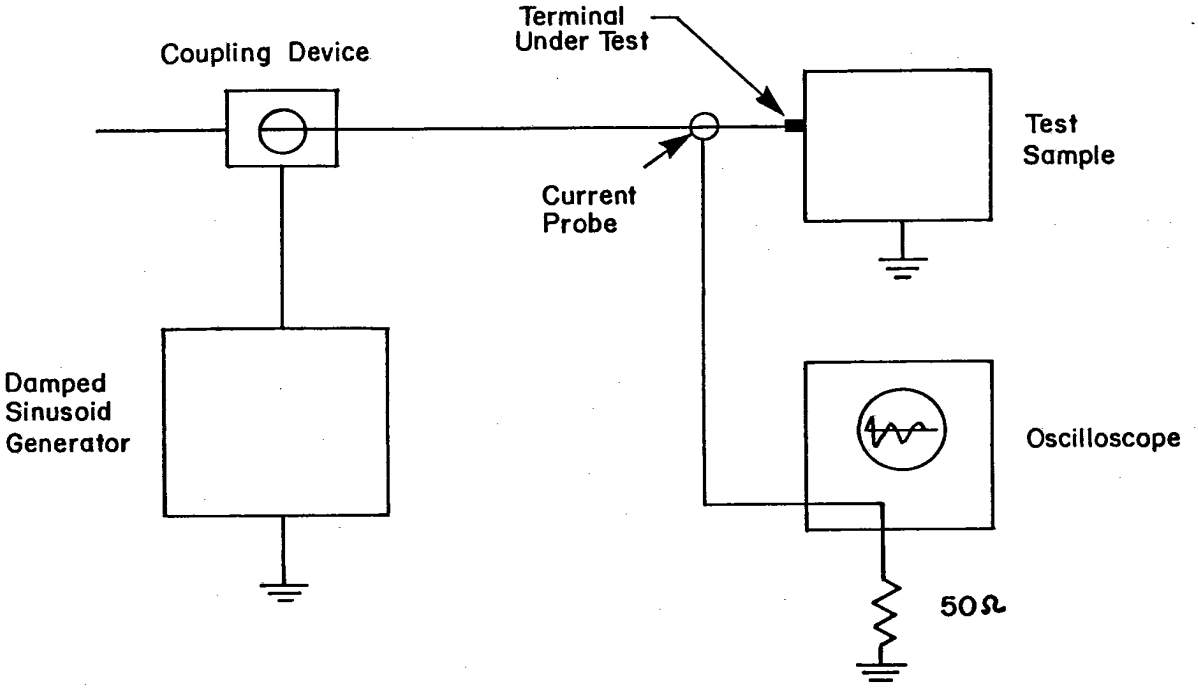
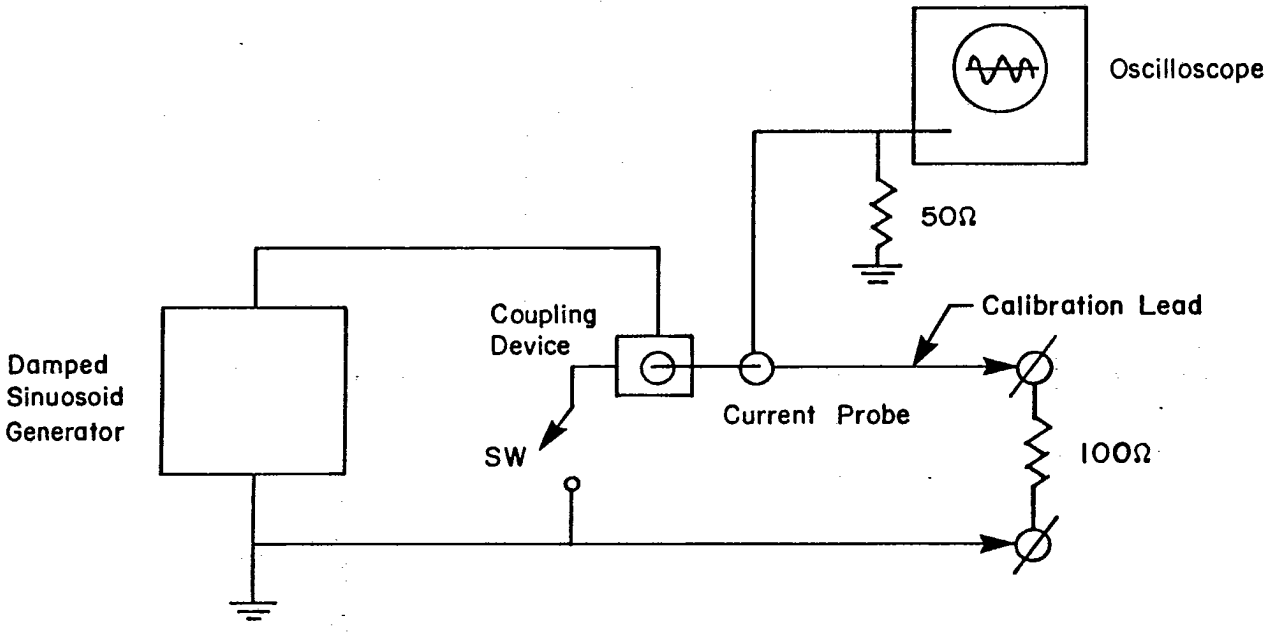


FIGURE CS10-2 - TYPICAL TEST SETUP FOR TERMINALS



NOTES:
1. When using an inductive coupling (transformer coupling) device, SW shall be closed.
2. When using a capacitive coupling device, SW shall be open.
3. When using an isolation box as shown in Figure CS10-1, the box shall be included between the SW and coupling device.
4. The calibration lead shall be 10 AWG or larger and as short as possible. The maximum length of the lead shall not exceed 25 centimeters external to the coupling device.

FIGURE CS10-3 – TYPICAL SETUP FOR CALIBRATION OF GENERATOR OUTPUT LEVEL

METHOD CS11

CONDUCTED SUSCEPTIBILITY, DAMPED SINUSOIDAL TRANSIENTS, CABLES, 10 kHz to 100 MHz

1. Purpose.- This test method is used to determine equipment or subsystem susceptibility to damped sinusoidal transients on control, signal and power cables.

2. Applicability.- This test is applicable for all equipment and subsystem interconnecting and intraconnecting control, signal and power cables, as specified in MIL-STD-461 or the individual equipment specification.

3. Apparatus.- The test apparatus shall consist of the following (See Table CS10-1):

(a) Damped Sinusoid Generator with the following characteristics:

(1)	Output	=	Peak current per applicable curve limit of MIL-STD-461 measured across a 100 ohm load.
(2)	Output Control	=	Adjustable from 10 to 100 percent of test limit.
(3)	Damping Factor, Q	=	15 $\pm$ 5.
(4)	Frequency Control	=	Adjustable over the 10 kHz to 100 MHz frequency range.
(5)	Pulse Repetition Rate	=	One pulse per second.
(6)	Output Impedance	=	100 ohms or less.
(7)	Synchronous Output	=	as appropriate.

(8) The damped sinusoid generator shall not interfere with normal operation of the test sample when the generator is connected (as specified in paragraph 4 below) but is untriggered.

(b) Oscilloscope.- 100 MHz bandwidth minimum and 5 nanosecond per division minimum sweep rate.

(c) Coupling Device.- Either capacitive or inductive indirect injection devices shall be used, as specified in the approved EMI Test Plan (See paragraphs 5.5 and 5.6).

(d) Calibrating Load.- 100 ohm non-inductive resistor.

(e) Current Probe.- Electrostatically shielded probe with the following characteristics:

(1)	Transfer Impedance	=	0.5 ohm or more.
(2)	Frequency Response	=	3 dB points 10 kHz to 100 MHz.
(3)	Current Measuring Capability	=	per applicable limit of MIL-STD-461, 10 amperes maximum.
(4)	Output Impedance	=	50 ohm.

(f) LISN.- 5 µH Line Impedance Stabilization Network with coaxial connector terminated in 50 ohms.

(g) Isolation Transformer.- As appropriate.

(h) Filter/Isolator Device.- As appropriate.

(i) Scope Camera.- As appropriate.

4. Test Setup and Procedure.- The test setup and procedure shall be as follows:

(a) Test sample and test instrumentation shall be as shown in Figure CS11-1.

(b) Bulk cable injection technique shall be used, as outlined in Table CS11-1. Each cable shall be tested individually.

(c) Shielded cables shall be tested by one of the following methods, as determined from Table CS11-1:

(1) When the length of cable is unknown, use indirect injection with the outer cable shield completely removed from the cable.

(2) When the shielding type and cable length are unknown but are essential for the test sample operation, use indirect injection with the outer cable shield circumferentially bonded to a shielded test box containing the coupling device, as shown in Figure CS11-2. The outer cable shield is to be eliminated within the shielded test box. The shielded test box also contains the current probe.

(3) When the cable length, type, and shield are known, a shielded cable may be tested at actual length with the shield, when approved by the procuring activity. Inductive current injection shall be used when both ends of the cable shield are grounded. Direct drive of the cable shield may be used when one end of the cable shield is removable from the ground without affecting the test sample normal performance. See CS11-3.

(d) The tests shall be performed at the following frequencies: .01, .1, 1, 10, 30 and 100 MHz. In addition, the tests shall be performed at the test sample's critical frequencies, such as: local oscillator, I.F. power switching frequencies and harmonics, clock frequencies, bandpass frequencies, and as specified in the EMI Test Plan. The maximum test frequency shall not exceed 100 MHz.

(e) The generator output shall be calibrated at each test frequency prior to application of the test signal to the test sample. The generator output shall be calibrated using a 100 ohm load, as shown in Figure CS11-4.

(f) The test signal shall then be applied to each cable of the test item sequentially. The bulk current measured by the oscilloscope shall follow the typical waveshape. The damped sine generator output level shall be adjusted to provide the specified current, but shall not exceed the precalibrated generator output level. If necessary, the current shall be maximized by varying the position of the coupling device along the cable under test. The peak current obtained shall be recorded.

(g) A minimum of ten positive first half-cycle pulses, followed by ten negative first half-cycle pulses, shall be applied at each frequency at all pertinent modes of operation of the test sample, as specified in the EMI Test Plan. The equipment shall also be tested in the power-off state.

(h) Pulse repetition rate shall be no greater than one pulse per second and no less than one pulse per minute.

(i) If any susceptibility, as defined in MIL-STD-461, is identified, determine and record the cable under test, test frequency, threshold level and time occurrence (for logic circuitry) at which a failure or degradation occurred.

5.0 Notes.

5.1 Test sample, instrumentation, and termination box shall be grounded as installed in the operational system.

5.2 All cables shall be 5 cm above the ground.

5.3 Signal and control pins of the cable under test shall be terminated at test sample instrumentation or termination box with actual or dummy loads.

5.4 AC and primary DC powerlines shall be tested using powerline impedance stabilization networks.

5.5 The following coupling devices shall be used:

(a) Distributive capacitor (above 10 MHz) with $X_C \leq 100$ ohms.

(b) Current transformer, with single-turn secondary (10 kHz to 10 MHz).

5.6 Alternate devices such as a discrete capacitor, diode, avalanche or Zener type diode, metal oxide varistor, or spark gap may be used, provided it is approved by the procuring activity.

5.7 Care shall be taken to prevent voltage breakdown from the cable under test to the current injection coupler.

5.8 Damping Factor.- The damping factor controls the sinusoid rate of decay and satisfies the following equation:

$$Q = \frac{\pi(N-1)}{\mathrm{Ln}\left(\frac{V_1}{V_N}\right)}$$

Q = Damping factor

N = Cycle number, e.g., 2, 3, 4, 5, ...

V_N = Peak voltage at Nth cycle

V_1 = Peak voltage at first cycle

Ln = Natural log

TABLE CS11-1

BULK CABLE COUPLING METHODS

CABLES & WIRE TYPE	FREQUENCY	COUPLING	FIGURE	COMMENTS
I. Unshielded Cable Harness				
I-1 Single Wires	10 kHz - 10 MHz	Inductive	CS11-1	
	Above 10 MHz	Capacitive	CS11-1	
I-2 Balanced Pairs	10 kHz - 10 MHz	Inductive	CS11-1	
	Above 10 MHz	Capacitive	CS11-1	
I-3 Shielded Balanced Pairs	10 kHz - 100 MHz	Inductive or Direct Drive	CS11-1 or CS11-4	Shields grounded at both ends (2)
	10 kHz - 10 MHz	Inductive	CS11-1	Shields grounded at one end only
	Above 10 MHz	Capacitive	CS11-1	Shields grounded at one end only
I-4 Multiple Coax or Shielded Wires	10 kHz - 100 MHz	Inductive or Direct Drive	CS11-1 or CS11-4	Shields grounded at both ends (2)
	10 kHz - 10 MHz	Inductive	CS11-1	Shields grounded at one end only
	Above 10 MHz	Capacitive or Direct Drive	CS11-1	Shields grounded at one end only
I-5 Mixed Combination of the above Wire Categories	10 kHz - 10 MHz	Inductive	CS11-1	
	Above 10 MHz	See Note (1)	CS11-1 or CS11-4	
II. Shielded Cable Harnesses (3)	10 kHz - 100 MHz	Inductive or Direct Drive	CS11-1 or CS11-4	Shield grounded at both ends (2)
	10 kHz - 10 MHz	Inductive	CS11-1 or CS11-3	Shield grounded at one end only
	Above 10 MHz	Capacitive	CS11-1 or CS11-3	Shield grounded at one end only (4)

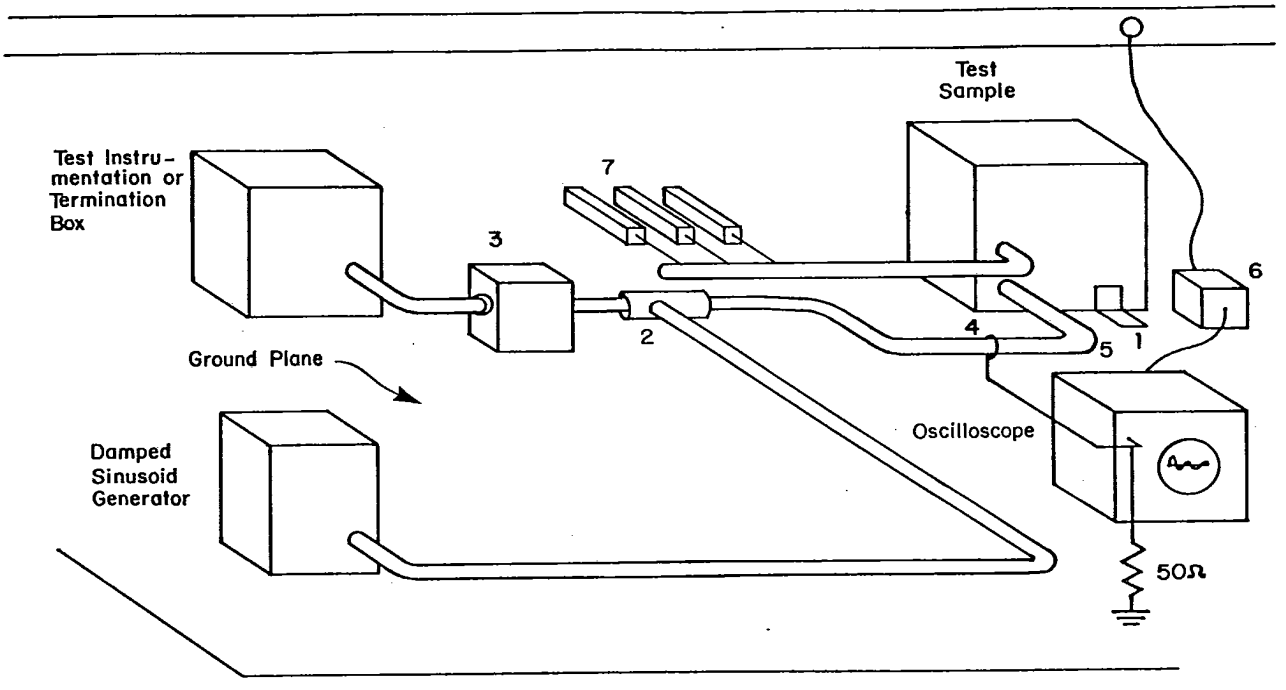
NOTES: 1. All wires of the same category shall be grouped and injected together. Categories utilizing the same coupling shall be grouped together.

2. CS11-4 is preferred when the cable with the shield is tested at its actual length for the system configuration.

3. Shielded cable harnesses may contain all of the above wire combinations and categories.

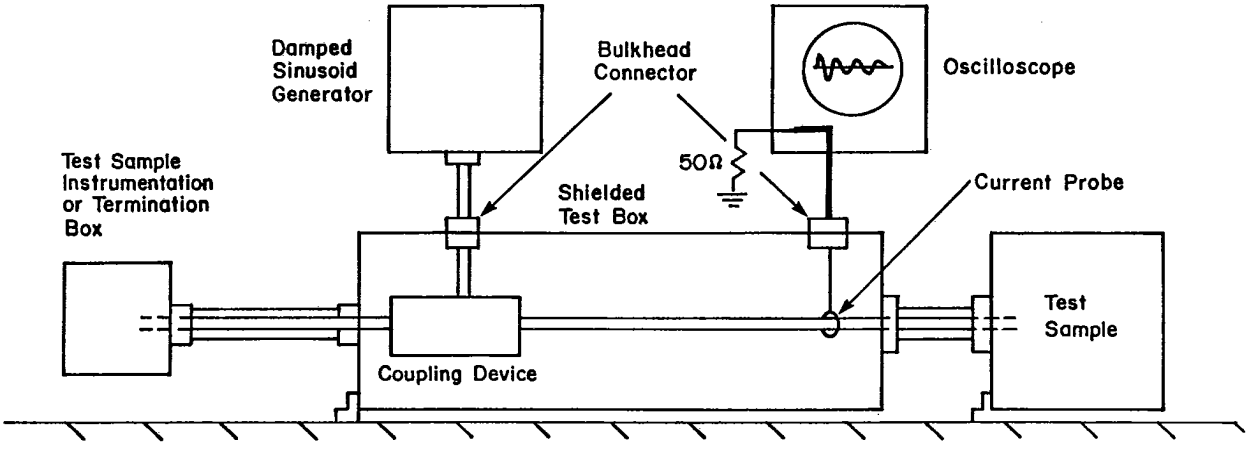
4. CS11-3 shall be performed when the outer harness shield is essential for test sample operation, but its type and length are unknown.

5. The 10 MHz cut-off frequency for inductive coupling is a guide. Inductive or capacitive coupling may be used for the entire 10 kHz - 100 MHz frequency range to achieve the current requirements.



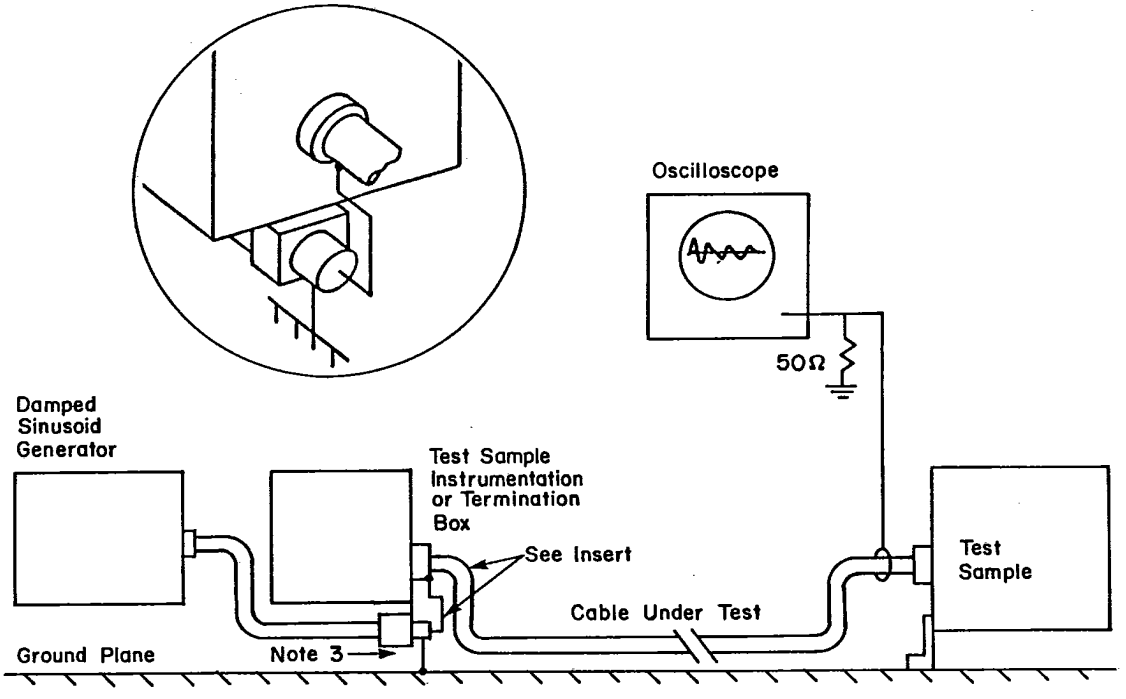
NOTES:
1. The DC bond resistance between the ground plane and the test sample shall not exceed 2.5 milliohms.
2. Capacitance or inductance coupling device.
3. A filter or isolator may be used to prevent damage or interference to the test instrumentation.
4. Current probe $\leq$ 15 cm from test sample connector.
5. Cable under test.
6. Isolation transformer.
7. LISN terminated in 50 ohms.

FIGURE CS11-1 — TYPICAL TEST SETUP FOR INDIRECT BULK CABLE INJECTION OF DAMPED SINUSOIDAL TRANSIENTS



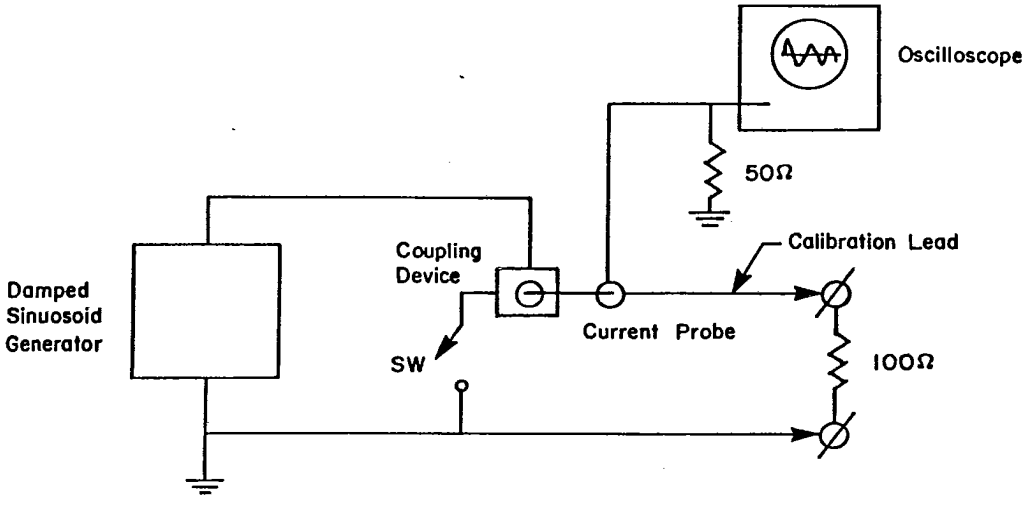
NOTES:
1. Shielded test box shall be bonded to the ground plane by a maximum resistance of 2.5 milliohms.
2. Current probe shall be electrically isolated from ground.
3. Shielded test box shall provide the minimum shielding effectiveness required at test frequencies in order for stray radiation not to interfere with normal operation of the test sample.
4. Calibration shall be performed in accordance with Figure CS11-2 set-up with coupling device and current probe installed within the shielded test box.
5. Interconnecting cable between test sample and shielded test box shall be $\leq$ 10 cm.
6. Current probe separation from entry point of cable under test shall be $\leq$ 5 cm.

FIGURE CS11-2 — TYPICAL TEST SETUP FOR BULK CURRENT COUPLING OF DAMPED SINUSOID TRANSIENTS INTO SHIELDED CABLES OF KNOWN OR UNKNOWN LENGTHS



NOTES:
1. The shield of the cable under test shall be circumferentially bonded to the instrumentation or termination box shield.
2. The cable under test shall be placed close to the ground plane to provide uniform low characteristic impedance, without causing cable insulation breakdown.
3. Impedance matching pad shall be used to match the generator output impedance to the cable above-ground impedance, when a low impedance cable reduces the signal duration.

FIGURE CS11-3 — TYPICAL TEST SETUP FOR DIRECT DRIVE BULK CURRENT COUPLING OF DAMPED SINUSOID TRANSIENTS INTO SHIELDED CABLES OF KNOWN LENGTHS



NOTES:
1. When using an inductive coupling (transformer coupling) device, SW shall be closed.
2. When using a capacitive coupling device, SW shall be open.
3. The calibration lead shall be 10 AWG or larger and as short as possible. The maximum length of the lead shall not exceed 25 centimeters external to the coupling device.
4. This calibration procedure is not applicable for direct drive injection tests.

FIGURE CS11-4 — TYPICAL SETUP FOR CALIBRATION OF GENERATOR OUTPUT LEVEL

METHOD RE02

RADIATED EMISSION, 14 kHz to 10 GHz, ELECTRIC FIELD

* 1. Purpose.- This method is used for measuring radiated electromagnetic emissions from electronic, electrical, and electromechanical equipment. This method is also applicable for testing to the UM03, UM04, and UM05 broadband radiated emission requirements of MIL-STD-461.

2. Applicability.- Any equipment or device to which this method is applicable shall be measured for radiated emissions from all units, cables (including controls, pulse, IF, video antenna transmission lines, and power cables), and interconnecting wiring. This method applies to the transmitter fundamental, spurious radiation, oscillator radiation, and broadband emissions, but does not include radiation emanating from an antenna.

2.1 Applicable Frequency Range for Test.-

2.1.1 Electronic Equipment.-

(a) Narrowband emissions shall be measured from 14 kHz to 10 times the highest used or intentionally generated frequency, or 1 GHz, whichever is greater; however, the measured frequency shall not exceed 10 GHz.
(b) Broadband emissions shall be measured from 14 kHz to 1 GHz.

2.1.2 Electrical Equipment (Classes IIB and IIC).-

(a) Class IIB items shall be tested from 150 kHz to 400 MHz, except electrical hand tools, which shall be tested from 150 kHz to 30 MHz.
(b) Class IIC items shall be tested from 150 kHz to 1 GHz.

3. Apparatus.- Test apparatus shall consist of the following:

(a) Test antennas.
(b) EMI Meters.
(c) 10-Microfarad Feed-Through Capacitor.

4. Test Setup and Procedure.-

4.1 Test Setup.- The basic test setups shall be as shown in Figures RE02-1 and RE02-2.

4.1.1 Nonportable Equipment.- Equipment which is permanently connected either physically or electrically, to a vehicle, system, or installation shall be tested in accordance with the setup shown in Figure RE02-1.

4.1.2 Portable equipment, including hand tools, administrative office machines, man-pack operable equipment, and test equipment shall be tested in accordance with the setup shown in Figure RE02-2.

4.1.3 Equipment falling into both of the categories indicated in 4.1.1 and 4.1.2 shall be tested both ways, unless otherwise specified by the procuring activity or as approved in the test plan.

4.2 Procedure.- The test procedures shall be as follows:

(a) Probe the test sample as indicated in Section 4 of this standard to locate the points of maximum radiation from the test sample.
(b) Select and position the test antennas as indicated in Section 4 of this standard. In the frequency range of 25 to 200 MHz, position the test antenna so as to make both vertical and horizontal measurements.
(c) For each test antenna, scan the applicable frequency range of this test with the EMI meter and take measurements as required.

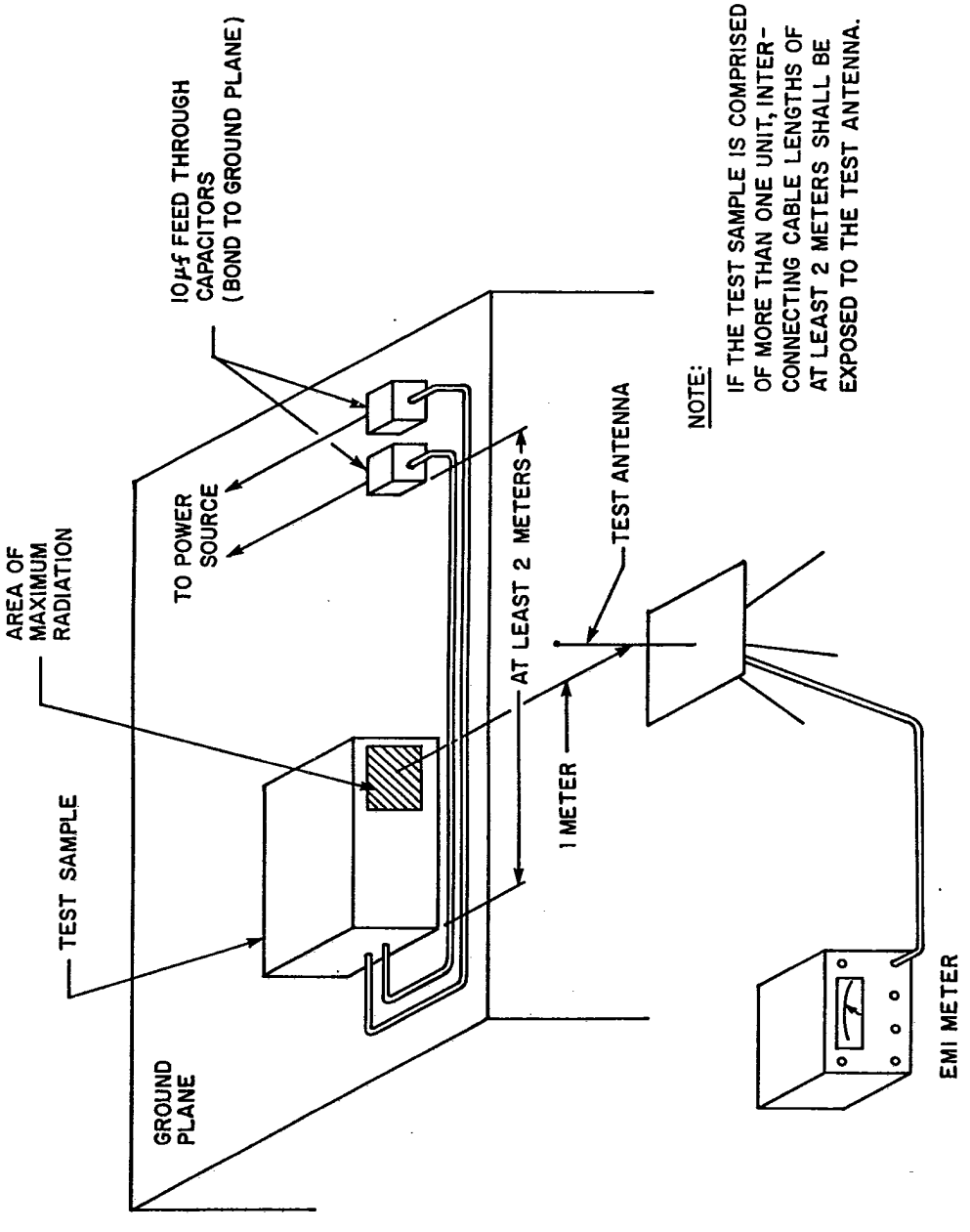


FIGURE RE02-1 – TYPICAL TEST SETUP FOR RADIATED MEASUREMENTS

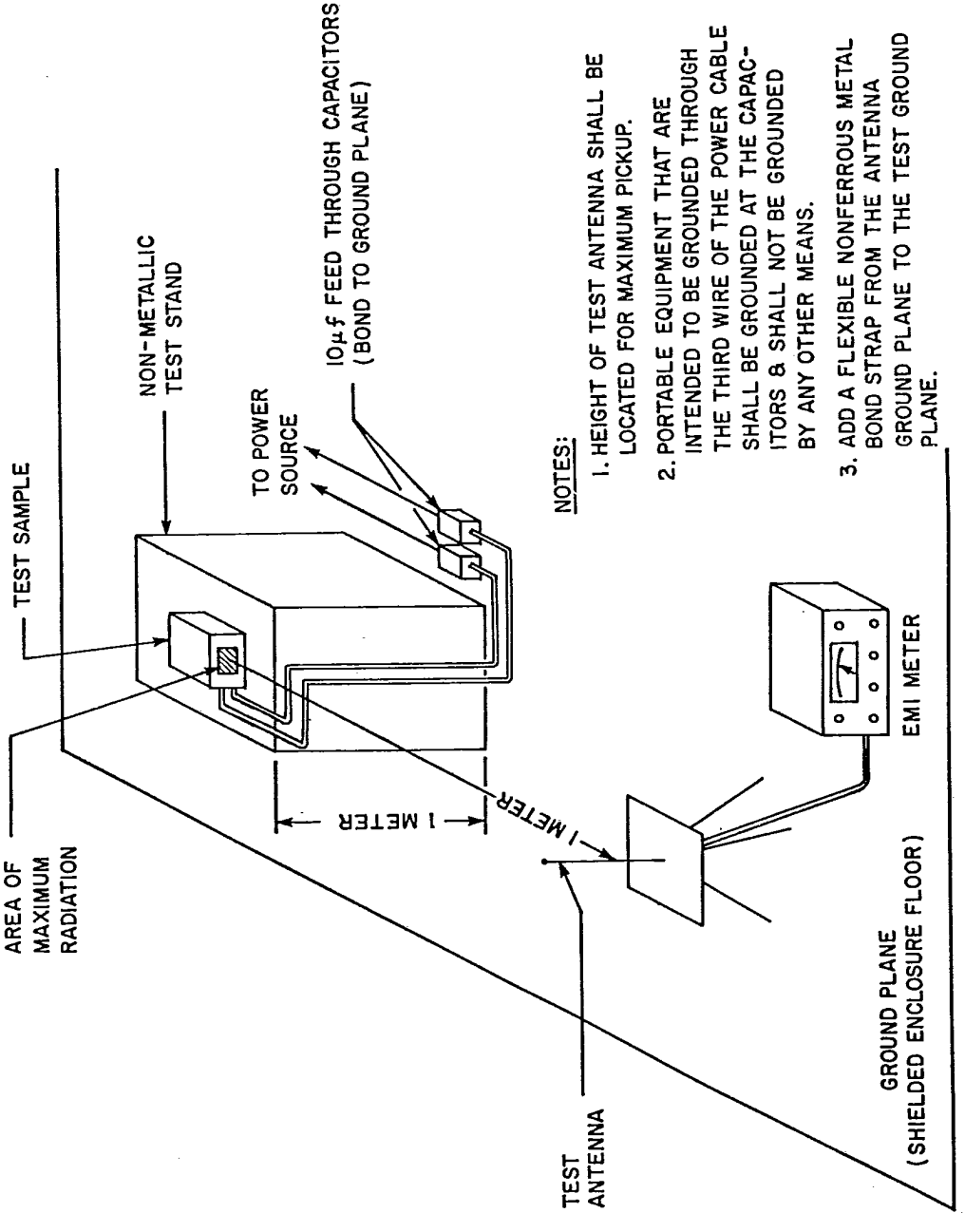


FIGURE RE02-2 — TYPICAL TEST SETUP FOR RADIATED MEASUREMENTS ON PORTABLE EQUIPMENT

Supersedes page 63/64 of 31 July 1967

METHOD RS03

RADIATED SUSCEPTIBILITY, 14 kHz to 10 GHz, ELECTRIC FIELD

* 1. Purpose.- This purpose of this test is to ensure that a test sample does not exhibit any degradation of performance, malfunction, or undesirable effects in the frequency range of 14 kHz to 10 GHz when immersed in an electric field. This method is also applicable for testing to the UM03 and UM04 radiated susceptibility requirements of MIL-STD-461.

2. Applicability.- This test method is applicable to Class I equipment (see MIL-STD-461).

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

(a) Signal source.
(b) EMI meter.
(c) Antennas (for receiving and transmitting specified Electric Field).
(d) Output Monitor - to monitor performance of test sample.

4. Test Setup and Procedures.-

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

4.2 Test signals shall be selected in accordance with MIL-STD-461.

4.3 Fields shall be generated, as required, with the antenna specified in MIL-STD-461. Care shall be taken so that the test equipment is not affected by the test signals.

4.4 The output of the signal generator shall be adjusted so the generated fields at the test sample correspond to the applicable limit. The specified field strengths shall be established by placing a field measuring antenna at the same distance, or relative location where the test sample will be placed. The power at the input terminals of the transmitting antenna required to establish the specified field shall be monitored and recorded. When a test is performed, this same power shall be applied to the transmitting antenna terminal. When baluns or other matching networks are used, any losses shall be properly compensated.

4.5 Determine those frequencies at which the test sample is susceptible. At these frequencies, determine the threshold of susceptibility. Record all pertinent data.

METHOD RS05

RADIATED SUSCEPTIBILITY, ELECTROMAGNETIC PULSE FIELD, TRANSIENT

1. Purpose.- This test method is used to determine equipment or subsystem susceptibility when immersed in a transient electromagnetic pulse field.

2. Applicability.- This test method is applicable for testing equipment and subsystems, as specified in MIL-STD-461 or the individual equipment specification. It does not address interconnecting cables which, when fully extended, exceed the usable volume of the test fixture. Such cables shall be protected with metallic conduit.

3. Apparatus.- The test apparatus shall consist of the following (See Table CS10-1).

(a) Parallel Plate Line with a characteristic impedance of 100 ohms ± 10 ohms.

(b) Transient Pulse Generator with the following characteristics:

(1)	Output	=	Peak voltage equal to E_o x h across 100 ohm load.
	E_o	=	Field strength in Volts/meter, as specified in MIL-STD-461.
	h	=	Separation of the parallel plates in meters.
(2)	Output Control	=	Adjustable from 20 to 100 percent of specified limit.
(3)	Rise Time	=	As specified in MIL-STD-461.
(4)	Pulse Duration	=	As specified in MIL-STD-461.
(5)	Fall Time	=	As specified in MIL-STD-461.
(6)	Pulse Repetition Rate	=	One pulse per second.

(c) Oscilloscope.- 200 MHz bandwidth minimum and 5 nanosecond per division minimum sweep rate.

(d) Load.- A 100 ohm low-inductive resistor, capable of handling the applied energy and voltage, as specified in MIL-STD-461.

(e) D-Dot Field Sensor.- with the following characteristics:

(1)	Frequency Response	=	150 MHz (3 dB point).
(2)	Rise Time	=	2.3 nsec (10-90%).
(3)	Maximum Output	=	5 kV.

(f) Balun.- A balun with the following characteristics shall be used whenever a balanced output D-Dot sensor is employed:

(1)	Frequency Response	=	20 kHz - 150 MHz 3 dB points.
(2)	Common Mode Rejection	=	40 dB up to 100 MHz.

(g) Integrator.- with time constant ≥ 1 μ sec. The oscilloscope input impedance shall comply with the integrator load requirements.

(h) Scope Camera.- As appropriate.

(i) LISN.- 5 μH Line Impedance Stabilization Network with coaxial connector terminated in 50 ohms.

4. Test Setup and Procedure.- The test shall be performed as specified herein:

(a) Set up the test sample as shown in Figure RS05-1.

(b) The transient generator output shall be calibrated as shown in Figure RS05-2 prior to the insertion of the test sample into the parallel plate line. The generator output level shall be adjusted so that the electric field corresponds to the applicable limit in MIL-STD-461.

(c) The equipment shall be tested, as a minimum, at three orientations: one where the front face of the upright equipment faces toward the front of the parallel plate and another where the front face is turned 90° towards the load or generator end. In the third orientation, the equipment shall be tilted downwards so that the top side is directed toward the front or back of the parallel plate. All test orientations (including alternative orientations) shall be described in the EMI Test Plan.

(d) A minimum of ten pulses shall be applied at each orientation and at all pertinent modes of operation of the test sample, as specified in the EMI Test Plan. The equipment shall also be tested in the power-off state.

(e) The equipment or subsystem and cables under test shall be grounded and connected as in the actual installation. Where possible such cables shall be 5 cm above ground (the bottom plate).

(f) Pulse repetition rate shall be no greater than one pulse per second and not less than one pulse per minute.

(g) The equipment shall be monitored to determine and record the E-field threshold level, operational mode, equipment orientation and time of occurrence (for logic circuitry) at which a failure or degradation occurred.

5.0 Notes.

5.1 Test sample instrumentation or termination box shall be grounded as installed in the operational system.

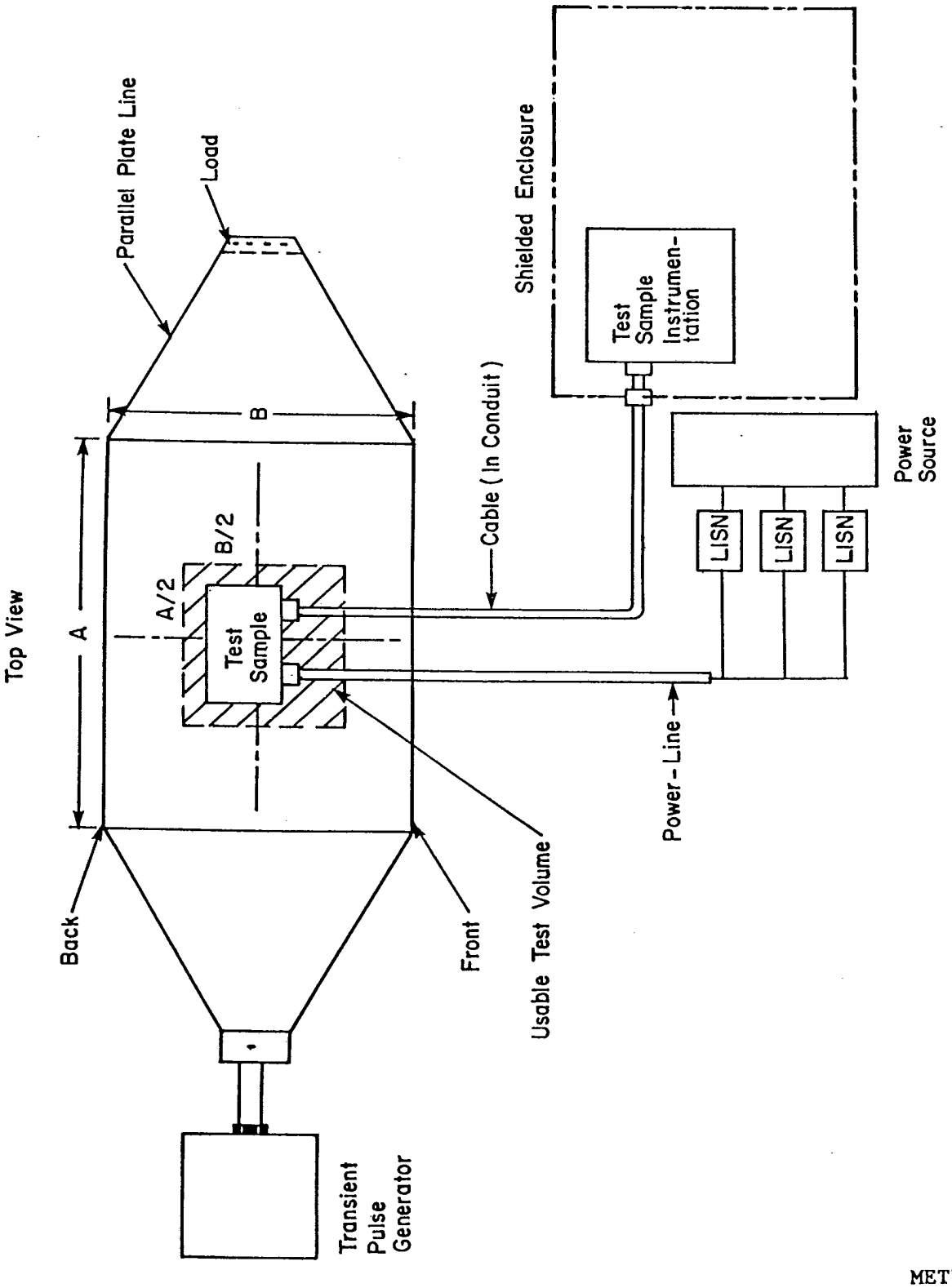
5.2 The clearance between the test sample, including its associated cables and conduits, and the upper plate shall be equal to, or greater than, half the spacing between the parallel plates. Examples of large bounded wave test radiators are shown in Figure RS05-3.

5.3 Care shall be taken to assure that the test sample instrumentation and the oscilloscope are not affected by a stray high intensity transient field. For example, cables may be placed in shielding conduit and test equipment in a shielded enclosure.

5.4 Other procedures may be used, such as a TEM cell radiators, upon approval of the procuring activity.

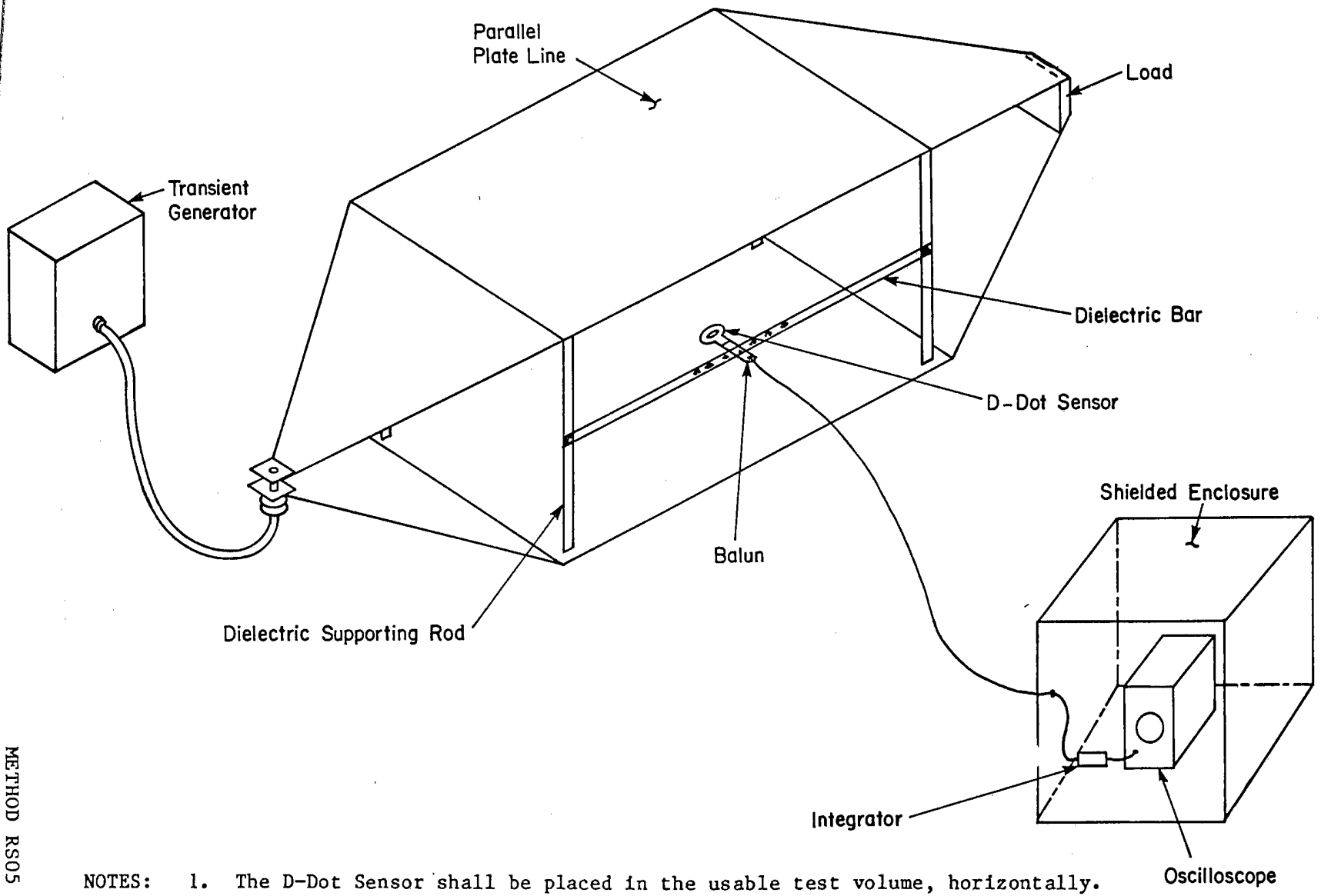
WARNING

- LETHAL LEVEL VOLTAGES ARE REQUIRED IN THE ABOVE TESTS.
- PROPER SAFETY PRECAUTIONS MUST BE IMPLEMENTED AT ALL TIMES.
- DO NOT TOUCH EXPOSED METAL SURFACES.
- THIS TEST MAY BE HAZARDOUS DUE TO THE UNGROUNDED CONDITION OF THE PARALLEL PLATE LINES.



RSO5-1 — TYPICAL RADIATED SUSCEPTIBILITY TEST SETUP

NOTES:
1. Voltage breakdowns shall be prevented between the test fixture and the test sample, including associated cables.
2. All cables to the test sample shall be in metallic conduit.
3. WARNING: See safety notice in test procedure.



NOTES: 1. The D-Dot Sensor shall be placed in the usable test volume, horizontally.

2. The sensor cable shall be triaxial cable, such as RG-214/U.

3. WARNING: See safety notice in test procedure.

FIGURE RS05-2 — TYPICAL CALIBRATION SETUP

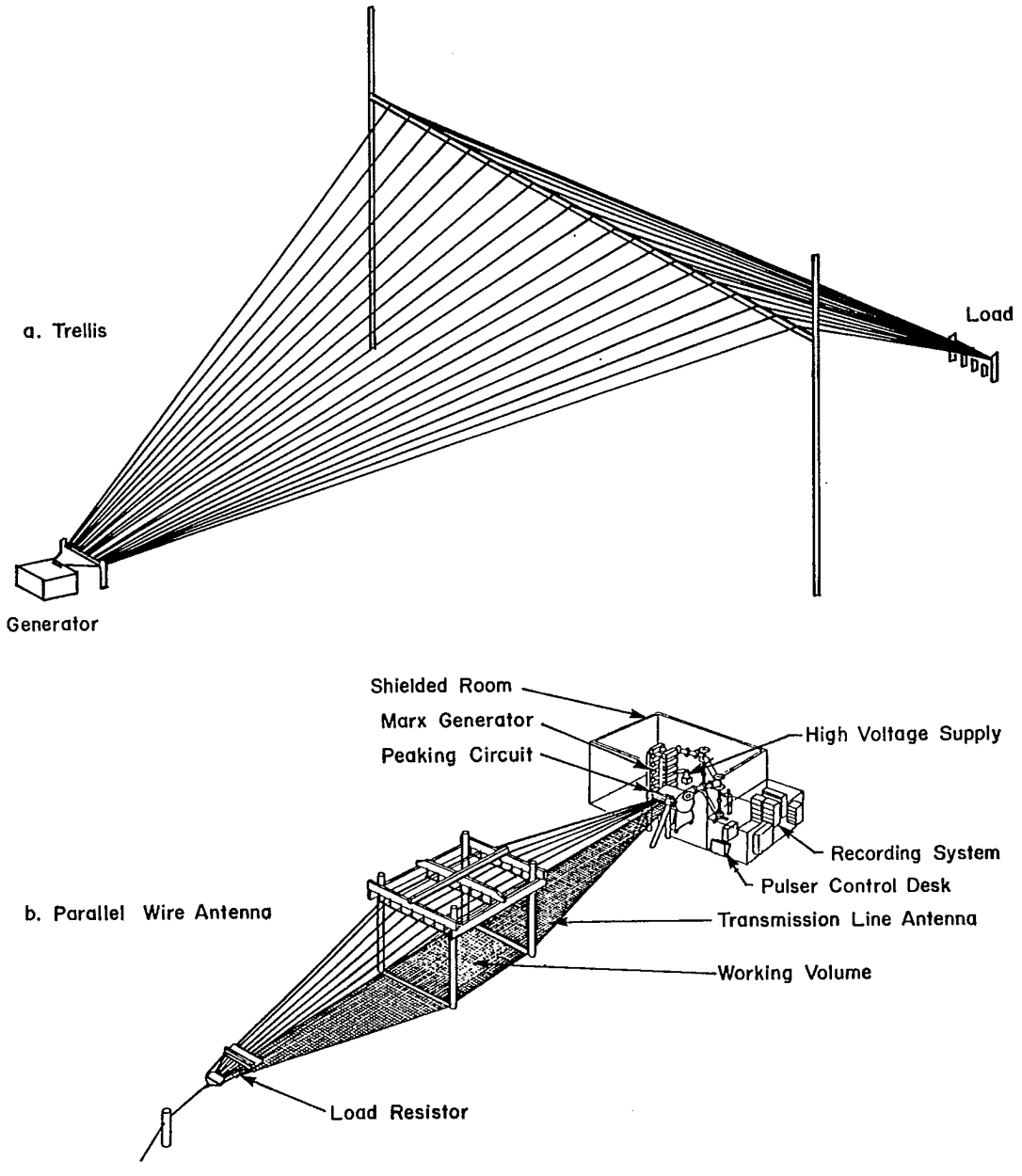


FIGURE RS05-3 — TWO TYPICAL PARALLEL PLATE LINES FOR TESTING OF LARGE EQUIPMENT

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