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14. ABSTRACT

This Test Operational Procedure (TOP) provides the Electromagnetic Environmental Effects (E3) interface requirements and verification criteria for airborne, sea, space, and ground systems, including associated ordnance, as stated in military standard (MIL-STD)-464A "Electromagnetic Environmental Effects Requirement for Systems", as well as ADS-37A-PRF "Aeronautical Design Standard for the Electromagnetic Environmental Effects (E3) Performance and Verification Requirements".

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Electrostatic Discharge	TEMPEST	High Power Microwave	

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US ARMY DEVELOPMENTAL TEST COMMAND
TEST OPERATIONS PROCEDURE

*Test Operations Procedure (TOP) 1-2-511 21 September 2009
DTIC AD No.

ELECTROMAGNETIC ENVIRONMENTAL EFFECTS SYSTEM TESTING

* This TOP supersedes TOP 1-2-511, dated 29 December 1989, TOP 1-2-512 Electromagnetic Compatibility Tests dated 15 May 1995 and TOP 6-2-560 Compatibility, Electromagnetic dates 12 October 1979.

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1. SCOPE.

This Test Operation Procedure (TOP) provides the Electromagnetic Environmental Effects (E3) interface requirements and verification criteria for airborne, sea, space, and ground systems, including associated ordnance, as stated in military standard (MIL-STD)-464 "Electromagnetic Environmental Effects Requirement for Systems" [1*], as well as ADS-37A-PRF "Aeronautical Design Standard for the Electromagnetic Environmental Effects (E3) Performance and Verification Requirements"[2] or the latest version of the documents as applicable.

1.1 Environments.

a. This TOP is applicable for complete systems and platforms, both new and modified, and applies to engineering development, production and sustainment phases of the system (e.g., E3 life-cycle programs such as hardness and sustainment assurance, and surveillance testing).

b. This TOP provides guidance for TEMPEST and test guidance for the addition of test procedures for implementing Electromagnetic Compatibility (EMC), Radiated Emissions (RE), receiver desensitization and electromagnetic (EM) noise on platforms, as well as the MIL-STD-2169B: " High Altitude Electromagnetic Pulse (HEMP) Environment"[3] and High Power Microwave (HPM). A test procedure for Grounds and Bonds is not addressed since it sufficiently discussed in MIL-STD-464. For Shielding Effectiveness reference "ASTM E1851-97, Standard Test Method for Electromagnetic Shielding Effectiveness of Durable Rigid Wall Relocatable Structures" for test procedures.

c. This procedure applies to all categories of materiel containing electronic, electrical, electro-mechanical , and electro-optical components to include Electrically Initiated Devices (EID) which may be exposed to electromagnetic environments (EMEs) of high-intensity radiated electromagnetic fields in the EM spectrum between 10 kilohertz (kHz) and 45 gigahertz (GHz), electrostatic discharge (ESD), and lightning effects (LE).

d. Each system tested is to be monitored for degraded performance or operation. This can be defined as a malfunction, degradation, or as an unacceptable system response. Since each specific system responds differently to the same test environment, the results from the test can only be applied to the specific system under test (SUT) configuration as tested. Therefore testing for each system configuration is required and warrants investigation.

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[*] Superscript numbers correspond to those in Appendix P, References.

e. The results of the tests conducted as outlined in this procedure will enable an evaluation to be made as to whether the system or platform tested meets the E3 requirements stated herein when subjected to the defined EMEs or conditions. In addition, these tests will enable a survivability assessment to the appropriate EMEs. Finally, these Tests outlined in this TOP will enable an evaluation of whether the system's/platform's operational performance and E3 requirements are met throughout the rated life-cycle of the system or platform.

f. The test methods with specific details for each of the specific electromagnetic environments are contained in Appendices A through N.

2. FACILITIES AND INSTRUMENTATION.

2.1 Facilities.

a. The facility must be capable of handling the test item in all of its configurations, from storage to prelaunch/operational and in-flight configurations as applicable; specifically stockpile to safe launch for ordnance items.

b. Fabrication facilities are required where instrumentation system(s) can be fabricated and installed in the test item in a manner that will not affect the electromagnetic radiation susceptibility characteristics of the tactical configuration of the test item, and that will protect the instrumentation from EME effects. Instrumentation should consist of sensing elements, transmitting units, and associated interconnections. The equipment required in the fabrication facilities includes such items as machine tools, micromanipulators, sheet metal fabricating tools, microscopes, Hazards of Electromagnetic Radiation to Ordnance (HERO) sensors, pneumatic switching, and those equipments associated with fiber optic technology.

c. Test facility examples can be seen in the applicable appendix for each test method.

d. Transmitters.

(1) Ideally, the entire system should be illuminated uniformly at full threat for the most credible demonstration of hardness. However, at many frequencies, test equipment does not exist to accomplish this task. Established test techniques are based on the size of the system compared to the wavelength of test frequency. At frequencies where the system is small compared to the wavelength of the illumination frequency [normally below 30 megahertz (MHz)], it is necessary to illuminate the entire system uniformly or to radiate the system such that appropriate electromagnetic stresses are developed within the system. Where illumination of the entire system is not practical, various aspects of the system's major physical dimensions should be illuminated to couple the radiated field to the system structure. At frequencies (normally above 400 MHz) where the size of the system is large compared to the wavelength, localized (spot) illumination is adequate to evaluate potential responses by illuminating specific apertures, cables and subsystems. 30 to 400 MHz is a transition region from one concept to the other where either technique may be appropriate, dependent upon the system and the environment simulator.

(2) For frequencies greater than 400 MHz, where the size of the test system is large compared to the wavelength, localized illuminations of specific apertures, cables and subsystems are permissible and recommended in evaluating potential responses. Typically, for a new system, 4 to 6 positions are used for low frequency illumination and 12 to 36 positions are used for spot illumination at higher frequencies. The emitters are radiated sequentially in both vertical and horizontal polarization. It usually is not practical to use circular and cross polarization. For an existing system which is undergoing retesting after installation of a new subsystem, 2 positions are normally used for low frequencies and 2 to 4 positions for high frequencies.

(3) For the situation where the external environment exceeds all available simulators or it is necessary to achieve whole system illumination, the method of bulk current testing may be used. The system can be illuminated from a distance to obtain near uniform illumination but at low levels. The induced current on the cable bundles from the uniform external field is measured. The induced current levels are then scaled to full current level based on the system's external environment. These extrapolated levels are compared to electromagnetic interference data on individual subsystems and equipment. If sufficient data is not available, cables can be driven at required levels on-board the system to evaluate the performance. The cable drive technique has been applied up to 400 MHz.

(4) The transmitter should be swept with fixed frequency steps (stepped frequency methodology), or dwell at selected discrete frequencies. No fewer than 100 discrete frequencies should be utilized for HERO testing. It is suggested that the recommended HERO test frequencies of Table H-3, Appendix H are utilized. For external RF EME testing it is suggested that no fewer than 275 discrete frequencies (utilizing the 100 suggested HERO frequencies) should be used based on test schedule. Inherent system frequencies should also be addressed for additional test frequency coverage. This will provide additional test frequencies in an effort to allow tailoring for a reasonable RS103 platform assessment. The need for testing below 1 MHz should be addressed with regard to magnetic fields and their affect on the item under test, as well as to the ¼ wavelength of the total system and the possibility of low frequency coupling.

(5) Pulsed Peak Power Transmitters must be capable of developing frequencies and field intensities sufficient for illuminating with regard to the field intensities shown in Tables 1A through 1F and 3A of MIL-STD-464A. Peak pulsed power testing should be conducted on all electronic performance tests of platforms from 10 kHz–45 GHz (should use test frequencies of Table B-3 above 1 GHz) to ensure possible EME coupling to digital and switching circuits are adequately addressed. Peak pulsed power testing should also be conducted on subsystems in accordance with (IAW) HERO, aviation and/or shipboard operations requirements.

(6) Sweep Transmitters. Sweep transmitters capable of generating a minimum of 10 percent of the criteria field intensities, shown in Tables 1A through 1F of MIL-STD-464A, can be used for determining resonant frequencies of the test item for full threat testing by the test transmitter requirements described in paragraph 2.1.d(3) above. For EME testing, sweep generators capable of generating the criteria fields are required. The use of sweep transmitters for EMR testing is limited to systems whose configurations are not continually changing as a function of time (nonoperational testing). Care should be taken to ensure that adequate sweep dwell times are considered when developing the system operations for assessment in order to capture potential anomalies.

(7) Modulations including continuous wave (CW), as well as several variations of amplitude, frequency and pulse modulation (AM, FM and PM); to include peak pulse are utilized in electromagnetic radiation testing to replicate those modulations encountered on the battlefield. It should be noted that AM, at a 1 kHz rate with a 50 percent duty cycle has been found to be a worst case modulation with regard to consistency and number of EME effects recorded. Should it be necessary, just AM at a 1 kHz rate with a 50 or 80 percent duty cycle can be utilized for most systems with confidence that the highest probability of EME induced effects will be captured. But, it is recommended that the modulations specified in MIL-HDBK-235 be utilized when possible.

(8) Vertical and horizontal polarizations will be used with all EME frequencies above 30 MHz while only vertical is necessary below 30 MHz (special consideration will be taken as specified in MIL-HDBK-235).

(9) Test Enclosure for Emissions Measurements. To prevent interaction between the SUT and the outside environment, shielded enclosures will usually be required for testing. These enclosures prevent external environment signals from contaminating emission measurements. The enclosures must be sufficiently large such that the SUT arrangement requirements and antenna positioning requirements of MIL-STD-461[4], as well as Appendices A and K for platform Intra system EMC and Appendix I for TEMPEST can be met.

2.2 Instrumentation.

The instrumentation specifics will be presented in the applicable appendix for each test method.

a. All Test equipment is calibrated regularly by calibration labs using procedures traceable to the NIST.

b. SUT instrumentation is permissible but it shall not influence test results. To minimize the possibility of instrumentation influencing test results or instrumentation susceptibility:

(1) Use fiber-optic based instrumentation whenever possible.

(2) Use twisted, shielded pair wiring when conductive leads are required.

(3) Instrumentation equipment and its leads should be buried inside the SUT with only the fiber optic leads exiting the SUT.

c. Safety Testing. When the SUT contains ordnance or safety critical circuits / functions [e.g., electrically initiated devices (EIDs) (previously called Electro-explosive Devices (EEDs) the SUT ordnance and safety critical circuits / functions shall meet their safety requirements during and after exposure to the electromagnetic environment. The following methods are routinely utilized on Army Materiel; additional guidance is provided in MIL-Hdbk 240 and the memorandum provided as a result of the Joint Service E3 Safety Testing Workshop held November 7-9 2007.

(1) There are two methods for testing EID safety which are described in detail in Section 3.6 (HERO Test Philosophy) of Army Technical Report TR-RD-TE-97-01, "Electromagnetic Environmental Effects Criteria and Guidelines for EMRH, EMRO, Lightning Effects, ESD, EMP, and EMI Testing of US Army Missile Systems"[5]. Electromagnetic Radiation Hazards (EMRH) is an antiquated term for HERO. The two methods for testing safety of SUT EIDs are:

(a) Instrumented, inert SUT testing: The SUT EIDs are replaced by inert versions (explosive material removed for personnel and SUT safety) that are instrumented to measure the currents, voltages, power, or energy induced at the EIDs during safety testing. The measured results are compared to the EID minimum no fire (MNF) parameter after the MNF parameter is reduced by the EID required safety margin. Note that the measurement results should be extrapolated if the test facility cannot produce the required test levels. The methods of instrumentation are shown below in Table 1.

(b) Go/No-Go SUT testing: The SUT EIDs are left intact in the SUT and are not instrumented. A large number of SUTs with their live EIDs are tested to the test level in order to obtain a meaningful statistical sample. If a large number of SUTs or EIDs are not available, a smaller number of SUTs are subjected to test levels that are raised by the required EID safety margin. This test method requires that multiple EIDs be tested in order to obtain a meaningful statistical sample. Testing is usually repeated a minimum of 10 times for ground systems and 22 times for airborne systems (statistically significant samples) with fresh EIDs each time to provide some measure of confidence that the EIDs will remain safe. This method is preferred for Joint Service E3 Testing as agreed upon by the Joint Service E3 Safety Testing Workshop held November 7-9 2007, with the exception of HERO testing.

Table 1 Instrumentation for E3 Safety Methodologies.

Test Methodology	E3 Ordnance Safety Test	Instrumentation	Comments
Instrumented EIDs -EIDs tested in SUT -CW E-field environment	HERO	-Field probes to determine environment -Thermal heating sensors (e.g., OPSENS, FISO or Metricor systems) used to detect bridgewire heating induced by field. -Fiber optics from sensor to monitor	-Small sensors that easily fit in SUT. -Can measure very small changes with appropriate sensitivity.
Instrumented EIDs -EIDs tested in SUT -Transient environment	PESD, HESD, NSL, DSL, EMP	-Field probes & discharge current probe used to determine environment -current probes on EID leads -Fiber optics from sensor to monitor	-Sensors not as small as those used for CW testing. -Much faster response than the CW testing –required for transients
Go/No-Go - EIDs tested stand-alone or in SUT - Either CW E-field or transient environment	HERO, PESD, HESD, NSL, DSL, EMP	-No instrumentation during test. -If not destroyed during test, live EID parameters measured pre- and post-test and compared.	-Used in PESD, HESD, NSL, DSL & EMP when specific EID data not required or statistical representation of items is available. - This method is preferred for Joint Service E3 Testing as agreed upon by the Joint Service E3 Safety Testing Workshop held November 7-9 2007.

Note: For exploding foil initiators (EFI) or low energy exploding foil initiators (LEFI) it is suggested that the firing capacitor voltage also be monitored in addition to the instrumented or live EID.

(2) Go/No-Go SUT testing is performed with the following concerns:

(a) The need for a large number of SUTs to test for a wide variety of test field conditions (e.g., different frequencies, waveforms, polarizations, orientations).

(b) A large number of SUTs may not be available.

(c) The chance of destruction of a large number of SUTs.

(d) High test levels required may not be obtainable (extrapolation is not an option without sensitive instrumentation.).

(e) Fully testing a large number of SUTs considerably increases test cost and schedule.

(f) Test personnel and test equipment safety.

d. EME and HERO Instrumentation

(1) Instrumentation and accuracies are required for the instrumentation methods and field intensity measurements associated with EM testing used to define the environment. Should it be necessary, real time measurement devices (as applicable) can be utilized for real time test item responses/operations to include firing circuit, ESAD, or additional firing pulse response, EFI firing capacitor voltage response, or similar measurements. The basic steps for incrementing ordnance for HERO tests are to minimize both the disturbance to the EM energy created by the instrumentation package and the coupling of the RF energy to the data channels. The instrumentation package should be small and internal to the ordnance item under test. Optical telemetry techniques may be used to reduce coupling of radio frequency (RF) energy into the signal leads. For example, no external hardwire connections and no changes to the EID circuit impedance are permitted unless the impact to the circuit can be quantified and documented. The instrumentation package itself should be mounted inside the ordnance item. Where power is required to operate the instrumentation it shall be provided internally through battery packs or air turbine power generators. The sensitivity of the entire instrumentation system should be taken into consideration from the sensor to the data acquisition system. For more detailed information see MIL-HDBK-240[6].

(2) The test item and each component requiring access for replacement and/or instrumentation should be studied and inspected to assure accessibility and durability. If these points are inaccessible, the test items or component must be modified to provide required accessibility. It may be necessary to have test items or components specially assembled by the original manufacturer to assure compatibility with test requirements. Great care must be taken to assure that any modifications or assembly techniques used to fabricate these special items do not jeopardize the electrical or shielding integrity of the test item, as well as the tactical electrical configuration of the test item.

(3) Data collection sources and recording devices such as personal computers are a necessity for facility operation as well as instrumentation documentation. Data stripline recorders are not recommended for testing beyond HERO instrumentation to indicate a change in induced current on a bridgewire. The instrumentation data collection and facility operation can utilize the same device, but it is not recommended due to the possible negative effect on the fidelity of both sets of data.

2.3 Measurement Tolerances.

Unless otherwise stated for a particular measurement, the following tolerances should be followed.

Item	Tolerance
Distance	±5 percent
Frequency	±2 percent
Amplitude, measurement receiver	±2 dB
Amplitude measurement system (includes measurement receivers, transducers, cables, and so forth)	±3 dB
Inert EID instrumentation	The measured voltage output of the thermocouple, vacuum thermocouple, or optical temperature sensor shall indicate, within ±2 percent, the actual EID stimulus.
Sensitivity	< 5 percent of the EID MNF current (MNFC) Applicable where MNFC is above 100 milliampere (mA).
Sensors/detectors	The measured output of the sensors/detectors shall indicate, within ±2 percent, the variable being measured.
Fiber optics data link	±5 percent of the measured variable
Current meter/monitor	±10 percent of actual discharge current
Magnetic field probe	±10 percent of the actual strike magnetic field
Field intensity probe	±2 dB of actual electric field
Waveform receiver	±5 percent of maximum peak discharge current
Field intensity meter	±2 dB of actual field intensity
Voltage meter/monitor	±10 percent of actual charge voltage
EID tester	±10 percent of the full-scale meter setting

3. REQUIRED TEST CONDITIONS.

3.1 Test Item.

Considerations prior to the start of the test include but are not limited to:

a. SUT description, components, manufacturer, part & serial number, etc., consider power source.

b. There are specific power requirements that are regularly utilized for shelters, or mobile systems. An onsite power source for these items may be necessary in order to test the system while utilizing all possible power sources. It is best to separate the system power source from the facility power source to preclude interference into the test setup.

c. System interfaces.

d. Description of built-in SUT electromagnetic hardening protection.

e. Test environments and limits.

f. Verification issues.

g. Pass/fail criteria, performance specifications, and margins required.

h. Test configurations and modes of operation and SUT control settings.

i. Peripheral equipment required (e.g., test fixture, test set, power supply).

j. Description of actions, outputs, or displays monitored.

k. Security/classification requirements for data/results.

l. EID electrical parameters data sheets for HERO calibration and data collection

When Built in Test Equipment (BITE) or other system status monitors are not used to observe test item performance, the test item will be instrumented using one of the methods outlined in section 2.2. The preferred operational performance method is to include operators as a part of the E3 test where applicable. These operators will run the system in the approved scenario and allow the test item to recover when an anomaly or susceptibility is encountered, or apply operator procedures for system recovery. At a minimum, there should be a method to stimulate the system in order to perform the operational functions.

3.2 Pre-test Evaluation.

A pre-test evaluation is performed to include the following. This evaluation is used for test planning and can often reduce the amount of testing required.

a. Determine test points as applicable.

b. Determine the primary current paths.

c. Determine the most/least susceptible SUT configurations.

d. Determine the most/least susceptible SUT modes of operation.

e. Determine the possible points of entry (POEs) for the electromagnetic energy.

f. Determine the bulk current measurement points.

g. Perform an energy coupling analysis to identify the type and capability requirements for the data acquisition system.

h. Determine critical SUT data required to be instrumented and monitored.

i. Determine which EIDs are to be instrumented and measured and how.

j. Determine SUT/platform critical functions and circuits.

k. Determine SUT EM protection features and their predicted performance and whether they are repairable or replaceable.

l. Determine verification and pass/fail criteria and required safety margins.

m. Determine the SUT operating and checkout procedures.

n. Pre-existing analyses and test data from previous tests may be evaluated and incorporated into the test planning and pretest analysis in order to enhance and reduce the scope of the new testing.

3.3 Personnel Exposure Policy and Guidance.

a. Permissible exposure levels (PEL). Care should be taken to ensure that when utilizing personnel in all phases of testing that the exposure limits are strictly enforced.

b. The specific limits used to protect personnel from hazardous EMEs from SUT emitters are those defined in:

(1) ANSI/IEEE C95.1-2005, "Institute of Electrical and Electronic Engineers, IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz"[7].is referenced for Permissible Exposure Levels. Tables 2 and 3 and Figure 1 (from Table 8 of C95.1-2005) is applicable to continuous personnel exposure in a controlled environment. A controlled environment is defined as an area in which personnel do not have un-controlled access and are aware that an EME is produced by the equipment. It is assumed that Army SUTs operate in a controlled environment and that personnel (e.g., Soldiers and EME test personnel) are aware of the EME. If this is not the case, refer to Table 9 of C95.1-2005 for the uncontrolled PEL limit tables. In addition, the PEL Tables in C95.1-2005 apply to continuous, whole-body exposure. If the exposure is intermittent or exposure of only part of the body is involved, refer to C95.1-2005 for tables and calculations that modify the C95.1-2005 PEL limit of Tables 8 and 9.

Table 2 C95.1-2005 Radiated PELs for Controlled Environments.

Electromagnetic Fields				
Frequency Range (MHz)	Electric Field Strength (E) (Vrms/m) (Note A)	Magnetic Field Strength (H) (Arms/m) (Note A)	Power Density (S) (E-field, H-field) (W/m2)	Averaging Time (Tavg) |E|2, |H|2 or S (minutes)
0.1–1.0	1842	16.3/fM	9000, 100000/fM2 (Note B)	6
1.0–30	1842/fM	16.3/fM	9000/fM2, 100000/fM2	6
30–100	61.4	16.3/fM	10, 100000/fM2	6
100–300	61.4	0.163	10	6
300–3000	-	-	fM/30	6
3000–30000	-	-	100	19.63/fG1.079
30000–300000	-	-	100	2.524/fG0.476

Note: fM is the frequency in MHz, fG is the frequency in GHz. Vrms is volts rms. Arms is Amps rms. /m is per meter. W/m^2 is watts per square meter.

Note A: Applicable for uniform exposures of the body. For non-uniform exposures, the mean values of the exposure fields, are obtained by spatially averaging the squares of the field strengths or averaging the power densities over an area equivalent to the cross section of the human body, or a smaller area depending on the frequency (refer to C95.1-2005)

Note B: These plane-wave equivalent power density values are commonly used as a convenient comparison with PELs at higher frequencies and are displayed on some instruments in use.

Table 3 C95.1-2005 Radiated PELs for Controlled Environments (Cont.).

Maximum Induced and Contact RF Body Currents					
Frequency Range (MHz)	Thru both feet (mArms)	Each foot (mArms)	Contact-Grasp (mArms)	Contact-Touch (mArms)	Averaging Time (Tavg)
.003–0.1	2000f	1000f	1000f	0.50f	0.2 seconds
0.1–110	200	100	100	50	6 or 30 minutes

Notes:

- f is in Hz.
- Assumes freestanding individual who is insulated from ground while touching a conductive path to ground.
- A grasp contact area is assumed to be 15 cm^2 & a touch contact area is assumed to be 1 cm^2.
- The .003 to 0.1 MHz range limits protect against electro-stimulation effects and the 0.1 to 110 MHz limits protect against tissue heating effects.

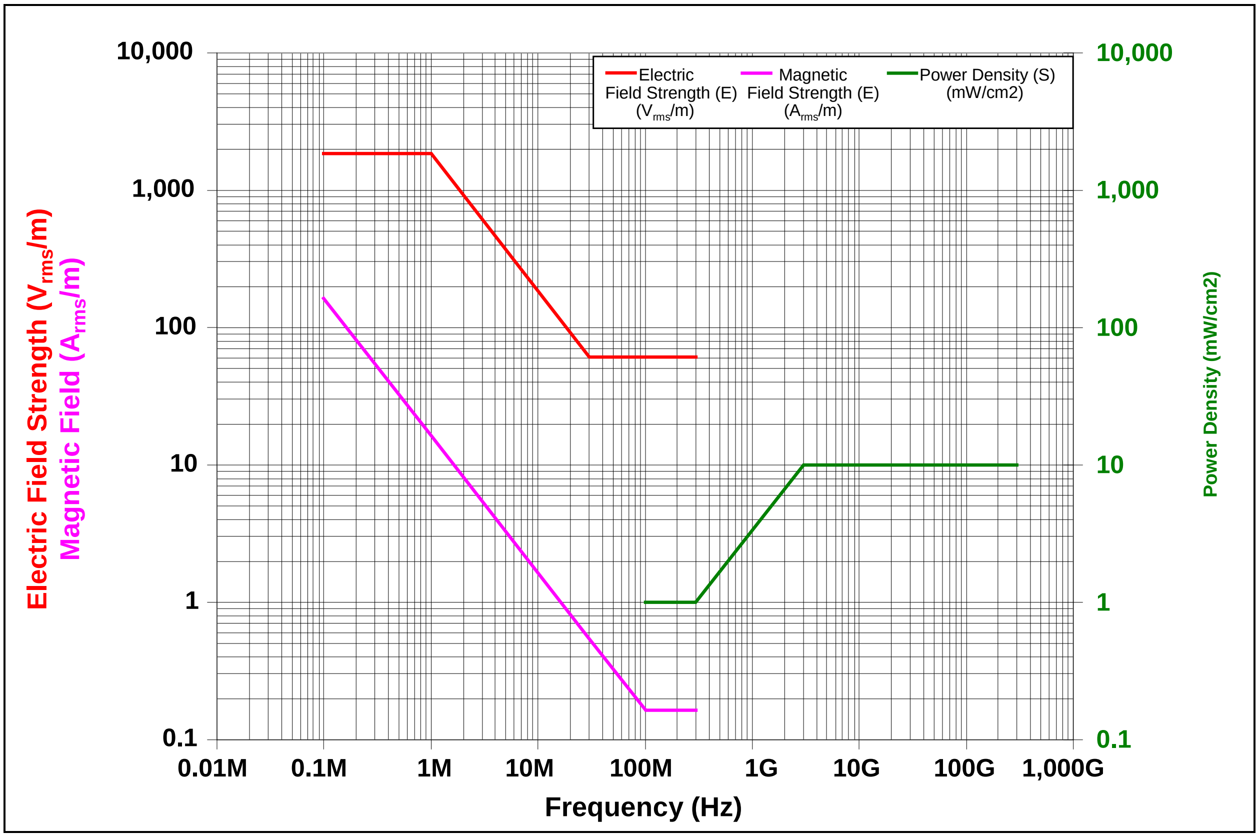


Figure 1. PELs based on ANSI/IEEE C95.1-2005 for Controlled Environments.

NOTE: When the field strength is equal to the PEL the exposure time is limited to 6 minutes or 360 seconds. This time decreases to 3.6 seconds for field strengths ten times the PEL, and conversely there is no time limit if the field strength is below the PEL.

3.4 Test Setup Calibration.

The test set up calibration specifics will be presented in the applicable Appendix of this TOP.

4. TEST PROCEDURES.

The test procedures for the appropriate environment are provided in Appendices A- N.

5. DATA REQUIRED.

Detailed test information includes but is not limited to:

a. Test plan/procedure including the following:

(1) SUT description, components, manufacturer, part & serial number, etc.

(2) SUT electrical schematics and interconnect diagrams.

(3) Description of built-in SUT electromagnetic hardening protection.

(4) Test objectives/reason for test.

(5) Test environments and limits.

(6) Test assumptions and limitations.

(7) Verification issues.

(8) Pass/fail criteria, performance specifications, and margins required.

(9) Test configurations and modes of operation and SUT control settings.

(10) Pre and post functional/operational check procedures.

(11) Peripheral equipment required (e.g., test fixture, test set, power supply).

(12) Description of actions, outputs, or displays monitored.

(13) Security/classification requirements for data/results.

b. Previous Data/Results.

(1) PESD test and/or analytical data to assist in selection of attachment points and to compare the results.

(2) Results of functional/operational and pre/posttest inspection checks.

(3) Results of each test run, test data sheets, plots and strip chart outputs.

(4) Results of calibration runs and calibration data sheets.

(5) Test log detailing chronological test events.

(6) Description of all anomalies, anomaly investigations, and results.

(7) TIRs.

(8) Changes/redlines to the test plan/procedure.

(9) Indications of compliance.

(10) Drawings and photographs of test setups and investigations.

(11) Data analysis results if performed during testing.

(12) Listing of test facility equipment used for each test along with the equipment manufacturer, model number, serial number, and calibration due date.

c. The data required for each applicable E3 test are listed in the related appendices.

6. PRESENTATION OF DATA.

Data to be collected shall be as follows:

a. List of subsystems that comprise the test item.

b. List of monitoring equipment used.

c. SUT details (e.g., hardware and operational description, model and serial numbers) as well as applicable specific EID parameters.

d. Drawings and/or photographs of test setups.

e. List all test and instrumentation equipment with applicable calibration data, calibration due dates, and transducer/cable factors used.

f. Include test instrumentation system checkout and pretest SUT checkout results (plots, graphs, data tables) used.

g. Test configurations/modes/operational procedures used.

h. Results (e.g., plots, graphs, data tables). Sample of data/results examples are shown in individual test methods. Note: Data should be reported at the level of accuracy of the test equipment.

6.1 Data Analysis.

a. Test data will be compared and evaluated against the criteria set forth in MIL-STD-464A, the SUT specification, and SUT test plan to determine if the SUT met the criteria. Deficiencies will be identified, and discussed in the test report.

b. The test data will be compared to the applicable criteria and the pre-event baseline measurements to determine the extent to which the test criteria are met and the effects of the test environment on the SUT. Pre-existing analyses and test data from previous tests may also be used as a comparison for the new test data. Test anomalies will be assessed to determine if they should be classified as SUT failures. Failures or degradation resulting in SUT performance outside specifications, will be addressed with regards to causes, test level at which they occurred, allowable downtime, and mission impact. The test system configuration will be evaluated against the expected production configuration and the differences documented. Corrective hardening and/or mitigation recommendations will be developed and documented. EID safety margins, as calculated below that could seriously impact mission performance or safety, should be discussed with regard to mission performance or outcome in the applicable test plan and report.

6.2 Safety Margins.

a. There are two classifications of EID situations, safety and reliability. When safety margins are necessary, IAW MIL-STD-464A, safety (hazardous) EIDs shall maintain a 16.5 dB safety factor below the Maximum No Fire value (MNF) (based on not exceeding 15 percent of the EID MNF) and reliability (nonhazardous) EIDs shall maintain a 6 dB safety factor below the MNF (based on not exceeding 50 percent of the MNF). See MIL-HDBK-240.

b. Safety margins are calculated using a number of equations depending on the test data obtained. HERO safety testing consists of testing EIDs, ESADs and other firing circuits. These may also be E3 safety tested as part of PESD, HESD, NSL, DSL, and HEMP testing. The following discusses the different sensors used and their resulting test data.

(1) The instrumentation sensor used for testing EIDs to a transient environment (PESD, HESD, NSL, DSL and HEMP) is a current probe (e.g., Nanofast or Pearson) EID specifications often specify a MNFC. However, this specification is a DC test value, not a transient test value and cannot be used to determine an accurate safety margin. Therefore, the current test data is integrated over time and then is divided by the resistance using the equation

$$E = \int {}^{I^2}\!/_{R}\, dt$$

to obtain the energy. Often, the MNFE to use to calculate the safety margin is also not available. When empirical maximum no fire energy (MNFE) for a specific, qualified, one-ohm, one-amp, one-watt no-fire EID is lacking, the Army may use a level of 17.6 millijoules (mJ) based on previous testing of a series of Stinger launch/flight motor EIDs when approved by the Army procuring authority and system evaluator.

(2) The instrumentation sensor used for testing ESADs to a transient environment (PESD, HESD, NSL, DSL, and HEMP) is a voltage probe (e.g., Nanofast or Pearson) across a voltage divider network. Again, the ESAD maximum fire voltage (MFV) of the ESAD firing capacitor may not be available. Most firing capacitor MFV are in the 1000 to 2000 volt range. MIL-STD-1316[8] 1316E Fuze Design, Safety Criteria for Fuze components, specifies a minimum firing voltage of 500 volts for an ESAD. This conservative value is typically used when the MFV is not known. In addition, many ESADs often are coupled with a mechanical safe and arm device (SAD) which further increases overall safety. The mechanical SAD is usually locked into the Arm position during E3 safety testing in order to test the ESAD in its worst case configuration (and which is usually necessary to obtain access to the ESAD electrical leads).

(3) The instrumentation sensor used for testing EIDs to the HERO CW environment is a relatively fast acting fiber optic sensor (e.g., OPSENS, FISO or Metricor) that is placed directly against the EID bridgewire to measure the heating induced in the bridgewire by the test environment which is, in turn, directly relatable to the current induced in the bridgewire.

c. Safety margins are calculated depending on the type of data measured which was discussed above. The safety margin calculations corresponding to the data measured are as follows:

(1) For transient testing, the current is measured but is converted, as described above, to energy. The following safety margin equation is used.

ENERGY SM (dB) = 10 log 10 (EMNF/E Induced)

where: EMNF = Max No-Fire energy of EID. Typically 17.6.milli-Joules

E Induced = measured energy induced in the EID circuit (J)

Note*:* If the induced current in the EID or firing circuit is below what can be measured by the instrumentation, minimum detectable current (MDC) is used for a conservative safety margin.

Previous test programs have used 17.6 mJ as the MNFE for safety margin calculations for MIL-DTL-23659[9] Detailed Specification, Initiators, Electric, General Design specification for qualified, one watt, no-fire initiators. The MNFE value was established during testing of a series of Stinger Launch/Flight motor EIDs. The EID testing evaluated 72 initiators tested with a one amp per millisecond current ramp. The data was used to derive the MNFE and is documented in technical document “RD-TE-87-4, MLRS AT2 Lightning Test Report”[10].

(2) For a regular firing circuit (e.g., a gun firing trigger safety circuit), induced current is usually measured and used to calculate the safety margin with the known required firing current. If the true transient MNFE is known for an EID, the EID current is used to calculate the safety margin as follows.

CURRENT: SM (dB) = 20 log 10 (IMNF/I Induced)

where: IMNF = Maximum No-Fire current of EID (A)

I Induced = measured value for the induced EID current (A)

(or Minimum Discernable Current, MDC, if signal below MDC)

(3) For ESADs and other capacitive firing circuits, induced voltage is measured (often using a voltage divider as the typical firing voltage is in the 1000 to 2000 volt range) and used to calculate the safety margin. If the true MFV is not known, MIL-STD-1316 specifies a minimum firing voltage of 500 volts for an ESAD and this conservative value is used. Note that if the induced voltage at the ESAD firing capacitor or firing circuit is below what can be measured by the instrumentation, the MDV is used for a conservative safety margin.

VOLTAGE: SM(dB) = 20 log 10 (MFV/V Induced)

where: MFV = ESAD capacitor Minimum Firing Voltage (MFV)
(Often 500 Volts[2])
V Induced = measured value for the induced ESAD capacitor firing voltage
(or minimum discernable voltage (MDV) if signal below MDV).

Note: MIL-STD-1316 requirement for minimum firing voltage = 500 volts. Most initiators have minimum firing voltages in the 1000 to 2000 volt range. This should only be utilized when an instrumented safety factor is required, and the methodology is agreed upon by the system Army E3 Board.

APPENDIX A. INTRA SYSTEM ELECTROMAGNETIC COMPATIBILITY - RECEIVER DESENSITIZATION.

1. APPLICABILITY.

a. This method is applicable to receiver systems that are installed on a platform.

b. Receiver Desensitization Limit.

No specific limits. The evaluation will be based on each receiver under test and its operational parameters.

2. REQUIREMENTS.

3. PURPOSE.

The purpose of the desensitization evaluation is to determine the extent to which each of the platform's receiver's performance is being degraded as a result of electromagnetic noise from the platform and installed systems. Several techniques have to be employed depending on the type of modulation and baseband of the transceiver system.

4. TEST SETUP.

4.1 Test Equipment.

a. Spectrum Analyzer (SA) with tracking generator

b. Data recording device

c. Pre-amplifier (amp)

d. Directional coupler

e. 50Ω termination

f. Baseband stimulation device

g. Antenna system (2)

h. Transmitter compatible with SUT.

The test setup shall be as follows:

i. SUT should be located in electromagnetically quiet area.

4.2 Calibration.

a. Configure the test setup and perform a measurement system check and reference level as shown in Figure A-1.

b. Configure the test setup as shown in Figure A-2. Sweep through the frequency range of the receiver under test with the level in (1) above and record the gain through the preamp.

c. Replace the preamp with the cables used for testing.

d. Configure the test setup as shown in Figure A-3. Sweep through the frequency range of the receiver under test with the level in (1) above and record the cable losses.

e. Configure the test setup as shown in Figure A-4. Sweep through the frequency range of the receiver under test and record the forward power. Sweep though the same range and record the reverse power (see Figure A-5). Ensure the unused port is terminated in 50 Ω's.

f. Ensure that test instrumentation is located far enough away not to add to the SUT EM noise environment.

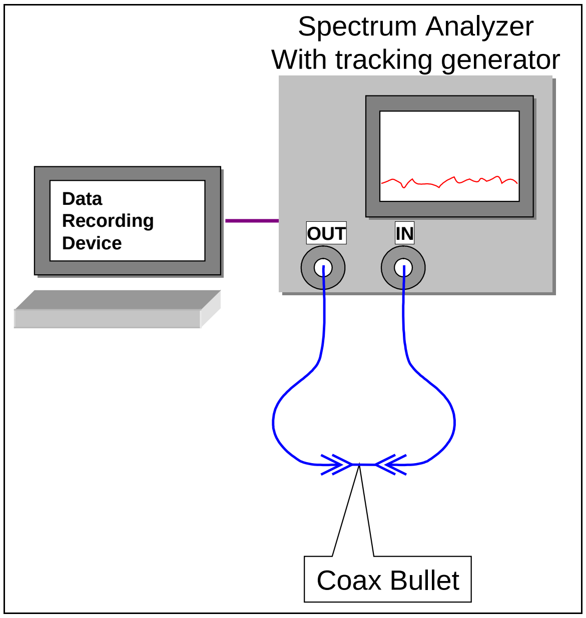


Figure A-1. Receiver Check Test Setup.

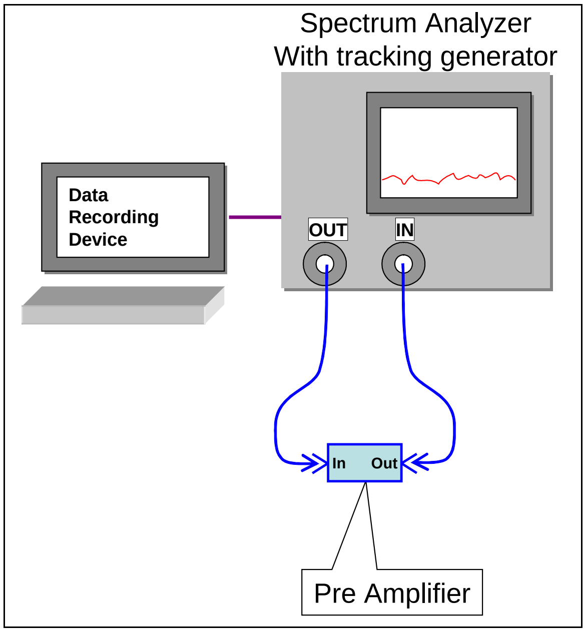


Figure A-2. Preamplifier Check and Gain Test Setup.

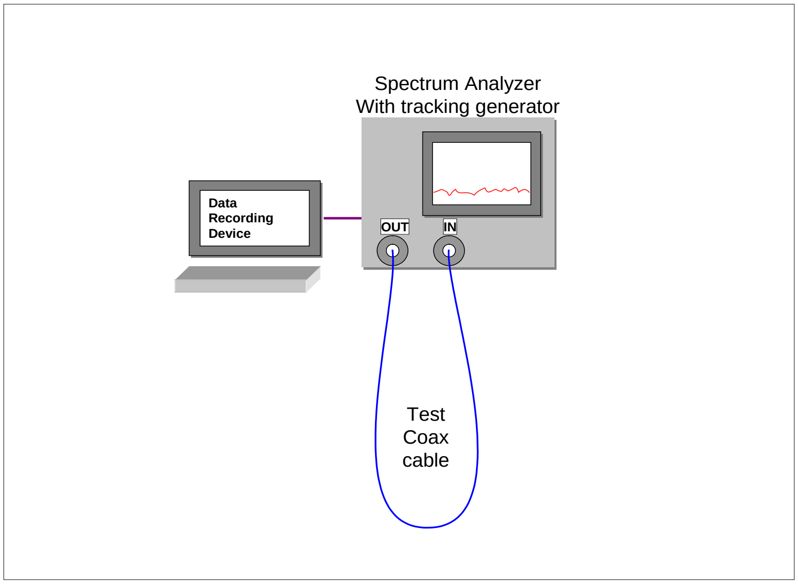


Figure A-3. Cable Loss Test Setup.

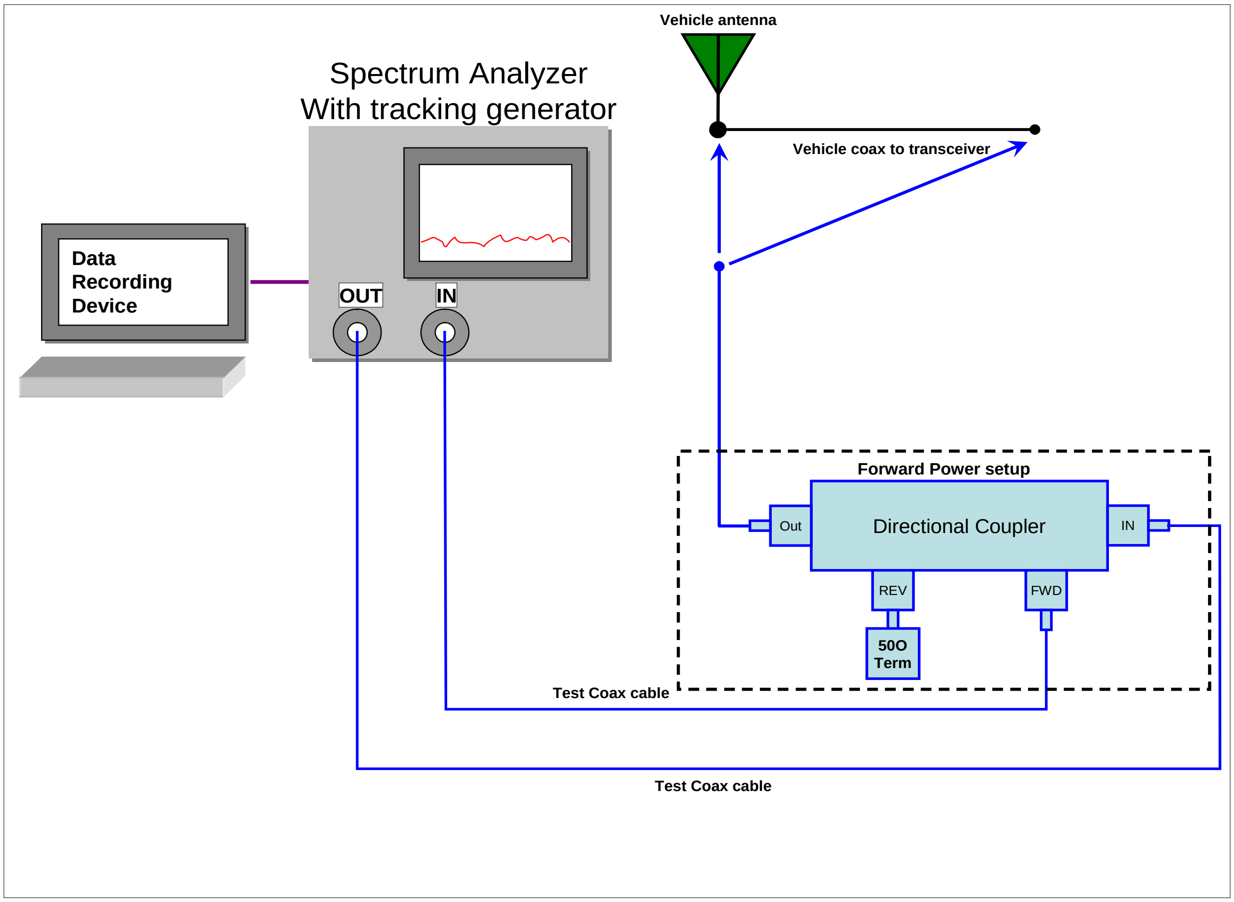


Figure A-4. Forward Power Test Setup.

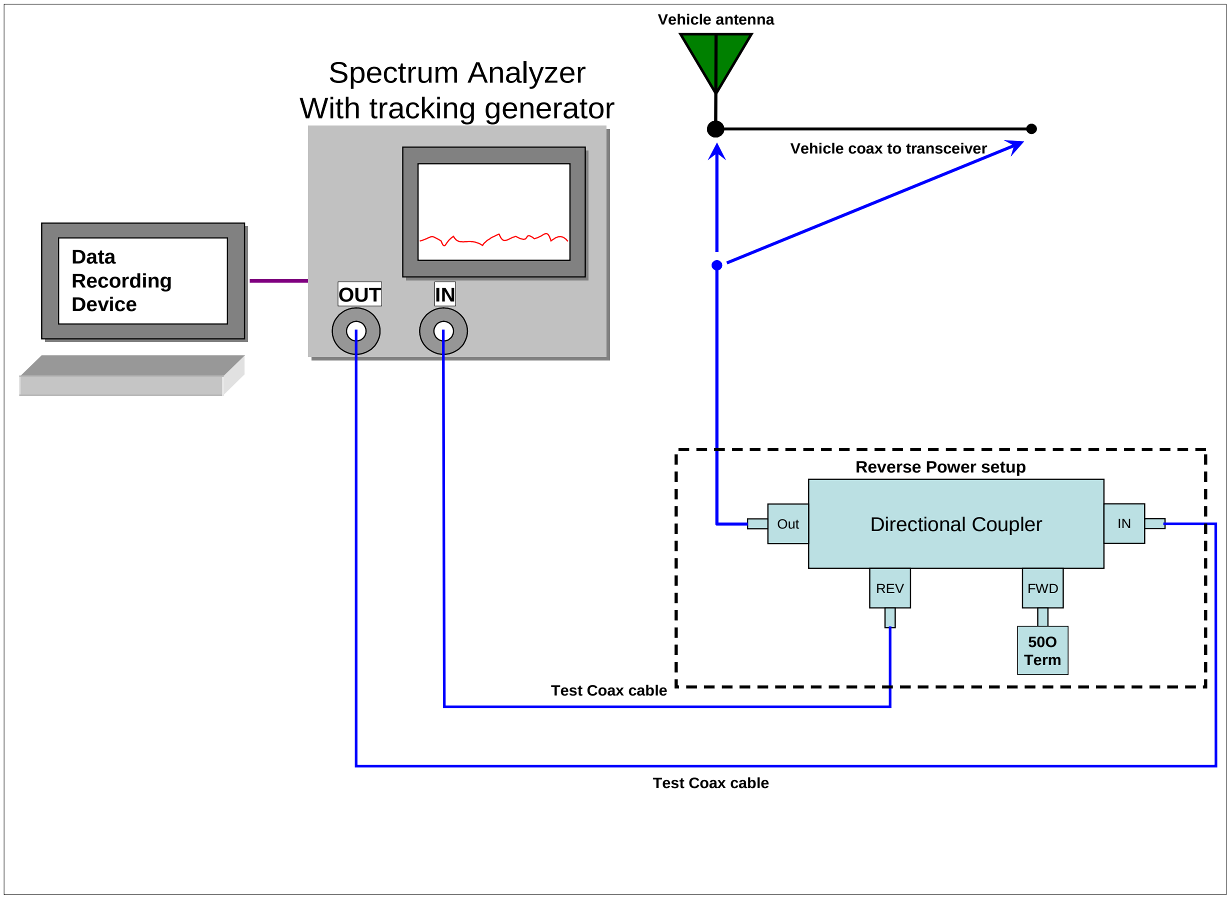


Figure A-5. Reverse Power Test setup.

5. TEST PROCEDURES.

5.1 SUT testing.

a. Configure the test setup as shown in Figure A-6. With all systems off, establish the reference parameter related to the particular baseband of the receiver SUT.

b. Configure the test monitor as shown in Figure A-6 away from the test setup and the SUT.

c. Turn on measurement equipment and allow sufficient time for stabilization.

5.2 Calibration.

Evaluate the overall measurement system from the tracking generator to the SA.

a. Sweep through the frequency range of the receiver under test. Verify the levels out of the tracking generator match what is being displayed on the SA (see Figure A-1).

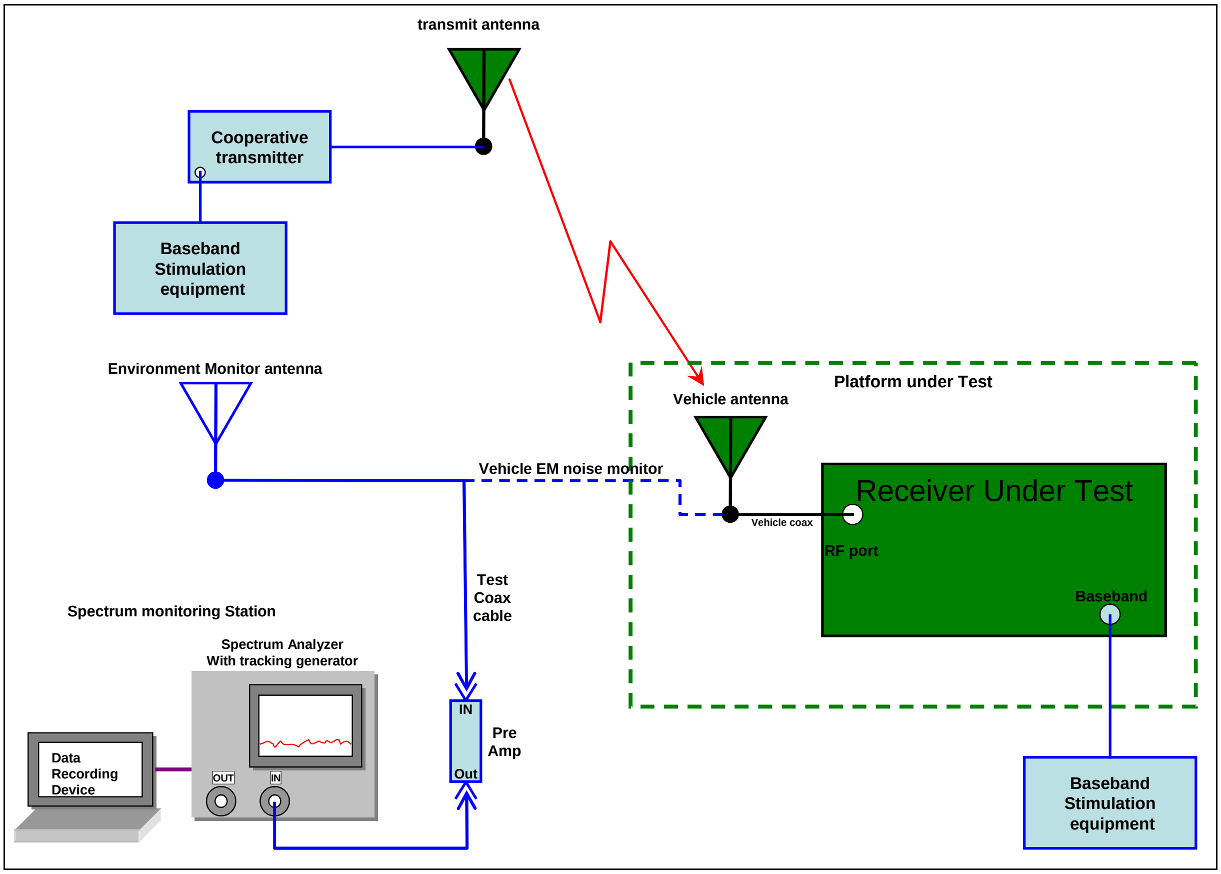


Figure A-6. Setup for Desensitization and Spectrum Monitoring.

b. Sweep through the frequency range of the receiver under test. Record the gain of the preamplifier as a function of frequency (see Figure A-2).

c. Sweep through the frequency range of the receiver under test and record the loss through the test cables as a function of frequency (see Figure A-3).

d. Sweep through the frequency range of the receiver under test and record the forward power as a function of frequency (see Figure A-4). Sweep though the same range and record the reverse power as a function of frequency (see Figure A-5). Insure that the unused port is terminated in 50 Ω's. Calculate the VSWR versus frequency using the following equation.

$$VSWR = \frac{\left(1 + \sqrt{\left(\frac{1}{10^{\left(\frac{\left(P_{forward}\,dBm - P_{reverse}\,dBm\right)}{10}\right)}}\right)}\right)}{\left(1 - \sqrt{\left(\frac{1}{10^{\left(\frac{\left(P_{forward}\,dBm - P_{reverse}\,dBm\right)}{10}\right)}}\right)}\right)}$$

5.3 SUT Testing.

Determine the desensitization of the receiver to the platform EM noise.

a. From the monitor antenna observe the environmental ambient to ensure no major EM noise sources are present (see Figure A-6).

b. From the antenna of the receiver under test measure the EM spectrum and record the spectrum (see Figure A-6).

c. All Off. Turn on the receiver under test and allow sufficient time for stabilization. Leave the platform and all other system off. This will require operation of the receiver under test on battery power or other external to vehicle means.

d. Establish a link with the transmitter.

e. Adjust the transmitter level so that receive signal at the receiver under test is close to the noise level of the "all off" operating environment. Establish a baseband reference and record this reference the corresponding power level of the distant end transmitter for this ambient state. See examples below:

5.4 Examples.

a. All On. Install the receiver under test back into the platform. Turn on the platform and all systems and allow them to stabilize.

b. From the antenna of the receiver under test measure the EM spectrum and record the spectrum.

c. Reconnect the receiver under test.

d. Re-establish the baseband reference parameter determined above by increasing the distant end transmitter level. Record the baseband parameter and corresponding power levels.

The difference between the all on and all off (ambient) conditions, in dB, is the desensitization of the receiver.

e. During the above process, the EM environment should be monitored via the remote monitoring antenna to ensure the environmental ambient remains somewhat constant.

f. Cease transmitting.

g. Examples.

For VHF single channel FM transceiver requires that a distant variable transmitter be set up with the appropriate FM deviation and modulated by a 1 kHz signal. At the receiver voice output a distortion analyzer is connected and the Signal, Noise, and Distortion (SINAD) on the 1 kHz signal is measured and set to obtain a 10 dB SINAD.

For SINCGARS 16Kbps data link having an 8% Bit Error Rate (BER) will be established from a nearby transmitter to a receiver that is installed in the platform.

For EPLRS establish a link and evaluate speed of service and message completion rate utilizing the lower tactical internet computer system as a stimulation source.

h. All On. Install the receiver under test back into the platform. Turn on the platform and all systems and allow them to stabilize.

i. From the antenna of the receiver under test measure the EM spectrum and record the spectrum.

j. Reconnect the receiver under test.

k. Reestablish the baseband reference parameter determined above by increasing the distant end transmitter level. Record the baseband parameter and corresponding power levels. The difference between the all on and all off (ambient) conditions, in dB, is the desensitization of the receiver.

l. During the above process, the EM environment should be monitored via the remote monitoring antenna to ensure the environmental ambient remains somewhat constant.

m. Cease transmitting.

n. Apply corrections for cable loss, amplifier gain and any other losses/gains that are required and record the corrected values.

o. Repeat a. and n. above for various combinations of equipment.

6. DATA PRESENTATION.

a. Manufacturer and serial numbers (SNs) of SUTs and test dates.

b. Model, SN, and calibration dates of the test equipment.

c. Results of operational verifications

d. List of all test equipment, including model, SN, and calibration dates

e. Results and photographs (if necessary) of physical inspections

f. Test configuration parameters.

g. Baseband stimulation technique and critical parameters used for each transceiver system.

h. Ambient "state” baseline and all "state" baseband numbers and power levels.

i. Data from the desensitization testing will be tabulated and presented as a table of desensitization in dB organized by victim radio and platform RF environmental state resulting from combinations of powered equipment.

7. DATA ANALYSIS.

a. The data tables will be analyzed as to the effects of hosting and integration of the C4ISR communications equipment into the platform to determine if the effective communication range has been reduced and the applicable criteria have been met.

b. A review of all pertinent data, all off ambient EM environment data/graphs, desensitization test data, modulation consideration and reasonable engineering judgment should be under taken to determine receiver degradation and impacts based on the link performance and reduction in range.

c. A simple GO / NO-GO test is not acceptable. The data should be analyzed to determine the range reduction impact of the platform EM environment. Figure A-7 shows examples of a testing matrix and graphs that are required to adequately determine receiver degradation and affect on the system.

Vehicle ---VSWR --- Noisefloor --- Desensitization

System	Vehicle	Bumper #	Location
M2A3	CDR	HQ-45	ATC

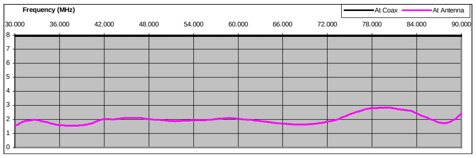
Date				
6-Jan-05				

System A	Radio	Antenna	RFPA	VAA/INC
Type	RT 1523 E	AS 3900	AM 7238	INC
Ser No				

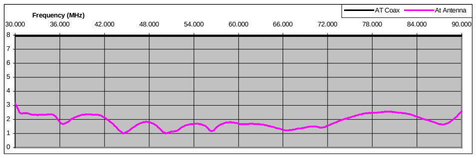
System B	Radio	Antenna	RFPA	VAA/INC
Type	RT 1523 E	AS 3900	N/A	INC
Ser No				

Other Systems	OTC Video	MILES XXI		

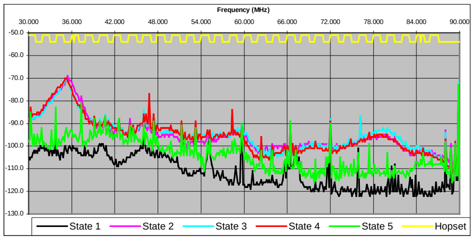
System A VSWR



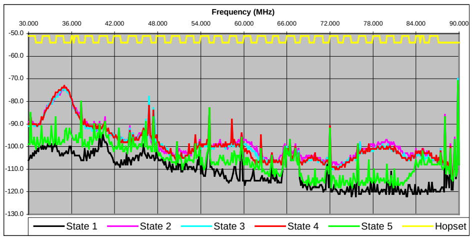
System B VSWR

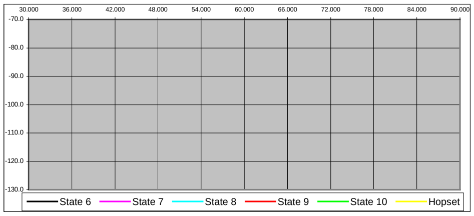


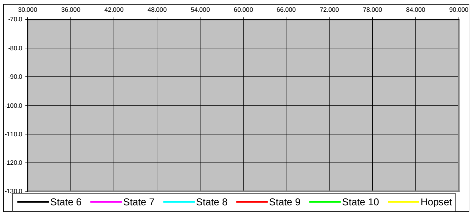
System A Noise Floor



System B Noise Floor







System A					System B		
BER	Atten (dB)	DESENS (dB)	STATE		DESENS	Atten (dB)	BER
8.07E-02	81		**Test State 1:**	**All equipment off**		84	8.33E-02
8.01E-02	62	19	**Test State 2:**	Vehicle, OTC pallet, ADMAS, and Miles XXI On	16	68	7.89E-02
7.93E-02	63	18	**Test State 3:**	Vehicle, OTC pallet, and ADMAS On	16	68	7.76E-02
7.98E-02	63	18	**Test State 4:**	Vehicle and ADMAS On	15	69	7.80E-02
7.95E-02	71	10	**Test State 5:**	Vehicle Instrumentation Only	7	77	8.02E-02
			Test State 6:				
			Test State 7:				
			Test State 8:				
			Test State 9:				
			Test State 10:				

Notes regarding SINCGARS system A	Notes regarding SINCGARS system B
Antenna is lacated on the Roadside Rear	Antenna is located on the Curbside Rear

Notes regarding entire vehicle
Turret position is Forward (zero deg. Azmuth)

Figure A-7. Example SINCGARS Desensitization Data Sheet.

APPENDIX B. EXTERNAL RF ELECTROMAGNETIC ENVIRONMENT (EME).

1. APPLICABILITY.

a. This test method is applicable to equipment at the system level in accordance with the equipment specification and MIL-STD-464. This methodology can also be tailored for MIL-STD-461 RS103 use on a system/platform, as well as ADS- 37- PRF as specified in those documents. To assess the operational survivability and identify susceptibilities to the SUT when exposed to its tactical operational Electromagnetic Environment (EME). This Appendix is meant to act as a guide and is not a replacement for a test plan. Compliance shall be verified by system-level test, analysis, or a combination thereof.

b. To determine whether the system's operational performance requirements are met when subjected to the specified external EME.

c. This subtest demonstrates survivability and compatibility of the SUT to EME from like systems, and external transmitters both hostile and non-hostile.

2. REQUIREMENTS.

a. The SUT shall be survivable and electromagnetically compatible when exposed to the specified external operational EM fields. The EM fields utilized in the external RF EME testing are derived from MIL-STD-461 (RS103) [SUT, line replaceable unit (LRU), and Shop Replaceable Unit (SRU) level] and MIL-STD-464 (platform/system performance), as well as ADS-37-PRF. It is recommended that the modulations specified in MIL-HDBK-235 be utilized.

b. Ideally, the entire system should be illuminated uniformly at full threat for the most credible demonstration of hardness. Since the SUT under External RF EME test is evaluated as a victim of interference from the EME, operational modes of the SUT equipment and components are of great consequence in the assessment; therefore, the SUT will be tested while operationally manned, or with every mission essential function exercised.

c. The systems must operate and meet mission requirements after introduction of the EME.

3. PURPOSE.

The purpose of this test procedure is to verify the ability of the system to operate without degradation when exposed to the specified External RF EME.

4. TEST SET UP.

4.1 Test Equipment.

Table B-1 is a listing of typical equipment used: Test equipment bandwidth should encompass in some cases 10 kHz to 45GHz. The electromagnetic environment transmitter source (amplifier, signal generator, power meter and power sensor) with the ability to deliver the required field. See MIL-STD-461, RS103 and MIL-STD-464 External RF EME tables.

a. Unless otherwise stated, test equipment tolerances shall meet the minimums specified in Section 2.3 of the main body of this document.

b. Test equipment software used shall be documented as to dates, developer, version number, etc.

c. RF hardened instrumentation to monitor electrical circuit and electronic functionality that does not degrade system performance and utilizes fiber optic transmission lines.

Table B-1. External RF EME Typical Test Equipment List.

Hardware	**Comments**
EME Simulator	Electromagnetic environment continuous wave transmitter source (amplifier, signal generator)
EME Simulator	Electromagnetic environment peak transmitter source (amplifier/magnetron, signal generator)
E and H Field Probes or Sensors	Probes required for calibration and real time field monitoring
Various Antenna	Used to radiate the electromagnetic environment dependent on frequency and power delivery.
Various Transmission Media	Used to deliver the electromagnetic environment to the antenna. Transmission line, waveguide and cabling dependent on frequency and power delivery.
Portable Computer	For integration and control of the electromagnetic simulator

4.1.2 SUT instrumentation is permissible, if the system's performance can be adequately verified but it shall not influence test results. SUT instrumentation may include the following:

a. Cameras connected to monitors using fiber optic lines. The cameras may be placed within shielded enclosures or care taken to preclude electromagnetic interference.

b. Test sets may be used to check out the SUT before and after each test event or may be required to operate and monitor the SUT during testing. If required during testing, test sets should be protected from the test environment and placed as far away from the source to target as possible. Any test set interface cabling should be well shielded and run to minimize coupling.

4.2 Pre-Test Evaluation.

a. Prior to the start of the test, the operators shall verify that all personnel are aware of the safety aspects associated with radiated fields and that all personnel have been briefed on this subject. The Permissible Exposure Limits (PEL) of DOD 6055.11 will be strictly adhered to during the test.

b. A pre-test evaluation will be performed to determine the primary current paths, ports of entry, test orientations and configurations, as well as the overall test conditions for the SUT.

c. The SUT status should be verified and documented before testing, using baseline self-test checks, system operational performance checks, and functional performance measures.

d. The pretest analysis should also address the system inherent frequencies. These should include at a minimum; the system frequencies of transmission as well as associated modulation parameters, frequencies associated with data rates, computer processors and generator power.

4.3 Setup.

a. Figure B-1 depicts a typical EME transmission and antenna equipment block diagram for External RF EME testing.

(1) The RF EME transmission test facility is calibrated at a distance from the facility antenna to determine the power required to achieve the specified field strength. This measurement is a free field calibration. During the environmental illumination, the field strength is monitored at the specified mapping point (distance and height above ground). The antenna placement will be no lower than 1.5 - 2 meters above ground. The Source-To-Target (STT) distance from the test item will vary dependant on the frequency range, radiating antenna and SUT and should be measured from the nearest conducting surface of the SUT. This minimum distance shall be 1 meter. A real time field calibration measurement can be made if the SUT fits within a 2 meter test volume.

(2) All EME illuminations will be IAW the test guidelines of MIL-STD-464 and can be tailored for MIL-STD-461 IAW that document with the Army E3 board approval.

(3) When the SUT is instrumented. Care must be taken to ensure that the installation of the data acquisition system, especially instrumentation to include power does not compromise or reduce the inherent shielding of the SUT. Fiber should be used where ever possible.

(4) When there is no instrumentation or external system stimulation provided the SUT must be operated and manned by trained personnel during each illumination.

(5) Throughout each illumination, the SUT configuration will be functional, in accordance with the SUT operating and mission function procedures. Problems with the EME simulator, SUT, or test set up will be identified, documented, and corrected if deemed detrimental to the test.

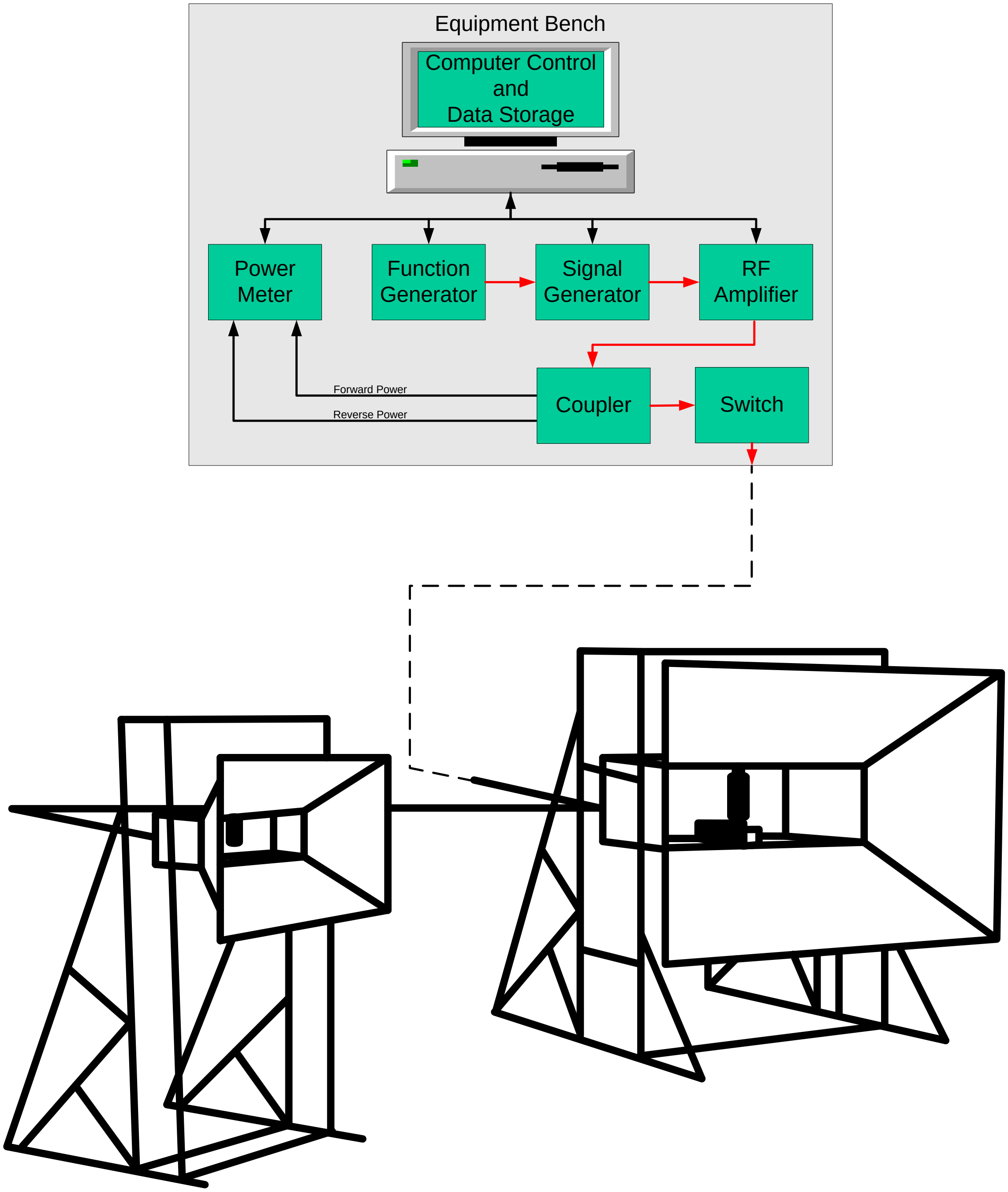


Figure B-1. Typical EME Transmission Equipment and Antennas.

5. TEST PROCEDURE.

The specific test procedures will be conducted IAW the test plan. Any changes to these procedures will be noted in the test report. Safety procedures must be initiated in accordance with the test facility Standard Operating Procedures (SOP), or the SUT specific Safety Assessment Report (SAR).

a. Sample test frequencies, field intensities (ground systems) and modulation used for testing are provided in Table B-2. A minimum of 100 frequencies is recommended as noted in Mil-STd-464 for Ground Systems (without the 6 dB margin allowed). Table B-3 has a list of 275 sample frequencies (including the 100 HERO frequencies) to provide additional frequency coverage.

Table B-2. Sample External RF EME Frequency List for Ground Systems.

Frequency (MHz)	Polarization (POL)	Modulation (MOD)	Electric Field Intensity V/m
3.03	V	AM	50
4	V	AM	50
5.28	V	AM	50
6.06	V	AM	50
8	V	AM	50
10.56	V	AM	50
12.13	V	AM	50
14.3	V	AM	50
16	V	AM	50
18.38	V	AM	50
21.11	V	AM/FM	50
24.25	V	AM/FM	50
27.86	V	AM/FM	50
30	V/H	AM/FM	50
32	V/H	AM/FM	50
34	V/H	AM/FM	50
36	V/H	AM/FM	50
40	V/H	AM/FM	50
42.85	V/H	AM/FM	50
45	V/H	AM/FM	50

Table B-2. Sample External RF EME Frequency List for Ground Systems.

Frequency (MHz)	Polarization (POL)	Modulation (MOD)	Electric Field Intensity V/m
49.99	V/H	AM/FM	50
53	V/H	AM/FM	50
57	V/H	AM/FM	50
60	V/H	AM/FM	50
63	V/H	AM/FM	50
71	V/H	AM/FM	50
80	V/H	AM/FM	50
88.7	V/H	AM/FM	50
94.1	V/H	AM/FM	50
100.1	V/H	AM/FM	50
103.3	V/H	AM/FM	50
107.7	V/H	AM/FM	50
138.02	V/H	AM/FM	50
145.1	V/H	AM/FM	50
152.25	V/H	AM/FM	50
165.3	V/H	AM/FM	50
174.1	V/H	AM/FM	50
185.2	V/H	AM/FM	50
200	V/H	AM/FM	50
213	V/H	AM/FM	50
230	V/H	AM/FM	50
244.9	V/H	AM/FM	50
264.15	V/H	AM/FM	50
290.2	V/H	AM/FM	50
303	V/H	AM/FM	50
333.7	V/H	AM/FM	50
348.05	V/H	AM/FM	50
372.4	V/H	AM/FM	50
400	V/H	AM/FM/PM	50
438	V/H	AM/FM/PM	50

Table B-2. Sample External RF EME Frequency List for Ground Systems.

Frequency (MHz)	Polarization (POL)	Modulation (MOD)	Electric Field Intensity V/m
459.2	V/H	AM/FM/PM	50
480	V/H	AM/FM/PM	50
527	V/H	AM/FM/PM	50
577	V/H	AM/FM/PM	50
632	V/H	AM/FM/PM	50
650	V/H	AM/FM/PM	50
693	V/H	AM/FM/PM	50
738	V/H	AM/FM/PM	50
760	V/H	AM/FM/PM	50
783	V/H	AM/FM/PM	50
805	V/H	AM/FM/PM	50
912	V/H	AM/FM/PM	50
942	V/H	AM/FM/PM	50
1220	V/H	AM/FM/PM	50
1250	V/H	AM/PM	50
1355	V/H	AM/PM	50
1400	V/H	AM/PM	50
1470	V/H	AM/PM	50
1543	V/H	AM/PM	50
1590	V/H	AM/PM	50
1670	V/H	AM/PM	50
1783	V/H	AM/PM	50
1820	V/H	AM/PM	50
1950	V/H	AM/PM	50
2000	V/H	AM/PM	50
2283	V/H	AM/PM	50
2380	V/H	AM/PM	50
2483	V/H	AM/PM	50
2757	V/H	AM/PM	50
2950	V/H	AM/PM	50

Table B-2. Sample External RF EME Frequency List for Ground Systems.

Frequency (MHz)	**Polarization (POL)**	**Modulation (MOD)**	**Electric Field Intensity V/m**
3178	V/H	AM/PM	50
3672	V/H	AM/PM	50
4243	V/H	AM/PM	50
4902	V/H	AM/PM	50
5665	V/H	AM/PM	50
5950	V/H	AM/PM	50
6545	V/H	AM/PM	50
7563	V/H	AM/PM	50
7950	V/H	AM/PM	50
8200	V/H	AM/PM	50
8500	V/H	AM/PM	50
9300	V/H	AM/PM	50
10098	V/H	AM/PM	50
11668	V/H	AM/PM	50
13482	V/H	AM/PM	50
14500	V/H	AM/PM	50
15578	V/H	AM/PM	50
17000	V/H	AM/PM	50
18000	V/H	AM/PM	50
21000	V/H	AM/PM	50
23500	V/H	AM/PM	50
26500	V/H	AM/PM	50
28500	V/H	AM/PM	50
31000	V/H	AM/PM	50
33000	V/H	AM/PM	50
39000	V/H	AM/PM	50
40000	V/H	AM/PM	50
43000	V/H	AM/PM	50

Table B-3. Sample Frequencies for External RF EM Environment (including 100 HERO frequencies from Mil-Std-464).

Frequency (MHz)	Frequency (MHz)	Frequency (MHz)	Frequency (MHz)	Frequency (MHz)
0.0100	4.5900	32.0000	77.0000	229.5000
0.0170	5.2800	32.9800	80.0000	230.0000
0.0290	5.4800	34.0000	81.3500	234.2000
0.0490	6.0600	35.1900	84.0000	244.9000
0.0609	6.3000	36.0000	86.3600	257.5000
0.0739	6.9600	36.9900	88.7000	260.0000
0.0830	7.6900	38.0000	89.4300	264.1500
0.11	8.0000	39.0800	94.1000	278.8000
0.1410	8.6600	40.0000	96.8600	290.2000
0.2380	9.2000	41.2800	100.1000	303.0000
0.4100	9.5700	42.8500	103.3000	317.4000
0.6920	10.5600	43.3900	107.7000	333.7000
0.7500	11.0000	45.0000	138.0200	340.4000
0.8800	12.1300	46.3000	140.8000	348.0500
1.0100	13.4000	48.0000	145.1000	352.5000
1.1750	13.9300	49.9900	152.2500	372.4000
1.3800	14.3000	51.1600	156.3000	385.6000
1.4600	16.0000	53.0000	160.3000	400.0000
1.6600	17.7000	54.8500	166.0000	411.4000
1.8400	18.3800	57.0000	172.7000	423.9000
1.9600	19.6000	58.2400	174.1000	438.0000
2.0000	21.1100	60.0000	185.2000	445.6000
2.3000	22.5000	61.8300	191.8000	459.2000
2.6400	24.2500	63.0000	196.7000	463.8000
2.9900	25.4000	64.0300	200.0000	475.5000
3.0300	26.7000	67.0000	206.7000	480.0000
3.4800	27.8600	71.0000	213.0000	497.3000
3.7900	30.0000	72.1700	221.7000	499.8000
4.0000	31.0700	75.5000	225.0000	505.0000
515.0000	1355.0000	4012.0000	7629.0000	21000.0000
520.0000	1400.0000	4109.0000	7721.0000	23500.0000

Table B-3. Sample Frequencies for External RF EM Environment (including 100 HERO frequencies from Mil-Std-464).

Frequency (MHz)	Frequency (MHz)	Frequency (MHz)	Frequency (MHz)	Frequency (MHz)
527.0000	1470.0000	4243.0000	7950.0000	26500.0000
552.0000	1543.0000	4363.0000	8105.0000	28500.0000
561.0000	1590.0000	4469.0000	8200.0000	31000.0000
577.0000	1670.0000	4541.0000	8372.0000	33000.0000
586.0000	1783.0000	4722.0000	8500.0000	36000.0000
619.0000	1820.0000	4837.0000	8670.0000	39000.0000
632.0000	1950.0000	4902.0000	8758.0000	40000.0000
645.0000	2000.0000	5014.0000	9002.0000	43000.0000
667.0000	2176.0000	5136.0000	9183.0000	
688.0000	2283.0000	5458.0000	9300.0000	
693.0000	2380.0000	5591.0000	9416.0000	
723.0000	2483.0000	5665.0000	9534.0000	
738.0000	2574.0000	5738.0000	9678.0000	
756.0000	2668.0000	5950.0000	9776.0000	
760.0000	2757.0000	6032.0000	9973.0000	
783.0000	2825.0000	6210.0000	10098.0000	
805.0000	2950.0000	6367.0000	10500.0000	
867.4900	2973.0000	6443.0000	11000.0000	
896.0000	3082.0000	6545.0000	11668.0000	
909.0000	3178.0000	6686.0000	12000.0000	
912.0000	3233.0000	6767.0000	12500.0000	
928.0000	3312.0000	6849.0000	13482.0000	
937.0000	3433.0000	7015.0000	14410.0000	
942.0000	3516.0000	7185.0000	15578.0000	
1220.0000	3672.0000	7272.0000	15710.0000	
1250.0000	3733.0000	7360.0000	16880.0000	
1270.0000	3824.0000	7448.0000	17490.0000	
1300.0000	3964.0000	7563.0000	18000.0000	

b. The SUT will be exposed at critical orientations taking into consideration placement of communication, electronics, harness cabling, shielded apertures and points of entry (POE). At least two antenna placement aspect angles should be considered for a very small system (less than 1m X 1m). All other items should have a minimum of four 90 degree aspect angles. Also, a 45 degree aspect angle should be considered dependent on the worse case orientation for POEs. Additionally, any system with a turret or rotating gun should also be exercised and considered in the test item orientations.

c. The following sequence will be observed for each test illumination:

(1) The environment will be adjusted to generate a peak pulsed power EME (as required for aviation and shipboard operations, as well as ground equipment), continuous wave (CW), or modulated field. Experience has shown AM modulation to provide a majority of induced Ext RF EME effects. It is suggested to utilize the modulations for applicable systems as specified in MIL-HDBK-235. Transmitter power will be increased until the criterion field is reached, or facility limitation is reached.

(2) If an anomaly or effect is observed an additional test exposure will be conducted to ensure that the EME was the cause of the effect. Observed data as well as real time SUT instrumentation data will be collected for every test illumination either by soft or hard copy.

(3) When susceptibility indications are noted in the SUT operation, a threshold level shall be determined where the susceptible condition is no longer present. Thresholds of susceptibility shall be determined as follows and described in the test report:

(a) When a susceptibility condition is detected, reduce the interference signal until the SUT recovers.

(b) Reduce the interference signal by an additional 6 dB.

(c) Gradually increase the interference signal until the susceptibility condition reoccurs. The resulting level is the threshold of susceptibility.

(d) Record this level, frequency range of occurrence, frequency and level of greatest susceptibility, and other test parameters, as applicable.

(e) Procedures will be repeated for each test frequency, polarization, modulation, and test item orientation.

(f) Personnel exposure limits averaging period should be taken into account for dwell times during testing. The illumination period that expose personnel to hazardous fields should not exceed three minutes or the direction of DODI 6055.11

(g) TIRs will be prepared to document anomalies.

(h) All test setups should be photographed.

d. Stepped frequency test procedures can also be utilized in order to cover more frequencies. Ensure that the test item test scenario/checkout allows sufficient time between stepped frequency changes for the system to stabilize.

6. DATA PRESENTATION.

a. Nomenclature, model and serial number of each test item

b. Provide graphical or tabular data showing frequency ranges, modulations, antenna polarization and field strength levels tested. An example data sheet is provided in Table B-4.

c. Provide graphical and photographs of antenna orientation in relation to SUT.

d. Provide the correction factors necessary to adjust sensor output readings for equivalent peak detection of modulated waveforms.

e. Provide graphs or tables listing any susceptibility thresholds that were determined along with their associated frequencies.

f. Provide diagrams and photographs showing actual equipment setup.

g. Calibration date and serial/model numbers of test/data acquisition instrumentation.

7. DATA ANALYSIS.

a. Data from the External EME test environment measurements will be scored against the criteria levels, to determine the extent to which the test environment criteria and safety margins (if applicable), as well as equipment specification were met. Deficiencies will be identified and discussed with respect to criteria compliance and the potential for encountering the same electromagnetic environment.

b. The environment data will be compared and evaluated against the systems required criteria.

DATA SHEET

Antenna placement 1 = Rear (90 degrees)
Antenna placement 2 =Right Side (270 degrees)

Run #	Frequency (MHz)	Polarization	Modulation	Configuration	Test Level (V/m)	Anomalies/Effect(s)	THRESHOLD (V/m)
				Test Site			
						Date	
1	18	V	CW	1	260	No Effects	
2	19	V	CW	1	260	No Effects	
3	18	V	AM	1	260	No Effects	
4	19	V	AM	1	260	No Effects	
5	18	V	PM	1	260	No Effects	
6	19	V	PM	1	260	No Effects	
7	18	H	CW	1	260	No Effects	
8	19	H	CW	1	260	No Effects	
9	18	H	AM	1	260	No Effects	

APPENDIX C. NEAR STRIKE LIGHTNING (NSL).

1. APPLICABILITY.

a. This Appendix provides general test methods to assess the safety and survivability of the SUT to the effects produced by the Near Strike Lightning (NSL) electromagnetic environment (EME). This Appendix is meant to act as a guide and is not a replacement for a test plan. Compliance shall be verified by system-level test, analysis, or a combination thereof.

b. This test method is applicable to equipment at the system level IAW the SUT specification. When the SUT is normally integrated into a platform, it is preferable to test it in that configuration but concerns about damage to the platform may drive the use of a test fixture that simulates the platform. The test fixture must be a suitable simulation that addresses the electrical properties of the platform (impedance, harnessing and coupling wavelength). The environment may apply to the SUT in multiple configurations including shipping.

2. REQUIREMENTS.

a. The SUT must perform its mission essential functions during and/or after exposure to a defined near strike lightning event, as specified in the system requirement document.

b. The NSL EME is produced by a cloud-to-ground or a cloud-to-cloud lightning stroke. The test parameters are extracted from MIL-STD464A, as shown in Table C-1.

Table C-1. MIL-STD 464A Cloud-to-Ground NSL Criteria.

Magnetic field (H) rate of change at 10 meters	2.2×10^9 A/m/s
Electric field (E) rate of change at 10 meters	6.8×10^{11} V/m/s

c. When the SUT contains ordnance or safety critical circuits / functions (e.g. EIDs, ESADs), the SUT ordnance and safety critical circuits / functions shall meet the calculated margin requirements during and after exposure to the NSL specification environment. The SUT EIDs, if any, will be considered to have passed when subjected to the NSL environment, if they exhibit sufficient margins. There are two classifications of EIDs situations; safety and reliability. In accordance with MIL-STD-464A, safety (hazardous) EIDs shall maintain a 16.5 dB safety factor below the Maximum No Fire (MNF) (based on not exceeding 15% of the EID MNF) and reliability (non-hazardous) EIDs shall maintain a 6 dB safety factor below the MNF (based on not exceeding 50% of the MNF). When empirical MNF for a specific, qualified, one-Watt no-fire EID is lacking, the Army may use a level of 17.6 mJ based on previous testing of a series of Stinger launch/flight motor EIDs providing the safety factor is necessary, and when the methodology is approved by the Army Electromagnetic Environmental Effects (E3) Board. MIL-STD-1316 specifies a minimum firing voltage of 500 volts for an ESAD. In some cases, EIDs are tested live with no instrumentation; GO-NO-GO. See Appendix N, Direct Strike Lightning procedures. See typical instrumentation setup in Figure C-1 and Table C-1.

3. Test Procedure.

3.1 Purpose.

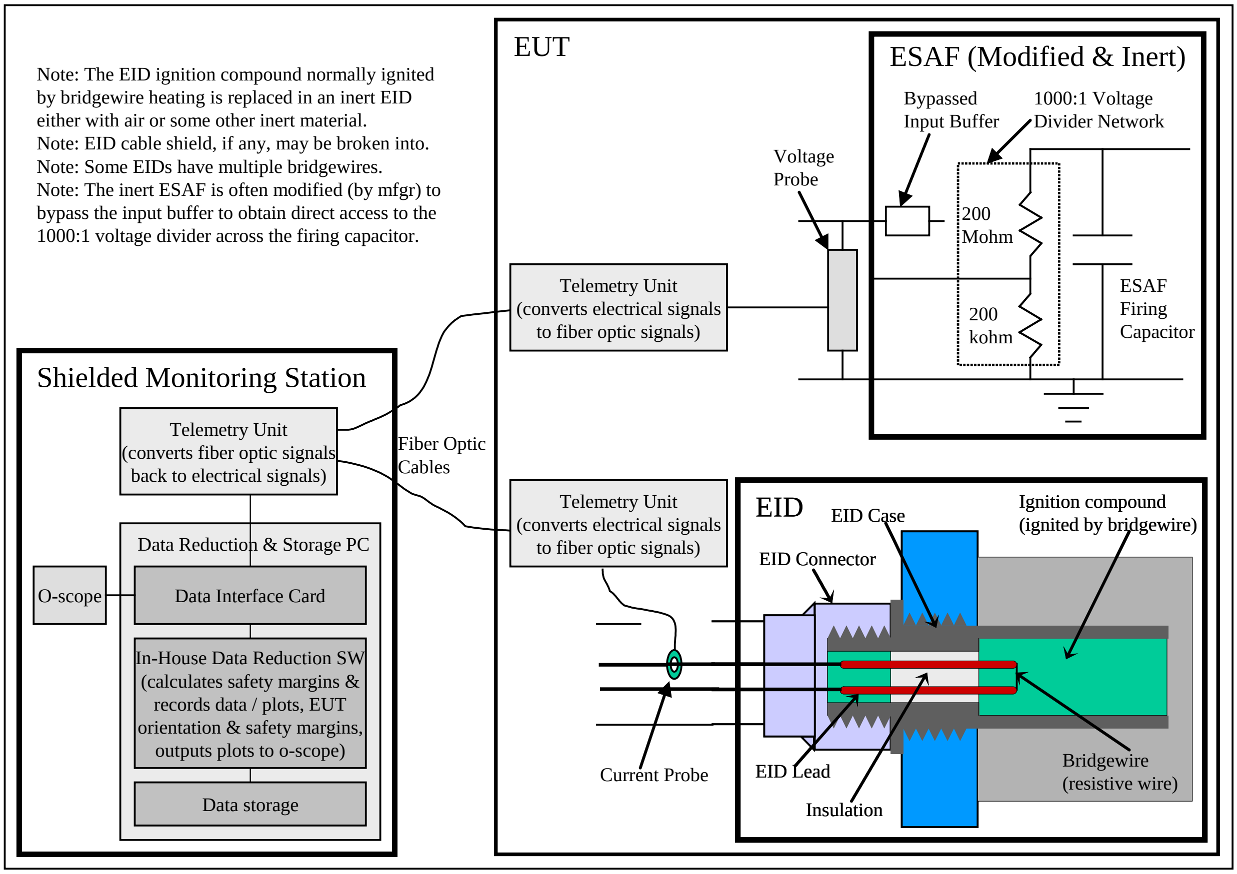
The purpose of this test procedure is to verify the ability of the SUT to survive near strike lightning IAW the specification performance requirements

3.2 Test Equipment.

A listing of the typical equipment used during NSL testing is provided in Table C-3.

a. Unless otherwise stated, test equipment tolerances shall meet the minimums specified in Section 2.3 of this document.

b. Test equipment software used shall be documented as to dates, developer, version number, etc. SUT instrumentation is permissible but it shall not influence test results. SUT Instrumentation may include the following:



Note: The EID ignition compound normally ignited by bridgewire heating is replaced in an inert EID either with air or some other inert material.
Note: EID cable shield, if any, may be broken into.
Note: Some EIDs have multiple bridgewires.
Note: The inert ESAF is often modified (by mfgr) to bypass the input buffer to obtain direct access to the 1000:1 voltage divider across the firing capacitor.

Figure C-1. Typical Instrumented EID Description.

Table C-2. Typical Instrumented EID Description if live EID samples are not provided.

EID	EID Type	MNFC / MNFE	Required Safety Margins	Bridgewire Resistance (Ω)	Comments
Control Battery	304-JTM-050	17.6 mJ	6.0 dB for reliability	0.5 (two 1±0.1 BWs in parallel)	Used Pearson 2877 probe.
Electronics Battery	MIS-40737A	17.6 mJ	6.0 dB for reliability	0.5 (two 1±0.1 BWs in parallel)	Used Pearson 2877 Probe.
Rocket Motor Igniter	PN: 2-101400-1 Dwg: 13287151	17.6 mJ	16.5 dB for safety	1.0	Used Pearson 2877 Probe.
Short Delay Fuze Detector	2-400020-1	3.4 mJ	16.5 dB for safety	2.5	2 tested. Used Pearson 2877 Probe.
Long Delay Fuze Detector	2-400020-3	3.4 mJ	16.5 dB for safety	2.5	2 tested. Used Pearson 2877 Probe.
2AW4E3 cable harness	The cable harness was instrumented to measure the current induced on it by the environments for contractor NSL analysis. Used a Pearson 91550-2 probe.				

Table C-3. Listing of Typical Equipment.

Hardware	Comments
NSL Simulator	Possibly an in-house design and build – usually a large Marx generator designed to generate the NSL waveform
Power Supply	High voltage power supply used to charge capacitor bank
Voltage Divider	Used to measure charge capacitor bank voltage
Current Probe	Used to measure current coupled to SUT or SUT EIDs. Need several in different physical sizes and current handling capabilities
Current Probe	Used to measure current coupled to SUT cable (a clamp type probe - used only when the wire cannot be cut). Need several in different physical sizes and current handling capabilities
Surface Current Probe	Used to measure currents on the surface of the SUT. Need several in different physical sizes and current handling capabilities
Fiber optic Telemetry Unit	Takes input from probes & drives fiber optic output. Need several in different physical sizes and current/voltage handling capabilities
Digital Oscilloscope	Used to record and display current and voltage measurements. Must operate in the 100 kHz to 400 MHz frequency range.
Portable computer	For data reduction (e.g. calculates safety margins, creates data plots for display, stores data)
NSL Test Software	For data reduction / presentation
E and H Field Probes or Sensors	Probes required for calibration and real time field monitoring

(1) Current probes to measure the current coupled to one or more SUT wires / cables due to the NSL environment.

(2) Current probes to measure EID induced currents to determine EID safety margins where applicable. See Appendix E.

(3) Voltage probes to measure ESAD firing capacitor induced voltages to determine ESAD safety margins. See Appendix E.

(4) Cameras connected to monitors in a shielded instrumentation room using fiber optic lines. The cameras may be placed within shielded enclosures.

(5) Test sets may be used to check out the SUT before and after each test event or may be required to operate and monitor the SUT during testing. If required during testing, test sets should be protected from the test environment and placed as far away from the strike point as possible. Any test set interface cabling should be well shielded and aligned away from the strike point to minimize coupling.

3.3 Pre-Test Evaluation.

a. A pre-test evaluation will be performed to determine the primary current paths, ports of entry, test orientations and configurations, test conditions for the SUT, and bulk current measurement points. Energy coupling analysis will identify the type and capability requirements for the data acquisition system to include the bulk current probes. Usually, clamp-on non-obtrusive current probes are used so as to not affect the inherent shielding integrity of the cable or the SUT shielding integrity. For hardening evaluation and corrective recommendations, the EMP test points should remain the same as NSL test points or be a subset there of to include all signal, control and power cables.

b. The SUT status is verified and documented before NSL testing, using baseline self-test checks, system operational performance checks, and functional performance measures.

(1) A pre-test evaluation is performed to include the following. This evaluation is used for test planning and can often reduce the amount of testing required.

(2) Determine the primary NSL current paths.

(3) Determine the most / least susceptible SUT configurations.

(4) Determine the most / least susceptible SUT modes of operation.

(5) Determine the probable Ports of Entry (POEs).

(6) Determine the bulk current measurement points.

(7) Perform an energy coupling analysis to identify the type and capability requirements for the data acquisition system. Usually, clamp-on non-obtrusive current probes are used to not affect the inherent shielding integrity of the cable or the SUT shielding integrity.

(8) Determine critical SUT data required to be instrumented and monitored.

(9) Determine which EIDs are to be instrumented and measured and how.

(10) Determine SUT/platform critical functions and circuits.

(11) Determine SUT NSL protection features and their predicted performance and whether they are repairable or replaceable.

(12) Determine verification and pass/fail criteria and required margins.

(13) Determine the SUT operating and check-out procedures.

c. Pre-existing analyses and test data from previous tests may be evaluated and incorporated into the test planning and pre-test analysis in order to enhance and reduce the scope of the new testing.

4. TEST SETUP.

Test setups vary. Some typical test setups and photographs are shown in Figures C-2 through C-4. Following are general / typical test setup guidelines.

a. The NSL environment is generated by discharging the energy in the capacitor bank through low resistance cables onto the NSL discharge point.

b. Fast response current probes are used to monitor current and to measure the test energy. Telemetry units are used to convert the electrical signals to optical signals and transmit them over fiber optic lines to a receiver in a shielded area where they are converted back to electrical signals, processed, observed (monitored on a digitizing oscilloscope), and recorded on a PC laptop for data reduction. Test data reduction software extracts the desired test parameters, calculates the EID / ESAF safety margins where applicable, plots the data and creates plots.

c. The test facility is calibrated along the radial axis from the center of the facility test volume to establish the distance required to achieve the specified field strength. During the environmental exposures, the field strength is monitored at a coinciding radial distance adjacent or opposite from the facility center.

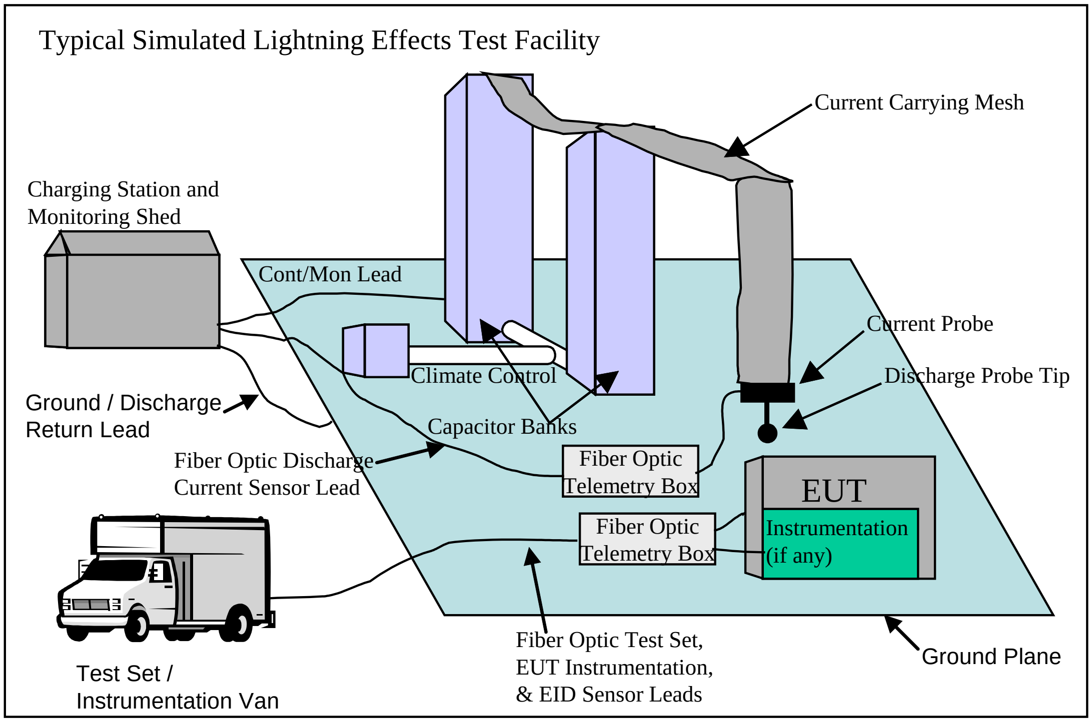


Figure C-2. Typical NSL Test Setup.

Figure C-3. Sub-system Level NSL Testing.

Figure C-4. System Level NSL Testing.

d. The SUT is tested in minimum of two orientations with respect to the magnetic field vector, i.e., longitudinal axis parallel to the magnetic field vector, and 90 degrees clockwise or perpendicular to the magnetic field vector. (The pre-test evaluation may determine more orientations are required based on the complexity of the system and the expected coupling paths).

Configurations involving long wire connections shall have the long wires oriented for maximum coupling and should be raised above the ground plane 1 meter to prevent reflection properties of the natural earth ground.

e. After each test event, the SUT, EIDs & platform are checked for proper operation and damage. If damage occurs, it will be documented and assessed. Testing will not be continued until the problem and its effect on the SUT has been assessed as well as potential impacts on the SUT if testing is continued.

f. The SUT and EIDs may be instrumented or live EID bridgewire resistances may be measured before and after each discharge to check for degradation and firing.

g. Allow sufficient time for test equipment to stabilize prior to calibration and testing. Periodically check for receiver or transducer overload conditions.

h. Test equipment (e.g. oscilloscopes) is calibrated regularly by calibration labs using procedures traceable to the National Institute of Standards and Technology (NIST). The typical NSL instrumentation system (e.g. Nanofast) has a self-calibration feature.

5. TEST PROCEDURES.

The specific test procedures will be conducted IAW the test plan. Any changes to these procedures will be noted in the test report. Lightning testing is potentially hazardous to personnel. Safety procedures must be initiated IAW the test facility Standard Operating Procedures (SOP).

a. Set up the SUT for NSL testing IAW Figure C-2 using the same test equipment and settings used during calibration. Set up the instrumentation equipment (e.g. to monitor EID current / energy coupling), if applicable.

b. Power up the SUT and run a pre-test baseline functional check.

c. Place the SUT in a test plan matrix specified configuration and mode.

d. Verify data acquisition and instrumentation equipment operation.

e. Secure the test area and insure that personnel are at a safe distance.

f. The SUT is illuminated by the simulated NSL environment. If no failures occur, the SUT is illuminated at least three times per orientation or until data from all the data acquisition test points have been collected.

g. After each discharge, perform a visual check of the SUT for any lightning induced damage.

h. After each discharge, repeat SUT operational checks and compare to baseline. Throughout each NSL illumination, the SUT will be fully operational, in accordance with the SUT operating procedures.

i. If there are any susceptibilities, determine the SUT components affected the required steps to recovery (e.g. cycling power) and the recovery time. If possible (if SUT not damaged), verify the repeatability of the susceptibility and determine the threshold and safety margins, if necessary. Should an upset occur, the effected equipment(s) and/or component(s) will be identified and the power cycled (OFF/ON) to re-establish normal operation and record the recovery time.

j. Repeat the test procedure for all test modes and configurations. Illuminate the SUT in different orientations (as defined during the pre-test analysis phase) at multiple levels (e.g. 50% and 100%) based upon the pre-test field calibration results.

k. Any anomalies or upsets must be documented. Testing shall not continue until the problem is understood and its effects on the SUT are assessed. Should an upset occur, the effected equipment(s) and/or component(s) must be identified and the power cycled (OFF/ON) in an attempt to re-establish normal operation and record the recovery time. Testing must be repeated at the same level and orientation to determine whether the upset is attributable to the specific EMP environment.

l. Document the upsets, failures, downtime, and corrective actions.

6. DATA PRESENTATION.

Data presentation shall be as follows:

a. SUT details (e.g. hardware and operational description, model and serial numbers), as well as applicable specific EID parameters

b. Drawings and/or photographs of test setups.

c. List all test and instrumentation equipment with applicable calibration data, calibration due dates, and transducer/cable factors used.

d. Include test instrumentation system check-out and pre-test SUT check-out results (plots, graphs, data tables) used.

e. Test configurations / modes / operational procedures used.

f. Results (e.g. plots, graphs, data tables). A sample data sheet is provided in Table C-4. Sample test data plots are provided in Figures C-5 through C-6. Note: data should be reported at the level of accuracy of the test equipment.

g. Present or reference limits or criteria used for comparison to test data. Include limits on plots and graphs.

h. Changes to test plan and rationale.

i. Discussion of results, conclusions and recommendations.

(1) Description/discussion of anomalies and investigations.

(2) Description of data reduction procedures / methods.

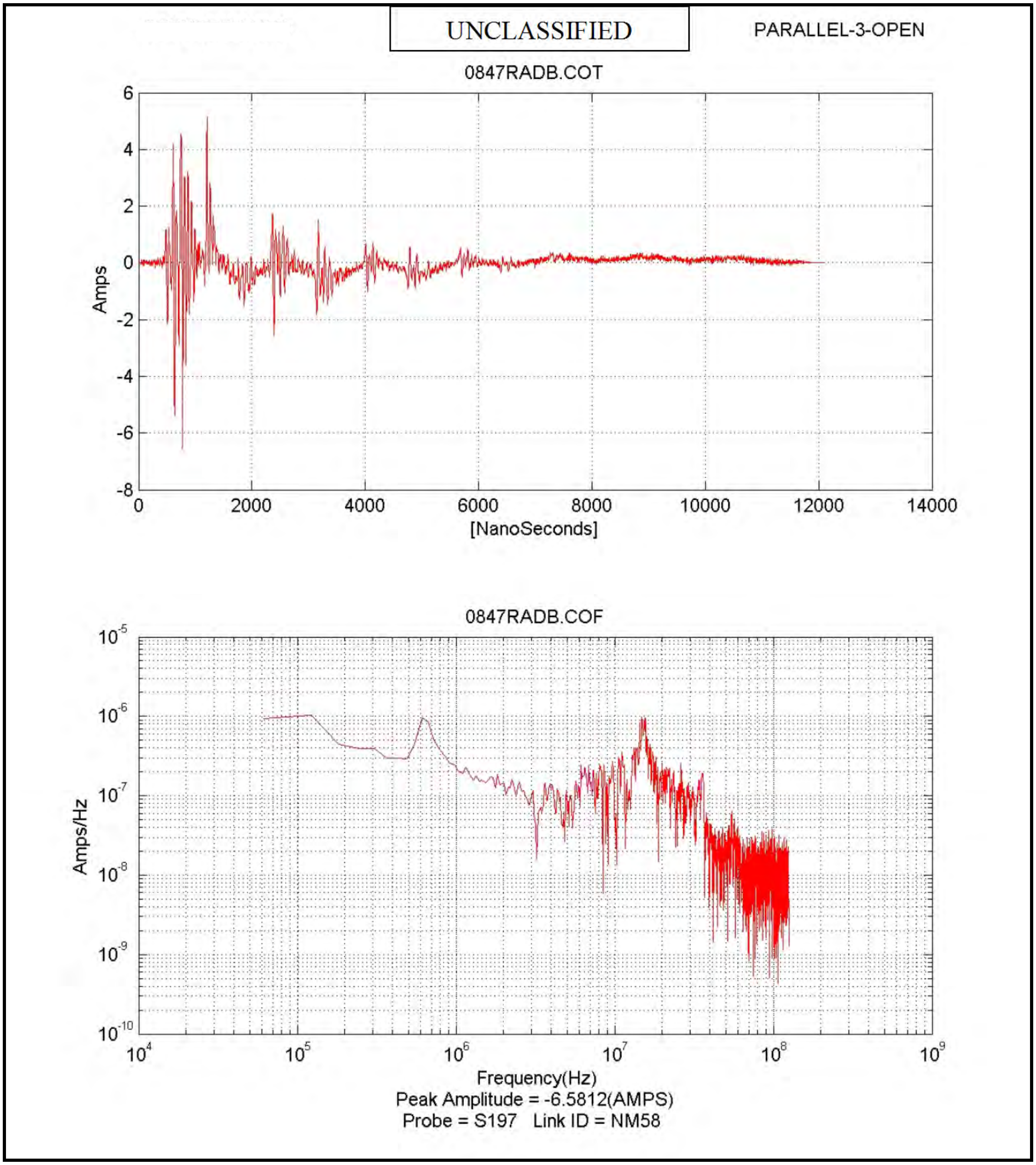
(3) Data Analysis.

7. DATA ANALYSIS.

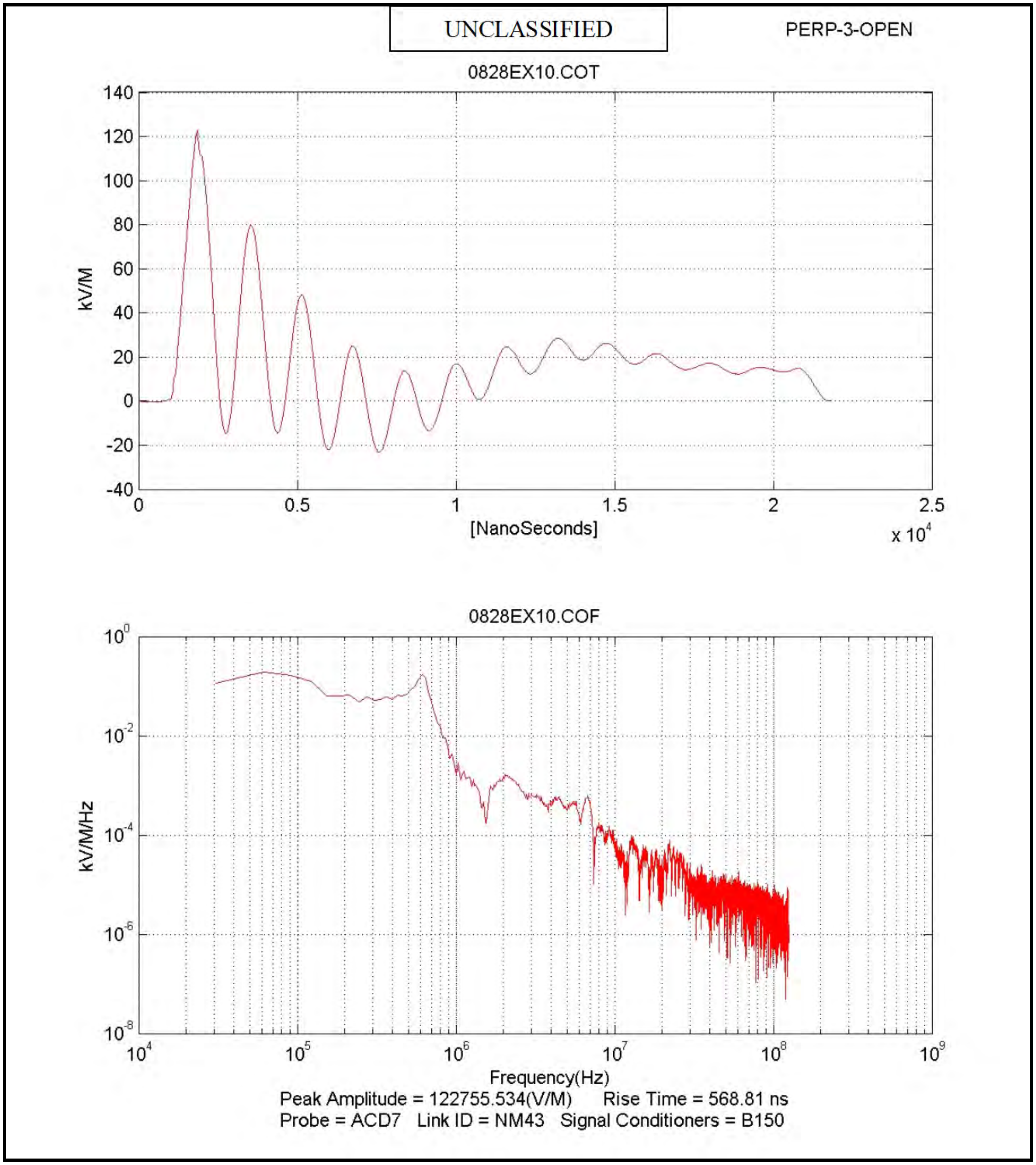
The test data will be compared to the applicable criteria and the pre-event baseline measurements to determine the extent to which the test criteria are met and the effects of the NSL test environment on the SUT. Facility criteria compliance should be addressed to ensure that any deficiencies are addressed either by increasing the amplitude of the environment, or application of direct drive techniques for compensation. Pre-existing analyses and test data from previous tests may also be used as a comparison for the new NSL test data. Test anomalies will be assessed to determine if they should be classified as SUT failures. Failures or degradation resulting in SUT performance outside specifications, will be addressed with regards to causes, test level at which they occurred, allowable downtime, and mission impact. Safety margins that could seriously impact mission performance or safety will be discussed. The test system configuration will be evaluated against the expected production configuration and the differences documented. Corrective hardening and/or mitigation recommendations will be developed and documented.

Table C-4. Example NSL Test Run Induced Current Data Sheet.

Sample Reduced NSL Induced Current Test Data										
Test Point	Orientation	Shot #	Peak I (Amps)	Res Freq (Hz)	Low Freq (Hz)	High Freq (Hz)	Bandwidth (Hz)	Alpha	Q	Damping Factor
95J1	perp-2-open	803	-0.307	638950	571691	663601	91910	288744	6.95	0.072
DATA	perp-2-open	803	-0.295	621342	583097	654056	70959.2	222925	8.76	0.057
HMU4	perp-2-open	803	0.076	617589	585772	656170	70397.4	221160	8.77	0.057
INS1	perp-2-open	803	0.400	602410	572629	663610	90981.9	285828	6.62	0.076
NAV	perp-2-open	803	-0.217	70172.2	52498.1	97312.3	44814.2	140788	1.57	0.319
VISPWR	perp-2-open	803	-0.222	615764	583356	653909	70553.1	221649	8.73	0.057



C-5. Sample Induced Current Waveform.



Peak Amplitude = 122755.534(V/M) Rise Time = 568.81 ns
Probe = ACD7 Link ID = NM43 Signal Conditioners = B150

C-6. Sample Tailored Environmental Wave Form.

APPENDIX D. ELECTROMAGNETIC PULSE (EMP).

1. APPLICABILITY.

a. This Appendix provides general test methods to assess the safety and survivability of the SUT to the effects produced by the Electromagnetic Pulse (EMP) environment. This Appendix is meant to act as a guide and is not a replacement for a test plan. Compliance shall be verified by system-level test, analysis, or a combination thereof.

b. This test method is applicable to equipment at the system level IAW the SUT specification. When the SUT is normally integrated into a platform, it is preferable to test it in that configuration but concerns about damage to the platform may drive the use of a test fixture that simulates the platform. The test fixture must be a suitable simulation that addresses the electrical properties of the platform (impedance, harnessing and coupling wavelength).

2 REQUIREMENTS.

a. The test parameters are extracted from MIL-STD-464, Electromagnetic pulse (EMP). The system shall meet its operational performance requirements after being subjected to the EMP environment. This environment is classified and is currently defined in MIL-STD-2169B. EMP is a probability for most military systems and should be addressed on a case by case basis as any other electromagnetic environment. Guidance should not remove this requirement due to costs. It should be noted that in some instances, basic lightning preventative measures can mitigate EMP catastrophic failures. The Army Acquisition Executive (AAE) policy clearly states that all mission essential tactical systems shall conduct EMP testing.

b. The SUT must perform its mission essential functions before and after exposure to a defined EMP event, as specified in the system requirement document, MIL-STD 464 or the Nuclear Survivability Criteria (NSC) developed by the United States Army Nuclear and Chemical Agency (USANCA).

c. The system must operate and meet mission requirements after introduction of the EMP environment, or survive as specified in the system requirements document.

d. There are also systems with the requirement to operate through the environment; i.e. missile defense programs must stay on line through the EMP event (function prior, during and post event).

e. A system may also have an allowable recovery time in which the system must be brought back on line (through crew intervention).

3. PURPOSE.

The purpose of this test procedure is to verify the ability of the system to safely withstand EMP IAW the specification requirements

4. TEST SET UP.

4.1 Test Equipment.

4.1.1 A listing of the typical test equipment used during EMP testing is provided in Table D-1. The test report shall include the actual test equipment used along with their serial numbers and calibration dates, if applicable. The test equipment should have a bandwidth of 100 kHz to 400 MHZ.

a. Unless otherwise stated, test equipment tolerances shall meet the minimums specified in Section 2.3 of this document.

b. Test equipment software used shall be documented as to dates, developer, version number, etc.

Table D-1. Typical EMP Test Equipment.

Hardware	Comments
EMP Simulator	Possibly an in-house design and build – usually a large Marx generator designed to generate the EMP waveform
Power Supply	High voltage power supply used to charge capacitor bank
Voltage Divider	Used to measure charge capacitor bank voltage
Current Probe	Used to measure current coupled to SUT or SUT EIDs Need several in different physical sizes and current handling capabilities
Current Probe	Used to measure current coupled to SUT cable (a clamp type probe - used only when the wire cannot be cut) Need several in different physical sizes and current handling capabilities
Surface Current Probe	Used to measure currents on the surface of the SUT Need several in different physical sizes and current handling capabilities
Fiber optic Telemetry Unit	Takes input from probes & drives fiber optic output Need several in different physical sizes and current/voltage handling capabilities
Digital Oscilloscope	Used to record and display current and voltage measurements. Must operate in the 100 kHz to 400 MHz frequency range.
Portable Computer	For data reduction (e.g. calculates safety margins, creates data plots for display, stores data)
EMP Test Software	For data reduction / presentation
E and H Field Probes or Sensors	Probes required for calibration and real time field monitoring

4.1.2 SUT instrumentation is permissible but it shall not influence test results. SUT instrumentation may include the following:

a. Current probes to measure the current coupled to one or more SUT wires / cables due to the EMP environment.

b. Current probes to measure EID induced currents to determine EID safety margins where applicable. See HESD appendix, page E-1.

c. Voltage probes to measure ESAD firing capacitor induced voltages to determine ESAD safety margins. See HESD appendix, page E-1.

d. Cameras connected to monitors in a shielded instrumentation room using fiber optic lines. The cameras may be placed within shielded enclosures.

e. Test sets may be used to check out the SUT before and after each test event or may be required to operate and monitor the SUT during testing. If required during testing, test sets should be protected from the test environment and placed as far away from the test volume as possible. Any test set interface cabling should be well shielded and aligned away from the strike point to minimize coupling.

4.1.3 Pre-Test Evaluation.

a. A pre-test evaluation will be performed to determine the primary current paths, ports of entry, test orientations and configurations, test conditions for the SUT, and bulk current measurement points. Energy coupling analysis will identify the type and capability requirements for the data acquisition system to include the bulk current probes. Usually, clamp-on inductive non-obtrusive current probes are used so as to not affect the inherent shielding integrity of the cable or the SUT shielding integrity. For hardening evaluation and corrective recommendations , the EMP test points should remain the same as Near Strike Lighting (NSL) test points or be a subset there of to include all signal, control and power cables.

b. The SUT status is verified and documented before EMP testing, using baseline self-test checks, system operational performance checks, and functional performance measures.

4.1.4 Setup.

Some typical test setups and photographs are shown in Figures D-1 and D-2. Following are general / typical test setup guidelines.

a. The test facility is calibrated along the radial axis from the center of the facility test volume to establish the distance required to achieve the specified field strength. During the environmental exposures, the field strength can be monitored at a coinciding radial distance adjacent or opposite from the facility center dependent on the design.

Figure D-1 Typical EMP Test Set-up.

Figure D-2. Typical EMP Instrumentation Set-up.

b. The SUT is tested in a minimum of two orientations with respect to the electric field vector, i.e., longitudinal axis parallel to the electric field vector, and 90 degrees clockwise or perpendicular to the electric field vector. (The pre-test evaluation may determine more orientations are required based on the complexity of the system and the expected coupling paths.)

c. The SUT is instrumented. Care must be taken so that the installation of the Data Acquisition System (DAS), especially the current probes does not compromise or reduce the inherent shielding of the SUT.

d. The SUT is illuminated by the simulated EMP environment. If no failures occur, the SUT is illuminated at least three times per orientation (as well as field amplitude), or until data from all the data acquisition test points have been collected.

e. Throughout each EMP illumination, the SUT will be fully operational, in accordance with SUT operating procedures.

5. TEST PROCEDURE.

a. Illuminate the SUT in different orientations (as defined during the pre-test analysis phase) and at multiple levels (e.g. 25, 50, 75, 100, and at least 125%) based upon the pre-test field calibration results and primary coupling of the SUT to compensate for any frequency and energy deficiencies that may exist. 200% of the level would provide the 6 dB requirement from Mil-Std-464/2169.

b. Repeat the SUT's pre-test baseline checks after each illumination to establish its operational and functional status

c. Perform detailed bulk current probe data measurements.

d. Any anomalies or upsets must be documented. Testing shall not continue until the problem is understood and its effects on the SUT are assessed. Should an upset occur, the effected equipment(s) and/or component(s) must be identified and the power cycled (OFF/ON) in an attempt to re-establish normal operation and record the recovery time. Testing must be repeated at the same level and orientation to determine whether the upset is attributable to the specific EMP environment.

e. Document the upsets, failures, downtime, and corrective actions.

6. DATA PRESENTATION.

Data presentation shall be as follows:

a. SUT details (e.g. hardware and operational description, model and serial numbers), as well as applicable specific EID parameters

b. Drawings and/or photographs of test setups.

c. List all test and instrumentation equipment and transducer/cable factors used.

d. Include test instrumentation system check-out and pre-test SUT check-out results (plots, graphs, data tables) used.

e. Test configurations / modes / operational procedures used.

(1) Results (e.g. plots, graphs, data tables). A sample data sheet is provided in Table D-2. Sample test data plots and photographs are provided in Figure D-2. Note: data should be reported at the level of accuracy of the test equipment.

(2) Present or reference limits or criteria used for comparison to test data. Include limits on plots and graphs.

(3) Changes to test plan and rationale.

(4) Discussion of results, conclusions and recommendations

7. DATA ANALYSIS PROCEDURE.

The test data will be compared to the applicable criteria and the pre-event baseline measurements to determine the extent to which the test criteria are met and the effects of the EMP test environment on the SUT. Facility criteria compliance should be addressed to ensure that any deficiencies are addressed either by increasing the amplitude of the environment, or application of direct drive techniques for compensation. Pre-existing analyses and test data from previous tests may also be used as a comparison for the new EMP test data. Test anomalies will be assessed to determine if they should be classified as SUT failures. Failures or degradation resulting in SUT performance outside specifications, will be addressed with regards to causes, test level at which they occurred, allowable downtime, and mission impact. Safety margins that could seriously impact mission performance or safety will be discussed. The test system configuration will be evaluated against the expected production configuration and the differences documented. Corrective hardening and/or mitigation recommendations will be developed and documented.

Table D-2. Induced Current Data Sheet Example for EMP Test.

Sample reduced EMP induced current test data										
Test Point	**Orientation**	**Shot#**	**Peak I**	**Resonant Frequency**	**Low Frequency**	**High Frequency**	**Bandwidth**	**Alpha**	**Q**	**Damping Factor**
CABLE	front-1	5030	-1.97203	1.41E+08	1.31E+08	1.45E+08	1.47E+07	4.62E+07	9.57185	0.0522365
CABLE	front-1	5031	-2.54641	1.39E+08	1.32E+08	1.45E+08	1.36E+07	4.29E+07	10.2223	0.0489128
CABLE	front-2	5032	-10.9096	1.33E+08	1.14E+08	1.41E+08	2.76E+07	8.67E+07	4.80658	0.104024
CABLE	front-3	5033	4.03576	1.39E+08	1.23E+08	1.46E+08	2.31E+07	7.26E+07	6.00284	0.0832939
CABLE	front-3	5034	4.22577	1.42E+08	1.26E+08	1.49E+08	2.34E+07	7.35E+07	6.06706	0.0824122

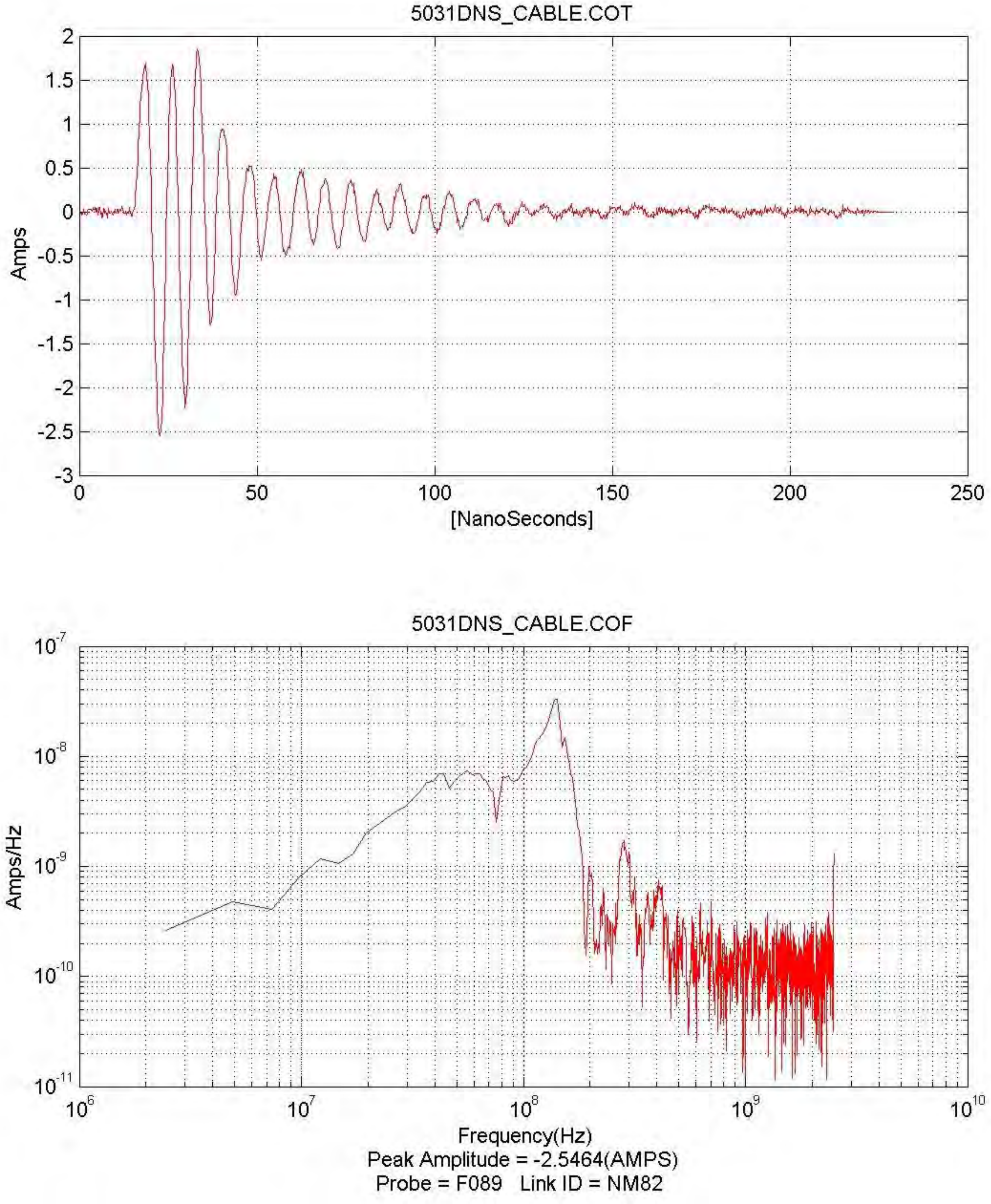


Figure D-2. Typical EMP Data Plots.

APPENDIX E. HELICOPTER GENERATED ELECTROSTATIC DISCHARGE (HESD).

1. APPLICABILITY.

a.. This Appendix provides general test methods to assess the safety and survivability of the SUT to the effects produced by the Helicopter-generated Electrostatic Discharge (HESD) environment. This Appendix is meant to act as a guide and is not a replacement for a test plan. Compliance shall be verified by system-level test, analysis, or a combination thereof.

b. The HESD or “vertical lift” environment was developed from measuring the charge build-up on helicopters, and is applicable to any equipment that may be transported by helicopter including equipment loaded onto and unloaded from a helicopter or carried by the helicopter using a sling, as well as equipment carried on personnel. It is also applicable to equipment installed external to the helicopter such as ordnance and fuel tanks. The applicability of the HESD environment has been extended by ADS-37A-PRF to all Army aircraft.

c. HESD testing is applicable at the system level IAW SUT specification. When the SUT is normally integrated into a platform, it is preferable to test it in that configuration but concerns about damage to the platform may drive the use of a test fixture that simulates the platform. HESD testing may apply in multiple configurations such as shipping because the SUT may be transported by helicopter. HESD testing is usually applicable to the SUT un-powered but may be applied when powered if the SUT is flight critical equipment, or equipment carried by Special Operation Forces personnel. The HESD environment is applied at points on the SUT that are contact points during loading and unloading including sling attachment points, and the bottom corners of the SUT which would make first contact when being loaded or unloaded. Note that if the SUT is integrated into a ground vehicle which is transported by aircraft, the contact points would be the points on the ground vehicle which make first contact during loading or unloading and its sling loading points.

2. REQUIREMENTS.

a. When exposed to the HESD environment, the SUT (and its platform, if any) shall meet the operational performance requirements detailed in their equipment specifications and test plan. A typical SUT HESD requirement is shown below. When the SUT is not flight or safety critical, often the “during and” is removed from the performance part of the requirement. Note that ADS-37A-PRF extends the requirement to all Army aircraft, not just helicopters.

b. The SUT shall remain safe in its helicopter transport configuration during and after exposure to the HESD environment and shall meet its operational performance requirements during and after exposure to the HESD environment. The HESD environment shall be as specified in MIL-STD-464.

c. The simulated HESD environment is defined in MIL-STD-464. The HESD test pulse parameters for Vertical Lift and In-Flight Refueling detailed in Table E-1 standardize the HESD pulse and simulate the equivalent circuit of the aircraft from which the electrostatic discharge may take place.

Table E.1. HESD Environment Parameters.

Voltage (V)	Capacitance (pF)	Series Resistance (Ω)
± 300,000 ±500 V	1000 ± 5 %	≤1

d. When the SUT contains ordnance or safety critical circuits / functions [e.g. Electrically Initiated Devices (EIDs) the SUT ordnance and safety critical circuits / functions shall meet their safety requirements during and after exposure to the HESD specification environment. There are two methods for testing EID safety which are described in detail in Section 3.6 (HERO/EMRH Test Philosophy) of Army Technical Report TR-RD-TE-97-01. Electromagnetic Radiation – Hazards, EMRH is another term for Hazards of Electromagnetic Radiation to Ordnance (HERO). The two methods for testing HESD safety of SUT EIDs are:

(1) Instrumented, inert SUT testing: The SUT EIDs are replaced by inert versions (explosive material removed for personnel and SUT safety) that are instrumented to measure the currents, voltages, power, or energy induced at the EIDs during HESD testing. The measured results are compared to the EID Maximum No Fire (MNF) parameter after the MNF parameter is reduced by the EID required test margin. Note that the measurement results can be extrapolated if the test facility cannot produce the required test levels.

(2) Go / No-Go SUT testing: The live SUT EIDs are left intact in the SUT and are not instrumented. A large number of SUTs with their live EIDs are tested to the HESD test level in order to obtain a meaningful statistical sample. If a large number of SUTs are not available, a smaller number of SUTs are subjected to HESD test levels that are raised by the required EID safety margin. This test method requires that multiple EIDs be tested in order to obtain a meaningful statistical sample. Testing is usually repeated a minimum of 10 times for ground systems and 22 for airborne systems (statistically significant samples) with fresh EIDs each time to provide some measure of confidence that the EIDs will remain safe. This is the preferred method as agreed upon by the Joint E3 Safety Testing Workshop on 7-9 November, 2007.

e. Go/No-Go SUT testing can be performed but may have several concerns:

(1) The need for a large number of SUTs to test to a wide variety of test field conditions (e.g. different frequencies, waveforms, polarizations, orientations). A large number of SUTs may not be available.

(2) The chance of destruction of a large number of SUTs.

(3) High test levels required may not be obtainable.

(4) Fully testing a large number of SUTs considerably increases test cost and schedule.

(5) Test personnel and test equipment safety.

f. Each test location is tested with both positive and negative polarity ESD transients.

3. PURPOSE.

The purpose of HESD testing is to verify the ability of the SUT to withstand the HESD environment IAW its specification performance requirements detailed in the test plan. A typical test plan purpose follows:

The purpose of HESD testing is to determine if the SUT remains safe (e.g. no ordnance ignition) during and after being subjected to the HESD environment when in a storage or transportation configuration and that the SUT meets its operational performance requirements (e.g. no damage or degraded performance) after being subjected to the HESD environment when tested un-powered in an operational configuration.

4. TEST SET UP.

4.1 Test Equipment.

A listing of the typical test equipment used during HESD testing is provided in Table E-2. The test report shall include the actual test equipment used along with their serial numbers and calibration dates, if applicable.

a. The test generation equipment consists of a capacitor bank to simulate the HESD waveform, a power supply to charge it up and a switching network to discharge it.

b. The test measurement equipment consists of an oscilloscope and current probe to measure the stimulus current waveforms to determine the adequacy of the simulated HESD environment and a voltage divider network to measure the HESD simulator capacitor bank voltage. The test measurement equipment is required to operate in the HESD environment frequency range (100 kHz to 100 MHz) as a minimum.

Table E-2. HESD Typical Test Equipment List.

Hardware	Comments
HESD Simulator	Possibly an in-house design and build – usually a large capacitor bank designed to simulate the ± 300 kV HESD waveform
Power Supply	High voltage power supply used to charge capacitor bank
Voltage Divider	Used to measure charge capacitor bank voltage
Current Probe	Used to measure current coupled to SUT or SUT EIDs Need several in different physical sizes and current handling capabilities
Current Probe	Used to measure current coupled to SUT cable (a clamp type probe - used only when the wire cannot be cut) Need several in different physical sizes and current handling capabilities
Differential Voltage Probe	Used to measure voltage across ESAD capacitor. Need several in different physical sizes and current handling capabilities
Telemetry Unit	Takes input from probes & drives fiber optic output Need several in different physical sizes and current/voltage handling capabilities
Digital Oscilloscope	Used to record and display current and voltage measurements. Must operate in the 100 kHz to 200 MHz frequency range.
Laptop PC	For data reduction (e.g. calculates safety margins, creates data plots for display, stores data)
ESD Test Software	For data reduction / presentation
Plotter	To print out data plots

c. Unless otherwise stated, test equipment tolerances shall meet the minimums specified in Section 2.3 of this document.

d. Test equipment software used shall be documented as to dates, developer, version number, etc. SUT instrumentation is permissible but it shall not influence test results. SUT Instrumentation may include the following:

(1) Current probes to measure the current coupled to one or more SUT wires / cables due to the HESD environment.

(2) Current probes to measure EID induced currents to determine EID safety margins (see Figure E-1).

(3) Voltage probes to measure ESAD firing capacitor induced voltages to determine ESAD safety margins (see Figure E-1).

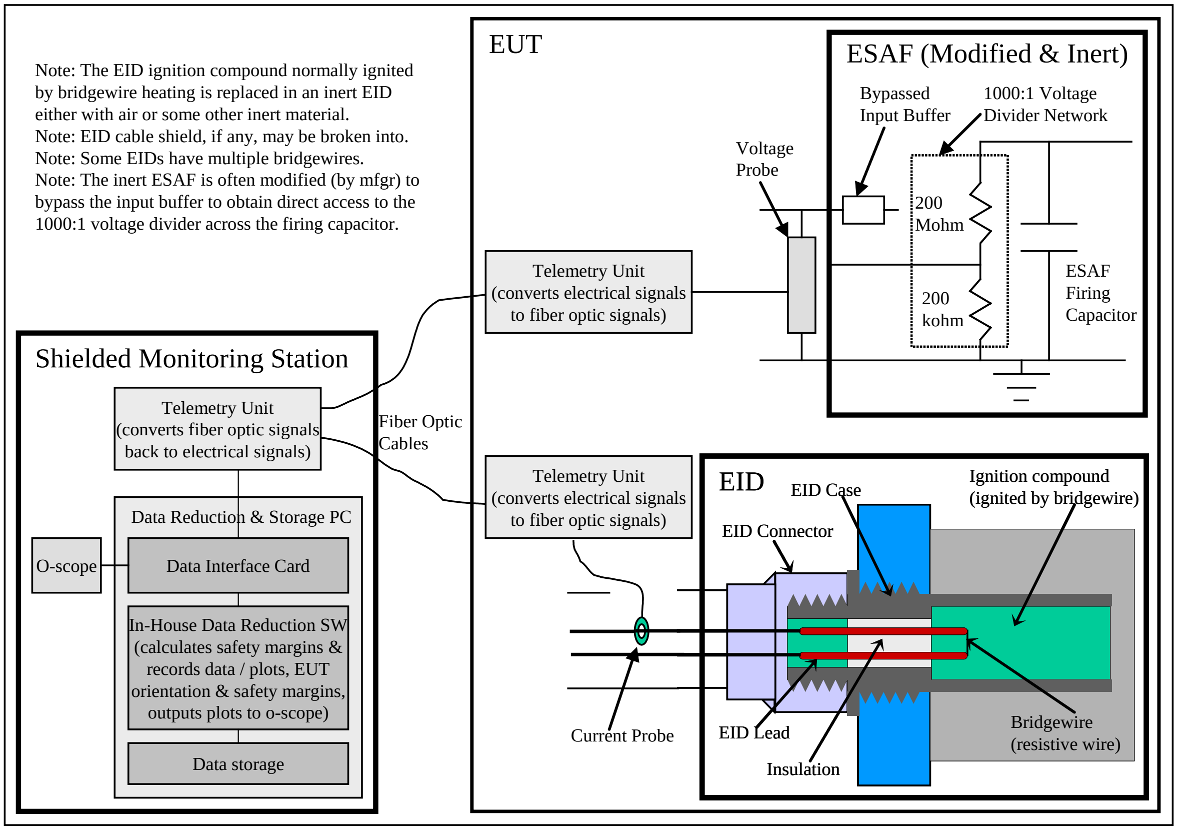

Note: The EID ignition compound normally ignited by bridgewire heating is replaced in an inert EID either with air or some other inert material.
Note: EID cable shield, if any, may be broken into.
Note: Some EIDs have multiple bridgewires.
Note: The inert ESAF is often modified (by mfgr) to bypass the input buffer to obtain direct access to the 1000:1 voltage divider across the firing capacitor.

Figure E-1. Typical Instrumentation Block Diagram.

(4) Cameras connected to monitors in a shielded instrumentation room using fiber optic lines. The cameras may be placed within shielded enclosures.

(5) Test sets may be used to check out the SUT before and after each test event or may be required to operate and monitor the SUT during testing. If required during testing, test sets should be protected from the test environment and placed as far away from the strike point as possible. Any test set interface cabling should be well shielded and lay in a radial pattern away from the strike point to minimize coupling.

4.1.2 EID.

SUTs are usually modified prior to test to remove all explosives, pyrotechnic, and combustible materials, including EIDs. If EIDs / ESADs are instrumented, the instrumented, inert EIDS are installed in the ordnance item at precisely the same location as the original EIDs or the test will be conducted GO-NO-GO on live EIDS as agreed upon by the Joint Service E3 Safety Testing Workshop held November 7-9 2007.

4.1.3 Setup.

Test setups vary. Some typical test setups and photographs are shown in Figures E-2 through E-6. Following are general / typical HESD test setup guidelines.

a. The HESD is generated by charging up the SUT to the specification voltage and then discharging the SUT to ground through a return path that should be less than 1.0 Ω resistance and less than 20 µH of inductance.

b. Fast response current probes are used to measure current and test energy. Telemetry units are used to convert the electrical signals to optical signals and transmit them over fiber optic lines to a receiver in a shielded area where they are converted back to electrical signals, processed, observed (monitored on a digitizing oscilloscope), and recorded on a PC laptop for data reduction. Test data reduction software extracts the desired test parameters, calculates the EID safety margins, plots the data and creates plots.

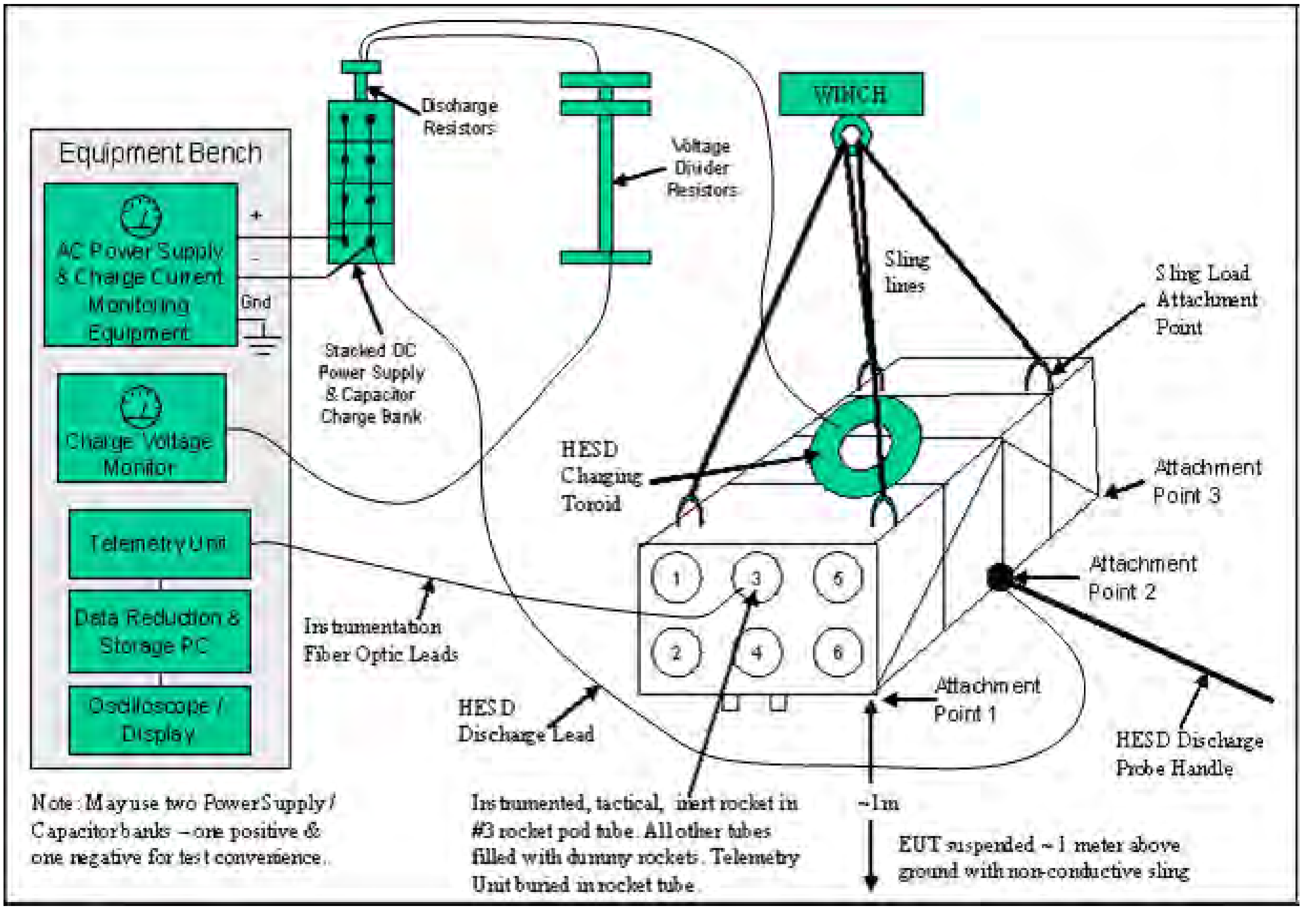
c. Due to concerns with damaging the platform (e.g. aircraft), when an SUT is integrated into a platform, a test platform (e.g. aircraft shell) may be used. When it is not platform mounted, the SUT is usually mounted on a non-conductive test fixture isolated from the ground or is sling loaded up off the ground. When it is platform mounted, it is mounted on the platform (or test shell) and the platform is isolated from the ground (e.g. a sling loaded HMMWV). To avoid un-intentional discharge, the SUT or platform is raised a minimum of one meter above the ground and away from conductive materials or structures. All SUT cabling is terminated. Dummy loads are typically used on un-connected SUT interface cables to increase simulation fidelity. The SUT may be tested in several different configurations (e.g. storage, transport, operational). The SUT is typically un-powered during HESD testing but flight critical equipment may be tested when powered and operational.

d. Discharge point selection is typically based on the points that may be contacted during helicopter loading, unloading and sling transport. These may include sling contact points and the points that would most likely touch the helicopter, ground or personnel first during sling transport or aircraft loading / unloading. Aircraft externally mounted equipment is usually tested at critical safety points (e.g. missile warhead), ends, and manhandling (loading / loading / maintenance) points. Each test location is tested with both positive and negative polarity ESD transients. If the possibility of SUT damage is envisioned, testing may be stepped up (e.g. performed at ±100 kV and ±200 kV first). Each test location is documented and photographed for test report clarity.

e. After each test discharge, the SUT, EIDs & platform are checked for proper operation. Testing will not be continued until the problem and its effect on the SUT has been assessed as well as potential impacts on the SUT if testing is continued.

f. The SUT and EIDs may be instrumented. EID bridgewire resistances (live or inert) may be measured before and after each discharge to check for degradation and firing.

g. The typical HESD instrumentation system (e.g. Nanofast) has a self-calibration feature.



Note: May use two Power Supply / Capacitor banks – one positive & one negative for test convenience.

Instrumented, tactical, inert rocket in #3 rocket pod tube. All other tubes filled with dummy rockets. Telemetry Unit buried in rocket tube.

EUT suspended ~ 1 meter above ground with non-conductive sling

Figure E-2. Typical HESD Test Setup.

Figure E-3. HESD Test Setup.

Figure E-4. Typical HESD Test.

Figure E-5. Typical HESD Test.

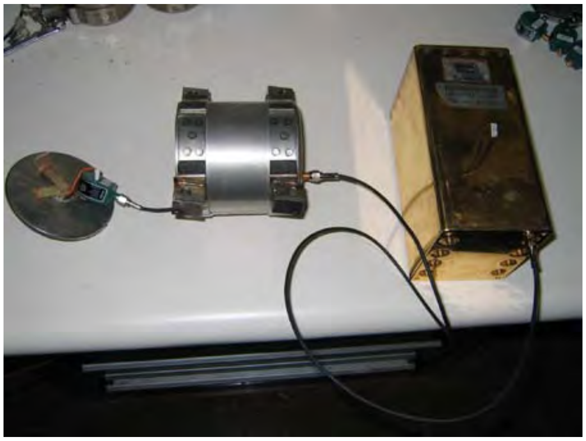


Figure E-6. Typical Test Instrumentation.

5. TEST PROCEDURES.

The specific test procedures will be conducted IAW the test plan. The exact order of testing may be altered for test efficiency with the approval of the test manager. Any changes to these procedures will be noted in the test report. HESD testing is potentially hazardous to personnel. Safety procedures must be initiated IAW the test facility Standard Operating Procedures (SOP).

5.1 Calibration (to verify simulator produces specification waveform):

a. Set up the HESD generator with settings that past experience has shown to discharge per the specification waveform parameters. Set up the voltage divider network to monitor the capacitor bank charge voltage. Place the high voltage toroid on a conductive surface to ground as a test setup checkout.

b. Secure the test area and insure that personnel are at a safe distance.

c. Charge up the HESD generator to the positive specification level.

Note: if the possibility of SUT damage is envisioned, calibration and testing may be stepped up (e.g. performed at ±100 kV and ±200 kV first).

d. Discharge the HESD generator by contacting the handheld ground return rod directly to the toroid. Repeat, adjusting the HESD generator until the HESD criteria is obtained.

e. Record the HESD generator calibration settings.

f. Repeat calibration for the negative specification levels.

g. Verify that the HESD generator is in a safe configuration.

5.2 ESAD Test.

a. Set up the SUT for HESD testing using the same test equipment and settings used during calibration. Set up the voltage divider network to monitor the capacitor bank charge voltage. Set up the instrumentation equipment (e.g. to monitor EID current / energy coupling), if applicable. Electrically isolate the SUT. Place the HESD toroid in contact with the SUT.

b. Connect the instrumentation to the data processing/collection system (oscilloscope and PC) using the telemetry system and fiber optic cables.

c. Place the SUT in a test plan matrix specified configuration and mode.

d. Verify data acquisition and instrumentation equipment operation. Exercise self-calibration features, if any. Test EIDs and their associated firing circuit continuity and operation.

e. Power up the SUT and run pre-test baseline functional checks.

f. Secure the test area and insure that personnel are at a safe distance.

g. Charge the HESD generator to the positive specification level using the settings determined during calibration. Then remove the generator from the circuit. Because the SUT is isolated, the charge will distribute itself from the toroid over the SUT structure simulating HESD charging effects. Note: if the possibility of SUT damage is envisioned, testing may be stepped up (e.g. performed at ±100 kV and ±200 kV first).

h. Discharge the charge on the SUT by moving the HESD ground contact probe toward an SUT test point until discharge occurs.

i. Verify the HESD generator is in a safe configuration.

j. After each discharge, examine the data to ensure that the HESD criteria were simulated, the test data is adequate, and the data is within pass/fail criteria. Calculate safety margins and measure EID bridgewire resistance (live or inert), if required.

k. After each discharge, perform a visual check for any HESD induced damage.

l. After each discharge, repeat SUT operational checks and compare to baseline.

m. If there are susceptibilities, determine the SUT components affected, the required steps to recovery (e.g. cycling power) and the recovery time. If possible (if SUT not damaged), verify the repeatability of the susceptibility and determine the threshold and safety margins, if necessary.

n. record the following for each discharge and mark on plots.

(1) Stimulus waveform parameter data / plots.

(2) Test configuration / test mode

(3) Test discharge point.

(4) Post-discharge functional check pass/fail results.

(5) Visual damage inspection results.

(6) SUT responses (e.g. components affected, wire/cable currents, EID currents, SUT upsets, recovery times, etc.).

(7) EIDs monitored; their calculated SMs and whether they met requirements.

(8) EID bridgewire resistance and determination of degradation, if required.

(9) Date, time, location.

o. Repeat the test procedure for the negative HESD transient.

p. Repeat the test procedure for all test discharge points.

q. Repeat the test procedure for all test modes and configurations.

6. DATA PRESENTATION.

Table E-3. Example HESD Test Run Data Sheet.

Test Config	**Test Mode**	**Discharge Location**	**Shot #**	**EID Name**	**Test Pulse Parameters**	**EID level (J) /Cable Current (mA)**	**Safety Margins (dB)**	**EID BW Resist. (Ω) Pre/Post**	**Pass / Fail**
In Storage Container	Un-powered Not operating	Bottom Left corner		Missile Motor EID #1	+300 kV				Visual chk: Funct chk: EID SM: BW resist:
					-300 kV				Visual chk: Funct chk: EID SM: BW resist:
				Missile Motor EID #2	+300 kV				Visual chk: Funct chk: EID SM: BW resist:
					-300 kV				Visual chk: Funct chk: EID SM: BW resist:

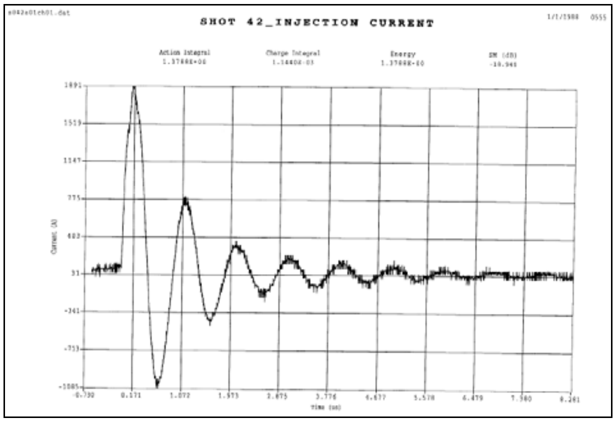


Figure E-7. Typical Injection Current Plot.

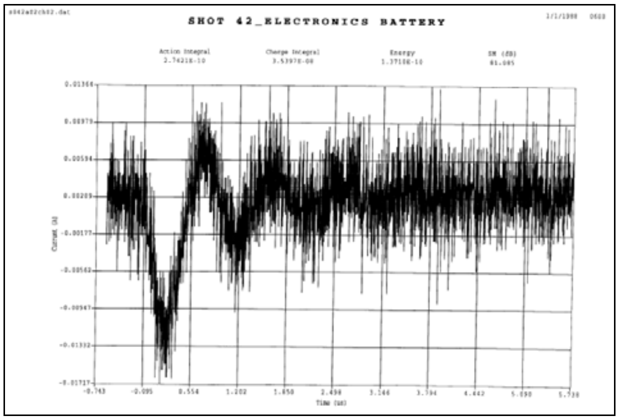


Figure E-8. Typical Battery EID Data Plot.

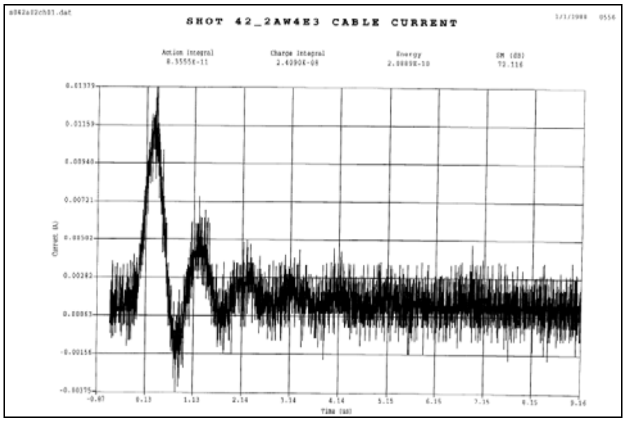


Figure E-9. Typical Cable Current Data Plot.

Figure E-10. Typical HESD Attachment Damage to Missile Case.

7. DATA ANALYSIS.

a. The test data will be compared to the applicable criteria set forth in MIL-STD 464A, the SUT specification, and SUT test plan and the pre-event baseline measurements to determine the extent to which the test criteria are met and the effects of the HESD test environment on the SUT. Test anomalies will be assessed to determine if they should be classified as SUT failures and if so, further assessed with regards to causes, test parameters at which they occurred, mission impact and safety. Safety margins will be calculated and compared to the criteria, as necessary.

b. The instrumentation sensor used for EIDs is a current probe (see Figure E-1). EID specifications often specify a Maximum No-Fire Current. However, this specification is a DC test value, not a transient test value and cannot be used to determine an accurate HESD safety margin. Therefore, the current test data (see Figure E-7) is integrated over time and then is divided by the resistance using the equation $E = \int I^2/R \, dt$ to obtain the energy. This result can be used to determine a safety margin typically using a Maximum No-Fire Energy (MNFE) of 17.6 milli-Joules (mJ). Refer to Section 4.4 of this document for more information on safety margin calculation.

c. Some HESD test facilities may not be able to test to the full 300 kV specification level. Therefore, the HESD test data may require extrapolation to the 300 kV specification level. If the test discharge current level available during the test is less than the criteria, then the measured (HESD induced) current, voltage or energy can be extrapolated analytically to the required criteria. The extrapolation expressions are defined as follows:

<u>ENERGY:</u> $E_{\text{extrapolated}} = E_{\text{induced}} (I_{\text{criteria}} / I_{\text{test}})^2$

where $E_{\text{extrapolated}}$ = the extrapolated value of the induced energy (J)

The extrapolated value for energy can then used in place of the measured induced energy value to calculate the safety margin or the following expression can be used:

$SM_{\text{extrapolated}}$ (dB) = $10 \log_{10} \{(E_{\text{MNF}} / E_{\text{induced}}) \times K\}$

where $K = (I_{\text{criteria}} / I_{\text{test}})^2$

<u>CURRENT:</u> $I_{\text{extrapolated}} = I_{\text{induced}} (I_{\text{criteria}} / I_{\text{test}})$

where $I_{\text{extrapolated}}$ = the extrapolated value of the induced current (A)
I_{criteria} = the required (criteria) discharge current (A)
I_{test} = the actual discharge current amplitude measured during test (A)

The extrapolated value for current can then used in place of the measured induced current value to calculate the safety margin or the following expression can be used:

$SM_{\text{extrapolated}}$ (dB) = $20 \log_{10} \{(I_{\text{MNF}} / I_{\text{induced}}) \times K\}$

where $K = (I_{\text{criteria}} / I_{\text{test}}) < 1$

<u>VOLTAGE:</u> $V_{\text{extrapolated}} = V_{\text{induced}} (I_{\text{criteria}} / I_{\text{test}})$

where $V_{\text{extrapolated}}$ = the extrapolated value of the induced voltage (V)

The extrapolated value for voltage can then used in place of the measured induced voltage value to calculate the safety margin or the following expression can be used:

$SM_{\text{extrapolated}}$ (dB) = $20 \log_{10} \{(\text{MFV} / V_{\text{induced}}) \times K\}$ where $K = (I_{\text{criteria}} / I_{\text{test}}) < 1$

APPENDIX F. PRECIPITATION-STATIC (P-STATIC).

1. APPLICABILITY.

a. This Appendix provides general test methods to assess the safety and survivability of the SUT to the effects produced by a precipitation-static (P-Static) Electromagnetic Environment (EME). This Appendix is meant to act as a guide and is not a replacement for a test plan.

b. The P-Static environment is applicable to all aircraft and to some ground vehicles and equipment that have antenna-connected equipment.

c. P-Static testing is applicable at the system level IAW the equipment and/or platform specification. “System level” in this case, generally refers to the SUT as integrated into a platform such as an aircraft or ground vehicle. P-Static testing is applicable to the platform and its radios and other equipment operating to determine if their operation is degraded.

2. REQUIREMENTS.

a. Aircraft electrostatic charging can occur due to precipitation (dust, sand, rain, snow and/or ice) striking and flowing on the surface of the aircraft or ground vehicle. This charge can couple to aircraft or ground vehicle receiver antennas causing interference with the receivers and other on-board electronics and, in turn, causing degradation of the aircraft performance. The accumulated charge develops a voltage on an aircraft or ground vehicle with respect to the surrounding air (corona). When the voltage becomes high enough, the air periodically breaks down in an impulse fashion at sharp contour points where the electric field is the highest. The sharp impulses produce broadband radiated interference which can degrade antenna-connected receivers, particularly lower frequency receivers. The impulses can occur so rapidly that the receivers produce only a hissing sound and become useless. In addition, puncture of structural materials and finishes and shock hazards from charge accumulation can occur. Exposure of the aircraft to the P-Static environment may also cause safety hazards (e.g. coupling to aircraft EIDs). Aircraft or ground vehicle crew may be affected (shocks) during flight and ground personnel may be affected after landing. The typical method of addressing P-Static is to ensure that all external sections of the aircraft or ground vehicle structure are at least mildly conductive (Meg-Ohms) and electrically bonded together in order to dissipate charge. In addition, P-Static dischargers (pointed rods) are often added on aircraft well away from its antennas to bleed off the aircraft charge in a more even manner and at a lower voltage level. Precipitation-static is sometimes referred to as “high-voltage corona”.

b. The simulated P-Static environment is defined in MIL-STD-464. The maximum P-Static charge voltage is ± 300 kV. The appendix of MIL-STD-464 defines an equation for estimating the total charging current as follows:

$$I_t = I_c \text{ x } S_a \times V/600$$

where:
I_t = total charging current in µA
I_c = charging current density in µA/m^2
S_a = frontal surface area in m^2
V = speed of aircraft in knots

Using the MIL-STD-464 general current density data and the statement that in rare cases I_c levels as high as 400 µA/m^2 have been observed, I_t has been calculated for various Army aircraft in Table F-1.

Table F-1. Total Charging Current Calculations.

Aircraft	**Estimated Frontal Area (m^2)**	**Maximum Speed (knots)**	**I_t (uA)**
AH-64 Apache	7	150	420,000
OH-58D Kiowa	4	147	235,200
UH-60A Blackhawk	11	139	611,600
UH-60L Blackhawk	11	150	660,000
CH-47D Chinook	17	170	1,156,000
C-12 Huron	8	294	940,800
C-23 Sherpa	10	251	1,004,000

The results of Table F-1 indicate the maximum worst case I_t. Charge rates lower than this will produce the same aircraft level effects and are much easier to produce without special, more expensive test equipment. Lower charge rates (e.g., 5 mA) can therefore be used, still limited by the 300 kV level. Charging at a lower rate will take longer but will have the advantage of more accurately determining the levels at which corona, radio degradation, etc. occur. The charge will be increased to the 300 kV limit or to when discharges (streamer or arcing) occur or radio interference becomes significant, whichever occurs first. The level at which corona is observed and its locations will also be determined.

c. When exposed to the P-Static environment, the SUT (and its platform, if any) shall meet the performance requirements detailed in their equipment specifications and test plan. In accordance with MIL-STD-464, the following is required as a minimum:

(1) Electrostatic Charge Control - The system shall control and dissipate the build-up of electrostatic charges caused by P-Static effects, fluid flow, air flow, exhaust gas flow, personnel charging, charging of launch vehicles (including pre-launch conditions) and space vehicles (post deployment), and other charge generating mechanisms to avoid fuel ignition and ordnance hazards, to protect personnel from shock hazards, and to prevent performance degradation or damage to electronics.

(2) Precipitation static (P-Static) **-** The system shall control P-Static interference to antenna connected receivers onboard the system or on the host platform so that system operational performance requirements are met. The system shall protect against puncture of structural materials and finishes and shock hazards from charge accumulation. Note that P-Static requirements for Army aircraft are also called out in ADS-37A-PRF as follows.

(a) Control of Static Electricity - The aircraft shall control and dissipate the build-up of electrostatic charges caused by P-Static effects, fluid flow and air flow to avoid fuel ignition and ordnance hazards, to protect personnel (ground servicing and flight crew) from shock hazards, and to prevent performance degradation or damage to electronics to include antenna coupled P-Static interference. The system shall preclude damage or upset from electrostatic discharge (ESD) due to handling of the equipment by operating or maintenance personnel.

(b) Precipitation Static - The aircraft shall control P-Static interference to receivers and other electronics on board the aircraft such that the aircraft's performance requirements are met.

(c) Static Electricity Analysis - A static electricity analysis will be conducted to determine maximum airframe charging rates for vertical and horizontal flight as well as hovering near the ground. The analysis will determine the adequacy of proposed design techniques to control P-Static noise in avionics and prevent hazards to personnel during sling-load operations, maintenance, rearming, and refueling. The analysis shall specifically address conditions experienced by a hovering helicopter, near the ground level in dry dust, sand and snow conditions.

(d) Static Electricity Tests - Static electricity tests shall be conducted to demonstrate the protection of personnel, equipment, fuel systems and ordnance from electrostatic build-up and discharge. Aircraft level tests shall be conducted on a fully configured aircraft; which means that all mission equipment, including complete provision items and applicable EEDs, are installed when these tests are performed.

(e) Aircraft Component Static Electricity Tests - As a minimum, the following full-scale production subsystems and equipment shall be tested using simulated static electricity discharges: fuel subsystem components and weapons subsystem components.

(f) P-Static Tests - A P-Static test will be performed by electro-statically charging the aircraft until corona develops. Avionics, fuel system, flight control and other equipment will be monitored for unintentional responses linked to P-Static build-up and discharge. Charge/discharge currents will be measured. Receiver noise floors shall be monitored for degradation and the amount of degradation shall be quantified.

(g) P-Static Control Tests - Testing shall be conducted to demonstrate the effectiveness of all P-Static dissipation devices on the aircraft. Results shall be used to demonstrate that the aircraft does not attain voltage potentials which are hazardous to personnel for the expected charging conditions.

2.1 SUT performance specification requirement wording for P-Static is often different and/or more detailed than that in MIL-STD-464A. Following are some typical performance requirements:

a. The SUT shall remain safe and meet its performance requirements while being subjected to the P-Static environment at the system (aircraft) level. The charge limit shall be 300 kV or when discharges (streamer or arcing) occur or radio interference becomes significant.

b. When the SUT contains ordnance or safety critical circuits / functions (e.g. EIDs,), the SUT ordnance and safety critical circuits / functions shall meet the safety margin requirements during and after exposure to the P-Static specification environment. The SUT EIDs, if any, will be considered to have passed when subjected to the P-Static environment, if they exhibit sufficient safety margins. There are two classifications of EID situations, safety and reliability. In accordance with MIL-STD-464A, safety (hazardous) EIDs shall maintain a 16.5 dB safety factor below the MNF parameter (based on not exceeding 15% of the EID MNF) and reliability (non-hazardous) EIDs shall maintain a 6 dB safety factor below the MNF (based on not exceeding 50% of the MNF). When empirical MNFE for a specific, qualified, one-Watt no-fire EED is lacking, the Army uses a level of 17.6 mJ based on previous testing of a series of Stinger launch/flight motor EEDs. MIL-STD-1316 specifies a minimum firing voltage of 500 volts for an ESAD.

c. When the SUT contains flight critical circuits / functions, the SUT flight critical circuits / functions shall operate through exposure to the P-Static specification environment without damage, upset, or degradation outside of its performance tolerances.

d. When the SUT is integrated into a platform, P-Static testing is performed at the platform level. If so, the platform level requirements must also be taken into account (e.g. the SUT response to the P-Static environment must preclude upset, degradation and damage to its aircraft platform which would preclude its safe return and landing).

3. PURPOSE.

The purpose of this testing is to verify the ability of the SUT to withstand the P-Static environment IAW its specification performance requirements detailed in the test plan. A typical test purpose follows:

The purpose of the P-Static testing is to determine if exposure of the SUT / platform to the P-Static environment results in interference with the SUT / platform receivers and other platform electronics due to antenna coupled P-Static. In addition, P-Static testing may be performed to ensure that exposure of the SUT / platform to the P-Static environment does not cause safety hazards (e.g. coupling to aircraft EIDs, personnel shocks).

4. TEST SETUP.

4.1 Test Equipment.

a. A listing of the typical equipment used during P-Static testing is provided in Table F-2. The test report shall include the actual test equipment used along with their serial numbers and calibration dates, if applicable.

(1) The test measurement equipment is required to operate up to and through the frequency range of the SUT / platform radios.

(2) Test Software: All software used, including measurement system software, SUT software, instrumentation and test set software shall be documented as to dates, developer, version number, etc. Any changes to the software during the test shall be documented. Special SUT software to better monitor SUT operation during testing is permissible, but shall not influence the test results.

Table F-2. P-Static Typical Test Equipment List.

Hardware	Model Number	Manufacturer	Comments
Simulator	7 Maxwell capacitors connected in series comprising a 1000 pF, 300 kV cap bank	In-house design	simulates a +/- 300 kV HESD waveform
Toroid	---	In-house design	Used to transfer charge onto SUT
High Voltage Cables	---	In-house design	Used between simulator & toroid
Power Supply	8300	Hipotronics	360 kV power supply used to charge caps
Voltage Divider	KVM400	Hipotronics	Used to measure charge voltage
Personnel Computer	--	Gateway	

4.2 Instrumentation.

SUT instrumentation is very unique due to the variation in SUTs. However, the following general statements can be made. Any alterations or modifications made to the SUT, such as adding in an instrumentation package or conductive monitoring leads may either enhance or decrease the SUT EME response. Monitoring of SUT performance through installations of special monitoring circuitry in the SUT is permissible; however these modifications shall not influence test results. Instrumentation and break-outs used to tie in the instrumentation to the test setup shall not influence the test results. The break-out shall not modify the signal impedance or the bonding, grounding and shielding scheme of the cable or SUT box it is tied into. The instrumentation itself may be susceptible to the EME. To minimize these issues, fiber-optic based instrumentation is preferable. Any conductive instrumentation leads required should use twisted, shielded pair wiring and be run internal to the SUT to minimize its exposure to the environment. Whenever possible, the instrumentation equipment should be buried inside the SUT with only the fiber optic leads exiting the SUT. There are a number of instrumentation options, some or all of which may be employed for P-Static testing IAW the test plan:

a. Test environment measurement instrumentation: The P-Static test environment parameters shall be recorded to determine the adequacy of the simulated P-Static environment. This information shall be digitized, reviewed, and stored for environment compliance analysis and inclusion in the test report.

b. SUT / test setup monitor cameras: Monitor cameras may be set up to observe the SUT / platform during testing. The cameras are connected to monitors in a shielded instrumentation room using fiber optic lines. The cameras may be placed within shielded enclosures.

c. SUT operational / check-out equipment: A test set or other instrumentation package may be used to check out the SUT before and after each test event. The equipment should be removed from the test setup during the test event (if it is not to be used during the test event).

d. The SUT may be instrumented. This is not typical because usually the SUT / platform operator just monitors the SUT / platform for proper operation (e.g. listens for noise on radios). If performed, SUT instrumentation typically consists of using current probes to measure the current coupled to one or more SUT wires / cables due to the P-Static environment. The same or different test sets and instrumentation packages used for SUT checkout may also be used to monitor SUT operation during testing. If the test set or other instrumentation packages are part of the test setup, caution should be exercised that they do not affect the test results. The test set itself should be protected from the effects of the P-Static environment and placed as far away as possible. Any test set interface cabling should be well shielded to minimize coupling.

e. The SUT EIDs may be instrumented to monitor them while the SUT / platform is subjected to the P-Static environment to determine their safety margins. In addition, SUT platform (e.g. aircraft) EIDs may be instrumented if the SUT is being tested while it is mounted on a platform. Typically, an optical sensor is used (see Table F-3) similar to the HERO instrumentation. The optical sensor based instrumentation is preferred over conductive type sensor instrumentation because it does not use conductive instrumentation leads thereby eliminating the conductive lead’s potential impact on the ordnance system’s P-Static response.

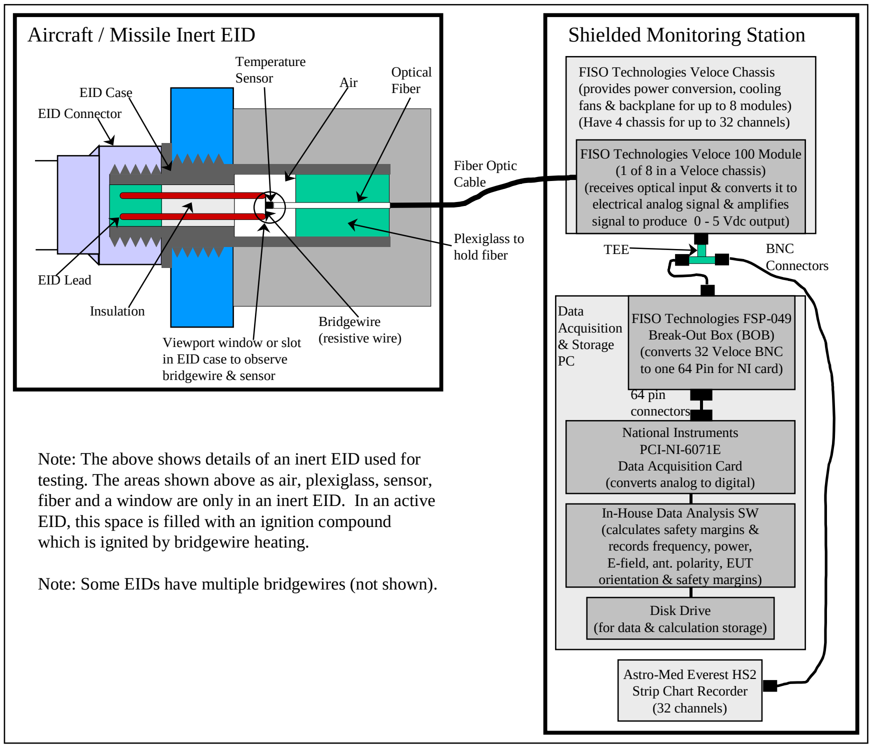
f. P-Static testing is typically performed using ordnance items that have been modified to remove all explosives, pyrotechnic, and combustible materials, including the EIDs. Test personnel instrument and install inert EIDs (a typical EID description table is shown in Table F-4) IAW Figure F-1 with temperature sensors and optical fibers. The EIDs typically contain resistive bridgewires which heat up as a current passes through them. The temperature sensors are used to sense the amount of bridgewire heating from which the P-Static induced current passing through them can be determined. Instrumented EIDs are installed in the ordnance item at precisely the same location as the original EID. The fiber optic lines from instrumented EIDs are routed to the outside of the SUT and then to a shielded instrumentation room. Inside the shielded room the lines are connected to data acquisition modules. Each module converts the fiber optic signal to an analog electrical signal. The module outputs are routed to a laptop PC data acquisition card for data reduction and to an Astro-Med strip chart recorder for real time viewing. Test software extracts the desired test parameters and calculates the EID safety margins by comparing the EID calibration data to the measured P-Static induced EID currents.

Table F-3. Typical EID Instrumentation Equipment List.

Hardware	Model Number	Manufacturer	Comments
Inert, Instrumented EIDs		In-house	
Temperature Sensor		OPSENS/FISO/Metricor	One for each EID bridgewire
Optical Fiber		OPSENS/FISO/Metricor	One for each temperature sensor
Signal Conditioner Chassis		OPSENS/FISO/Metricor	Provides power conversion, cooling & backplane for Modules.
FO receiver modules	100	OPSENS/FISO/Metricor	One for each instrumented bridgewire
BNC TEE			One used at each module output.
Data Acquisition PC			
Data Acquisition SW	--------	IN-house	Calculates SMs, Records SMs, Frequency, Power, E-Field, Ant Pol, and SUT orientation.
Data Acquisition Card	PCI-NI-6071E	National Instruments	Converts analog signals to digital signals
Strip Chart Recorder	Everest HS2	Astro-Med	32 Channel Records Veloce 100 output.
Fiber Optic Cables			

Table F-4. Typical Instrumented EID / Cable Description.

EID	EID Type	MNFC / MNFE	Required Safety Margins	Bridgewire Resistance (Ω)	Comments
Control Battery	304-JTM-050	17.6 mJ	6.0 dB for reliability	0.5 (two 1± 0.1 BWs in parallel)	1 Control Battery EID instrumented & tested. Used Pearson 2877 probe.
Electronics Battery	MIS-40737A	17.6 mJ	6.0 dB for reliability	0.5 (two 1± 0.1 BWs in parallel)	1 Electronics Battery EID instrumented & tested. Used Pearson 2877 Probe.
Rocket Motor Igniter	PN: 2-101400-1 Dwg: 13287151 Mgr: Pacific Scientific	17.6 mJ	16.5 dB for safety	1.0	1 Rocket Motor Igniter EID instrumented & tested. Used Pearson 2877 Probe.
Short Delay (1.2+.6-.4ms) Fuze Detector	2-400020-1	3.4 mJ	16.5 dB for safety	2.5	2 Fuze Detector EIDs instrumented & tested. Used Pearson 2877 Probe.
Long Delay (30±7.5ms) Fuze Detector	2-400020-3	3.4 mJ	16.5 dB for safety	2.5	2 Fuze Detector EIDs instrumented & tested. Used Pearson 2877 Probe.
2AW4E3 cable harness (near J1 conn)	The cable harness was instrumented to measure the current induced on it by the environments. This data was taken for informational purposes only for the contractor to use in their P-Static analyses. Used a Pearson 91550-2 probe.				



Note: The above shows details of an inert EID used for testing. The areas shown above as air, plexiglass, sensor, fiber and a window are only in an inert EID. In an active EID, this space is filled with an ignition compound which is ignited by bridgewire heating.

Note: Some EIDs have multiple bridgewires (not shown).

Figure F-1. Typical Optical Thermocouple Instrumentation Block Diagram.

4.3 <u>Pre-Test Evaluation</u>.

a. A pre-test evaluation is performed to include the following. This evaluation is used for test planning and can often reduce the amount of testing that is required.

(1) Determine / select the most likely P-Static streamer, arcing, and corona discharge points (e.g. antennas, wing-tips, intentional charge dischargers).

(2) Determine the radios / antennas to be checked, their operating frequency ranges and their operating modes and procedures.

(3) Determine the most / least susceptible SUT configurations.

(4) Determine the most / least susceptible SUT modes of operation.

(5) Determine the probable Ports of Entry (POEs).

(6) Determine the bulk current measurement points.

(7) Perform an energy coupling analysis to identify the type and capability requirements for the data acquisition system.

(8) Determine what critical SUT data is required to be instrumented and monitored.

(9) Determine which EIDs are to be instrumented and measured and how.

(10) Determine SUT / platform flight / mission / safety critical functions and circuits.

(11) Determine SUT P-Static discharger protection features and their predicted performance and whether they are repairable or replaceable. Determine if and how all external sections of the aircraft structures are at least mildly conductive and electrically bonded together in order to dissipate charge.

(12) Determine verification and pass/fail criteria and required safety margins.

(13) Determine the SUT operating and check-out procedures.

b. Pre-existing analyses and test data from previous tests may be evaluated and incorporated into the test planning and pre-test analysis in order to enhance and reduce the scope of the new testing.

c. The SUT status shall be verified and documented prior to P-Static testing, using baseline Built-In-Test (BIT) checks, system operational performance checks, and functional performance measures.

4.4 Setup.

Test setups vary depending on the SUT. Some typical test setups and photographs are shown in Figures F-2 through F-6. Following are general test setup guidelines.

a. The P-Static requirement is verified by aircraft / ground vehicle level testing. The aircraft / ground vehicle shall be electrically isolated either by being raised up several feet on a non-conductive platform or by using a non-conductive sling and a crane. The charging probe or salient shall be placed at various test points on the aircraft / ground vehicle. If there are materials that are non-metallic (e.g. canopies, fiberglass panels) or are covered with non-conductive finishes, they should be designated as test points as they are more likely to accumulate electrostatic charge. Each test location will be tested to both positive and negative polarities.

b. Using a slow (e.g. 5 mA) charging rate and starting from an initial charge level of 25 kV, the charge will be increased to the 300 kV limit or to when discharges (streamer or arcing) occur or radio interference becomes significant, whichever occurs first. In addition, the level at which corona is observed and the locations and effects of any corona and discharges will be monitored and recorded. It will be determined if the corona or discharges degrade the aircraft performance (e.g. radio communication interference) (subjective call of the pilot) or creates a safety hazard (e.g. shocks to pilots). In addition, the SUT and/or platform EIDs may be monitored for safety hazards.

c. The aircraft / ground vehicle will be powered using its APU, when available, in order for the pilots to monitor the performance of the radios and all other aircraft equipment while the aircraft is charged. The SUT will be powered and operating. The radios and other equipment being monitored shall be operated in all their normal configurations and modes.

d. During and after each test event, the SUT / platform will be checked for proper operation and damage and to determine if further testing is possible. If damage occurs, it will be documented and assessed. Testing will not be continued until the problem is completely understood, and its effect on the SUT / platform has been assessed as well as potential impacts on the SUT / platform and results if testing is continued.

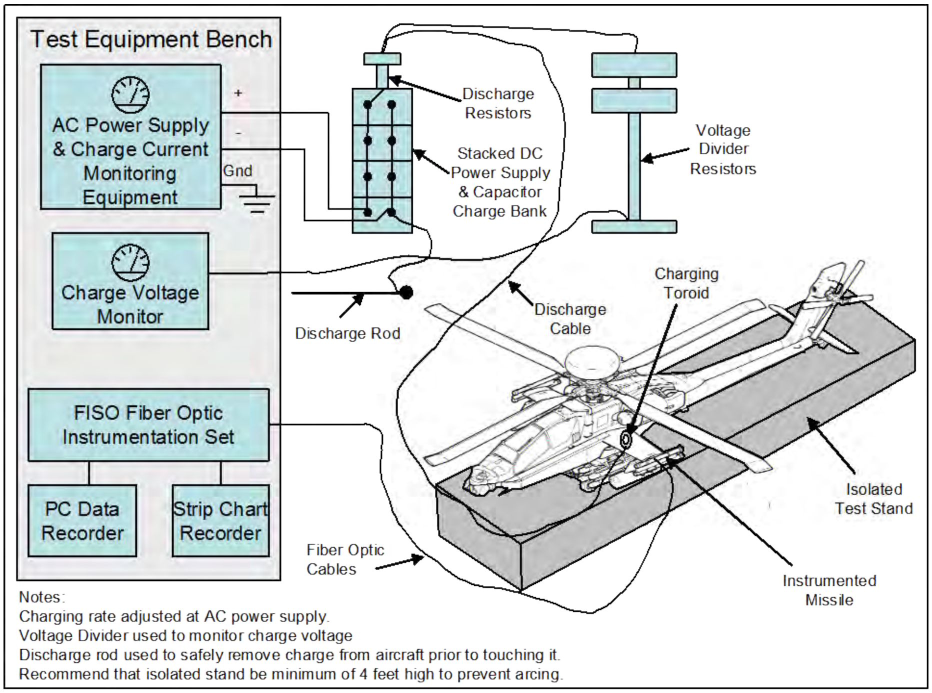
e. P-Static testing is potentially hazardous to personnel. Safety and security procedures must be initiated and the safety officer notified IAW P-Static Standard Operating Procedures (SOPs). Voltage probes will be used to measure the static voltage on the various equipment that the crew will be near or contact (e.g. radio controls) during the testing. In addition, the crew will be bonded to the contacted equipment (e.g. the instrument and control panels) during the testing. Charge levels on the equipment near the crew will be limited to not exceed the point at which personnel can detect a shock.

f. The SUT and/or EIDs may be instrumented. The EID bridgewire resistances (live or inert) may also be measured before and after each test event to check for degradation and firing. Care must be taken so that the installation of the SUT instrumentation does not compromise or reduce the inherent shielding of the SUT.

g. EIDs may be instrumented. When the SUT or system contains EIDs or firing circuits it can be tested in either of two methods. One method is a “go / no-go” type of test with live EIDs but with no EIDs or firing circuits instrumented. The live EID bridgewire resistances are checked before and after each discharge and the measurements compared to check for degradation and firing. With this method the test is repeated a minimum of 10 times (22 is preferable) with a fresh EID each time to provide some measure of confidence that the EIDs will remain safe. The second method is to test using inert, instrumented EIDs and firing circuits. With this method, safety margins can be determined.

h. Sufficient time shall be allowed for test equipment to stabilize prior to performing calibration and testing, typically five minutes. Measurement receivers and transducers are subject to overload. Periodic checks shall be performed to assure that an overload condition does not exist.

i. Calibration of the test equipment shall be traceable to the National Institute of Standards and Technology (NIST). The Nanofast instrumentation system for each EID is calibrated by applying to the bridgewire a known step input current with a duration that is at least 10 times the thermal response time of the EID. The instrumentation output is measured and recorded. This calibration establishes the relationship of the step input into the EID bridgewire to the output parameter of the instrumentation. This instrumentation output value can then be related to the EID MNFE. The calibration also establishes the instrumentation system’s dynamic range and minimum sensitivity (the minimum detectable current, MDC).



Notes:
Charging rate adjusted at AC power supply.
Voltage Divider used to monitor charge voltage
Discharge rod used to safely remove charge from aircraft prior to touching it.
Recommend that isolated stand be minimum of 4 feet high to prevent arcing.

Figure F-2. Typical P-Static Test Setup.

Figure F-3. Example P-Static Test Setup.

Figure F-4. Example P-Static Test Setup with Charge Generator & Voltage Divider.

Figure F-5. Example P-Static Test Setup – Isolation Test Stand Close-up.

Figure F-6. Example P-Static Test Setup – Discharging the Aircraft.

5. TEST PROCEDURES.

The specific test procedures will be conducted IAW the test plan. The exact order of testing may be altered for test efficiency with the approval of the test manager and test safety officer. Any changes to these procedures will be noted in the test report. P-Static testing is potentially hazardous to personnel. Safety and security procedures must be initiated and the safety officer notified and involved IAW the test facility Test and Safety Standard Operating Procedures (SOP).

5.1 Calibration.

a. Calibration of the test equipment shall be traceable to the NIST.

b. P-Static Test Setup Calibration (to confirm proper operation of the test instrumentation and capacitor banks):

(1) Set up the voltage divider network to monitor the power supply charge voltage and a current meter to monitor the charging current.

(2) Set up the P-Static generator with settings that past experience has shown to charge per the required test parameters but set the output to minimum.

(3) Secure Test Area and initiate SOP for P-Static testing.

(4) Place the high voltage toroid on a conductive surface with a 1 Meg-Ohm resistance to ground as a test setup checkout.

(5) Slowly adjust the generator output upward in 25 kV steps from zero to produce up to a 0.4 Ampere current charging while not allowing the charge voltage to go over + 300 kV.

(6) Monitor the operation of the test setup and instrumentation and ensure that it is working correctly.

(7) Record the P-Static generator calibration settings.

(8) Repeat for the -300 kV test polarity.

(9) Allow the charge to self-discharge for a period of time. Then discharge the remaining charge to ground through a 1 Meg-Ohm resistor using the safety wand. Verify that the P-Static generator is in a safe configuration.

5.2 EID Instrumentation Calibration:

a. Instrument the EIDs.

b. Test the EIDs and their associated firing circuit's continuity to ensure that their bridgewires and associated firing leads are intact and operational.

c. Inject a range of current levels below the EID MNFCs through the EIDs and record the corresponding receiver output voltage levels. These are used to calculate receiver output voltage measurement vs. injection current in order to determine the safety margins. Verify the receiver output voltage readings at the safety margin levels using a multi-meter.

d. Check the EID instrumentation system operation and calibrate and 'zero out' the equipment, as necessary.

5.3 Test.

a. Place the SUT / platform in the P-Static test setup IAW the test plan using the same test equipment and settings used during calibration. Electrically isolate the SUT / platform by placing them on an isolated test stand and / or suspending them in a non-conductive sling at least one meter from the ground and away from other grounded items.

b. Set up the voltage divider network to monitor the power supply charge voltage and a current meter to monitor the charging current.

c. Install instrumentation, if required. Instrument the EIDs IAW the test plan, if required.

d. Connect the instrumentation to the data processing/collection system (oscilloscope and PC) using the telemetry system and fiber optic cables.

e. Place the SUT / platform in a configuration and mode to be tested IAW the test plan matrix.

f. Verify that the test data acquisition equipment (and instrumentation equipment, if any) is working properly.

g. Power up the SUT / platform and run pre-test baseline functional checks. Then power or un-power the SUT IAW test plan.

h. Secure the test area and insure that all personnel are at a safe distance from the SUT / platform. Notify the P-Static safety officer and initiate the test facility P-Static SOP.

i. Place the P-Static toroid in contact with the SUT / platform at a specified test point.

j. Set up the P-Static generator using the settings determined during calibration with the output turned OFF. Slowly increase the generator output in 25 kV intervals until the required charging level is attained without going over the +300 kV charge voltage limit. Because the SUT is isolated, the charge distributes itself from the toroid over the aircraft structure simulating P-Static charging effects.

k. Monitor the SUT / platform operation, especially the radio performance. Record any observed susceptibilities, damage and effects (e.g. radio noise, corona or arcing).

l. Power down the P-Static generator and verify that it is in a safe configuration.

m. Allow the aircraft to self-discharge for a period of time. Then discharge any remaining charge on the aircraft through a 1 Meg-Ohm resistor using the safety wand.

n. After each discharge, examine the test instrumentation to ensure that the environment parameters met the P-Static criteria, examine the SUT / platform measured data for adequacy, ensure that the data is within the pass/fail criteria and calculate safety margins, if necessary. Measure the EID bridgewire resistance, if required.

o. After each discharge, perform a visual examination of the SUT / platform for any P-Static induced damage.

p. After each discharge, repeat the SUT / platform operational checks and compare to the baseline.

q. If there are any susceptibilities, perform assessment to determine the SUT / platform components affected, the required steps to recovery (e.g. cycling power) and the recovery time. If possible (if SUT not damaged), verify the repeatability of the susceptibility and determine the susceptibility threshold. Calculate EID safety margins, if necessary.

r. Record the following for each discharge. Mark all data / plots with the SUT / platform, date, time, configuration, mode, etc.

(1) The test environment parameters developed and charge/discharge currents.

(2) The test point / test matrix intersection.

(3) The test configuration / mode.

(4) The results of the operational checks performed during the testing (e.g. radio degradation) and any other effects observed during testing (e.g. corona, arcing).

(5) SUT / platform responses (e.g. components affected, wire/cable currents, EID currents, SUT / platform upsets, recovery times, etc.). Save / print out instrumentation data (e.g. EID current strip chart data).

(6) The results of the pre- and post-discharge functional checks.

(7) The results of the post-test visual inspection (e.g. damage due to arcing across panel interfaces).

(8) The EIDs being monitored, if any, their calculated safety margins and whether they met requirements.

(9) The EID bridgewire resistance measurements and determination of degradation, if required.

s. Repeat the test procedure for the negative P-Static test polarity.

t. Repeat the test procedure for all test injection points.

u. Repeat the test procedure for all test modes and configurations.

6. DATA PRESENTATION.

a. The following will be presented in the test report:

(1) Test setup / equipment / instrumentation descriptions and photographs.

(2) Test configurations / modes / operational procedures used.

(3) Pre- and post-test check results.

(4) Calibration run data / plots.

(5) Test run data / plots.

(6) Redlines to test plan.

(7) Description of data reduction procedures / methods.

(8) Discussion of results, conclusions and recommendations.

b. A sample tabular data sheet is provided in Table F-5.

Table F-5. Example P-Static Test Run Data Sheet.

Test Configuration	**Injection Toroid Location**	**Test Pulse Parameters**	**Discharge Currents, Corona / Arcing / Streamering Development Levels, Anomaly Descriptions / Levels / Post Test Check Results**	**EID**	**EID level (J) / BW Resistance (Ω) (pre/post)**	**EID SM (dB)**	**Pass / Fail**
ATAS missile in top rail of AH-64D port (left) missile launcher	Left Wingtip Region	0.4 A charging current +110 kV attained					
		0.4 A charging current -220 kV attained					

7. DATA ANALYSIS.

The safety margins are calculated using the following formulas:

CURRENT: SM (dB) = 20 log10 (I_{MNF} / $I_{Induced}$)

where I_{MNF} = Maximum No-Fire current of EID (A)
$I_{induced}$ = measured value for the induced EID current (A)
(or Minimum Discernable Current, MDC, if signal below MDC)

VOLTAGE: SM (dB) = 20 log10 (MFV / $V_{Induced}$)

where MFV = Min ESAD capacitor Firing Voltage. Typically 500 Volts [1]
$V_{induced}$ = measured value for the induced ESAD cap firing voltage
(or Minimum Discernable Voltage, MDV, if signal below MDV)

ENERGY: SM (dB) = 10 $\log_{10}$ (E_{MNF} / $E_{Induced}$)

where E_{MNF} = Max No-Fire EID energy. Typically 17.6 milli-Joules [2]
$E_{induced}$ = measured energy induced in the EID circuit (J)

NOTE (1) - MIL-STD-1316 requirement for minimum firing voltage = 500 volts. Most initiators have minimum firing voltages in the 1000 to 2000 volt range.

NOTE (2) - Previous test programs have used 17.6 milli-Joules as the MNFE for safety margin calculations for MIL-I 23659 qualified, one watt, no-fire initiators. The MNFE value was established during testing of a series of Stinger Launch/Flight motor EIDs. The EID testing evaluated 72 initiators tested with a one amp per millisecond current ramp. The data was used to derive the MNFE and is documented in technical document RD-TE-87-4, MLRS AT2 Lightning Test Report.

The test data will be compared to the applicable criteria set forth in the SUT specification, and SUT test plan and the pre-event baseline measurements to determine the extent to which the test criteria are met and the effects of the P-static test environment on the SUT. Test anomalies will be assessed to determine if they should be classified as SUT failures and if so, further assessed with regards to causes, test parameters at which they occurred, mission impact and safety.

APPENDIX G. HAZARDS OF ELECTROMAGNETIC RADIATION TO FUEL (HERF).

1. APPLICABILITY.

This test method is applicable to equipment at the system level IAW the equipment specification. To provide the method to assess the survivability of a system with on-board fuel to the effects produced by its operational electromagnetic environment, with a 6 dB safety margin.

2. REQUIREMENTS.

a. The System-Under-Test (SUT) must remain safe and perform its mission essential functions during and/or after exposure to the systems operational electromagnetic environment, as specified in the system requirement document.

b. The EME is produced by the system itself and co-located equipment both friendly and hostile.

c. The test parameters are to be extracted from the applicable table in MIL-STD464. Fuels shall not be inadvertently ignited by radiated EMEs. The EME includes onboard emitters and the external EME. Compliance shall be verified by test, analysis, inspection, or a combination thereof."

3. PURPOSE.

The purpose of this test procedure is to verify the ability of the SUT while carrying fuel to withstand the required operational environment with a 6 dB safety margin applied.

4. TEST SET UP.

4.1 Test Equipment.

The typical equipment used in performing a HERF test on a system fueled by JP8 are the same high power transmitters used during operational testing, with the output increased to include the 6 dB safety margin. This testing is relatively simple and straight forward while using one of the safest fuels JP8. For more volatile fuels extreme measures may be required to protect test assets and personnel. For volatile fuels the containers will require evacuation and the introduction of fiber optics connected to a camera to monitor for sparks and arcs. The evacuation procedures should include but is not limited to the following; 1) the fuel container is completely filled, 2) nitrogen gas (inert) is applied to the container under positive pressure and flow, 3) the fuel is drained from the system as nitrogen is used to fill the void created, 4) nitrogen flow is continuous and provides positive pressure to insure the evacuation the fuel container.

4.2 Pre-Test Evaluation.

a. A pre-test evaluation will be performed to determine the primary fuel and if special precautions and methods are required.

b. The SUT status is verified and documented before HERF testing, using baseline self-test checks, system operational performance checks, and functional performance measures.

4.3 Setup.

a. The test facility is calibrated at the radial test distance required to provide the operational EME with 6dB margin.

b. The SUT is tested in minimum of four orientations with respect to the poynting vector, i.e., all four sides with special attention to the fuel container areas.

c. The SUT is instrumented and nitrogen purged, when extremely volatile fuel is used. Care must be taken so that the installation of the spark and arc detector, does not create an electrical path into the fuel container and that a positive pressure nitrogen purge is maintained.

d. The SUT is illuminated by the EME.

e. Throughout each HERF illumination, the SUT will be fully operational, in accordance with SUT operating procedures.

5. PROCEDURES.

a. Illuminate the SUT in various orientations (0, 90, 180 and 270 degrees).

b. Monitor the fuel for ignition, or monitor the instrumentation for light created in the fuel container by sparks or arcs.

c. Any problems that occur will be documented. Testing will not continue until the problem is understood and its effects on the SUT are assessed.

d. Document the failures and corrective actions.

6. DATA PRESENTATION.

a. Photos of the test setup and position.

b. Typical photos of instrumentation.

Table G-1. Example HERF Results.

Freq Number	Freq (Hz)	Polarity	Mod	F/I [V/m]	Result P/F
1	2.99E+06	V	AM	100	P
2	3.24E+06	V	AM	100	P
3	3.50E+06	V	AM	100	P
4	3.79E+06	V	AM	100	P
5	4.11E+06	V	AM	100	P
6	4.45E+06	V	AM	100	P
7	4.82E+06	V	AM	100	P
8	5.27E+06	V	AM	100	P
9	5.71E+06	V	AM	100	P

7. DATA ANALYSIS.

a. The EME data obtained from the EME Facility will be corrected to account for the percent error associated with the calibration system. The environment data will be compared and evaluated against the systems required criteria.

b. Compliance will be met if no fuel hazards are created.

c. Degradation cause(s) will be identified and impact(s) on the system’s mission will be discussed.

d. The system checkouts, environmental data, and test results will be processed and provided in graphical or table format.

e. Sample data presentation is provided in Table G-1. Note: data should be reported at the level of accuracy of the test equipment.

APPENDIX H. HAZARDS OF ELECTROMAGNETIC RADIATION TO ORDNANCE (HERO).

1. APPLICABILITY.

a. This test method is applicable to equipment at the system level IAW the equipment specification. To provide the methods to assess the survivability of the SUT Electrically Initiated Devices (EIDs) to the required HERO Electromagnetic Environment (EME) for the platform in all phases of the stockpile to launch sequence. This Appendix is meant to act as a guide and is not a replacement for a test plan. Compliance shall be verified by system-level test, analysis, or a combination thereof.

b. The ultimate objective is to provide supporting data, analysis, and reports relative to the suitability of the SUT's EIDs for use in its battlefield transportation to tactical electromagnetic environment (stockpile to launch sequence configurations) with respect to the MIL-STD-464 HERO requirements.

c. Determine the Maximum No-Fire Stimulus (MNFS) safety or reliability margin as applicable (16.5 dB for safety and 6 dB for reliability); and the Maximum Allowable Environment (MAE) for the SUT.

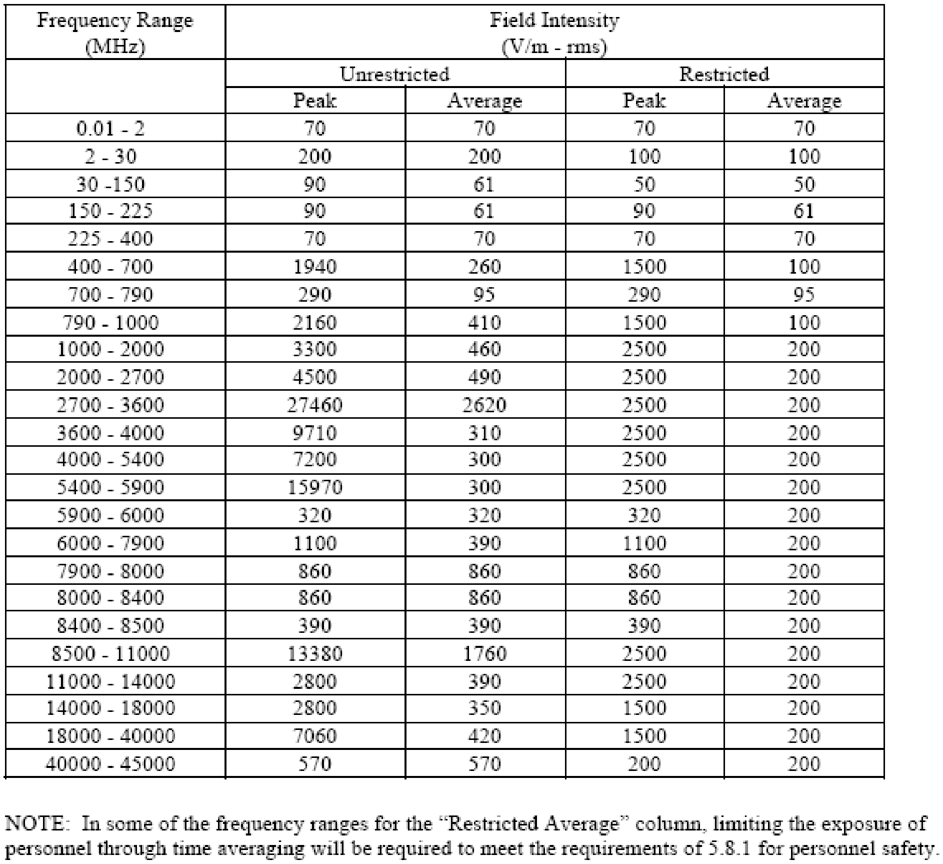
d. To establish the SUT data for inclusion into the Joint Ordnance Electromagnetic Risk Assessment Database (JOERAD).

2. REQUIREMENTS.

a. The SUT's EIDs shall be exposed and assessed to determine whether: the EIDs shall not inadvertently actuate, or experience degraded performance characteristics after exposure to the external EME levels of Table H-1 for both, direct Radio Frequency (RF) induced actuation of the EID and inadvertent activation of an electrically powered firing circuit as stated in MIL-STD-464A/B. It should also be noted that there are separate EME requirements for Army rotorcraft operations, the onboard ordnance should also comply with that EME. If threat levels cannot be achieved, a minimum field level of 200 V/m will be provided and then the instrumentation responses extrapolated to threat criteria level. MIL-HDBK-240[6] delineates HERO test procedures and methodology as well as maximum extrapolation values. There is also an EMROH (old term) environment for Army that denotes that time just prior to launch where electrically powered firing circuits are active; at this point the ground system EME has a 6 dB margin placed on it for reliability of ordnance. It this item is carried by a person then the item should be tested at no less than 200 V/m for operations.

b. Ordnance shall have a margin of at least 16.5 dB of MNFS for safety assurances and 6 dB of MNFS for other applications (reliability). A prematurely ignited EID that results in injury to personnel or destruction of property must meet a safety assurance margin of 16.5 dB to the MNFS. Prematurely ignited EIDs that result in unacceptable degradation in SUT performance must meet a safety margin of 6 dB to the MNFS.

Table H-1. External EME For HERO.



Frequency Range (MHz)	Field Intensity (V/m - rms)			
	Unrestricted		Restricted	
	Peak	Average	Peak	Average
0.01 - 2	70	70	70	70
2 - 30	200	200	100	100
30 -150	90	61	50	50
150 - 225	90	61	90	61
225 - 400	70	70	70	70
400 - 700	1940	260	1500	100
700 - 790	290	95	290	95
790 - 1000	2160	410	1500	100
1000 - 2000	3300	460	2500	200
2000 - 2700	4500	490	2500	200
2700 - 3600	27460	2620	2500	200
3600 - 4000	9710	310	2500	200
4000 - 5400	7200	300	2500	200
5400 - 5900	15970	300	2500	200
5900 - 6000	320	320	320	200
6000 - 7900	1100	390	1100	200
7900 - 8000	860	860	860	200
8000 - 8400	860	860	860	200
8400 - 8500	390	390	390	200
8500 - 11000	13380	1760	2500	200
11000 - 14000	2800	390	2500	200
14000 - 18000	2800	350	1500	200
18000 - 40000	7060	420	1500	200
40000 - 45000	570	570	200	200

NOTE: In some of the frequency ranges for the "Restricted Average" column, limiting the exposure of personnel through time averaging will be required to meet the requirements of 5.8.1 for personnel safety.

c. The ordnance MNFS margin safety assurance requirement of 16.5 dB or 6 dB shall be met throughout the life cycle of the SUT. No degradation is allowed due to maintenance, repair, age, storage, enhancements, and corrosion, handling actions or technology insertions / substitutions.

d. HERO instrumentation installed in SUT components during testing for margins data collection shall capture the maximum system response and shall not adversely affect the normal response characteristics of the component.

e. The SUT must operate and meet mission requirements after introduction of the HERO environment.

3. PURPOSE.

The purpose of HERO testing is to verify the ability of the SUT to withstand the HERO environment IAW its specification performance requirements detailed in the test plan. A typical test plan purpose follows:

The purpose of this test procedure is to verify the ability of the SUT EIDs to not prematurely actuate, or dud when exposed to the HERO EME.

4. TEST SETUP.

4.1 Test Equipment.

Following is a listing of typical equipment used. Test equipment bandwidth should encompass 100 kHz to 45 GHz.

Table H-2. HERO Typical Test Equipment List.

Hardware	Comments
EME Simulator	Electromagnetic environment continuous wave transmitter source (amplifier, signal generator)
EME Simulator	Electromagnetic environment peak transmitter source (amplifier/magnetron, signal generator)
E and H Field Probes or Sensors	Probes required for calibration and real time field monitoring, as well as fiber optic cable
Various Antenna	Used to radiate the electromagnetic environment dependent on frequency and power delivery.
Various Transmission Media	Used to deliver the electromagnetic environment to the antenna. Transmission line, waveguide and cabling dependent on frequency and power delivery.
Portable Computer	For integration and control of the electromagnetic simulator
EID Data Collection	Metricor, FISO, vacuum thermocouple, or OPSENS sensors, instrumentation controller and fiber optic cables
Portable Computer	For integration and control of the HERO EID data collection, as well as safety margin calculation

4.2 Pre-Test Evaluation.

a. Prior to the start of the test, the operators shall verify that all personnel are aware of the safety aspects associated with high intensity radiated fields and that all personnel have been briefed on this subject. The Permissible Exposure Limits (PEL) of DOD 6055.11 will be strictly adhered to during the test. Due to the intense levels and the fact that most operations are verified under External RF EME Testing, there will be a need for personnel to enter the EME during this subtest during the handling/loading phase (only up to 1GHz). When necessary for monitoring/functioning of firing circuits or conduct of handling/loading operations the restricted HERO levels will apply and be utilized for those operations.

b. A pre-test evaluation will be performed to determine the primary current paths, port of entries, test orientations and configurations, and test conditions for the SUT. The bare EID test configuration may be assumed to be worst case for energy transfer to the ordnance itself due to the lack of shielding from the SUT. The possibility exists that this configuration will provide a higher probability of HERO susceptibility data, but it may not contribute the full range of susceptible frequencies.

c. The SUT status is verified and documented before HERO testing, using baseline self-test checks, SUT operational performance checks, and functional performance measures.

d. The pretest analysis should also address the system inherent frequencies. These should include at a minimum; the system frequencies of transmission as well as associated modulation parameters, frequencies associated with data rates, computer processors and generator power.

4.3 Setup.

a. Figure H-1 depicts a typical EME transmission and antenna equipment block diagram for HERO testing.

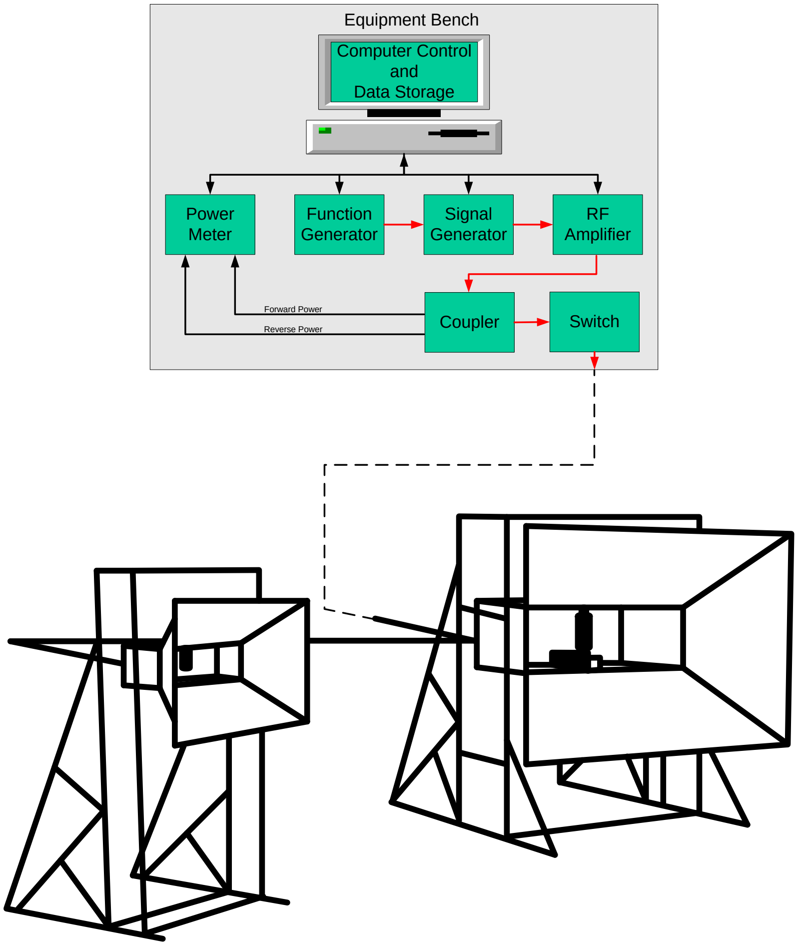


Figure H-1. Typical EME Transmission Equipment and Antennas.

b. The RF EME transmission test facility is calibrated at a distance from the facility antenna to determine the power required to achieve the specified field strength. This measurement is a free field calibration. During the environmental illumination, the field strength is monitored at the specified mapping point (distance and height above ground). The antenna placement will be no lower than 1.5 to 2 meters above ground. The Source-To-Target (STT) distance from the test item will vary dependant on the frequency range, radiating antenna and SUT and will be measured from the nearest conducting surface of the SUT to the radiating antenna, or to the target electronic UUT. This minimum distance shall be 1 meter. A real time field calibration measurement can be made if the SUT fits within a 2 meter test volume.

c. When the SUT is instrumented. Care must be taken so that the installation of the Data Acquisition System (DAS), especially the HERO instrumentation to include power and fiber optic link does not compromise or reduce the inherent shielding of the SUT.

d. The SUT is illuminated by the simulated HERO environment.

e. Throughout each HERO illumination, the SUT HERO configuration will be functional as applicable to the tested stockpile to safe separation sequence, in accordance with the SUT operating procedures; ie prelaunch, handling and loading. These HERO situation/configurations require use of the restricted HERO environment due to personnel interaction with the SUT.

4.4 Instrumentation.

a. The EIDs will be instrumented with a thermal sensor capable of detecting the smallest change in temperature. This change in temperature will be translated into current (mA), and a safety margin calculated as shown in Para 2 below. OPSENS, FISO or Metricor instrumentation systems are currently utilized IAW guidance from MIL-HDBK-240.

b. A 16.5 dB safety margin for safety assurance for ordnance must be attained for MIL-STD-464A/B HERO compliance by EIDs designated as safety hazards. A 6 dB safety margin must be attained for EIDs designated as reliability hazards. If the EMR field level is less than the required EMR field level, than the instrumentation data will be extrapolated to the full criterion level.

$$SM(dB) = 20\log\frac{[MNFS]}{\begin{bmatrix} Induced\_EMR\_Current\_or\_ \\ Minimal\_Detectable\_Current \end{bmatrix}}$$

c. Prior to testing, a functional inspection of the optical sensor instrumentation will be performed in order to ensure proper operation. The instrumentation shall be calibrated to ensure accuracy of the response data for safety assurance determination. This calibration will involve injecting a known signal to verify the correct data output as specified in MIL-HDBK-240.

d. HERO data will be collected utilizing a computer interfaced to a thermal sensor instrumentation controller unit.

e. Should a composition EID, exploding foil initiator, or additional non linear device be utilized, MIL-HDBK-240 procedures will be followed for GO-NO-GO testing. Either the field will raised the equivalent of 16.5dB for testing of the live LEFI (may be impossible), or the LEFI will be instrumented as a linear EID as well as the firing capacitor circuit will be instrumented and monitored during the test. A sample size of 22 should be provided for GO-NO-GO testing, or the firing capacitor can be instrumented and the safety margin applied to the recorded data.

5. TEST PROCEDURES

The specific test procedures will be conducted IAW the test plan. Any changes to these procedures will be noted in the test report. Safety procedures must be initiated IAW the test facility Standard Operating Procedures (SOP), the system Safety Standard Operating Procedures (SSOP) or the SUT specific Safety Assessment Report (SAR).

a. Sample test frequencies, field intensities and modulation used for testing are provided in Table H-3. A minimum of 100 frequencies is recommended IAW Mil-Std-464.

Table H-3. Sample Hero Unrestricted Frequency List (utilizing frequencies from MIL-STD-464).

Item #	Frequency (MHz)	Polarization	Peak (V/m)	Continuous Wave Average (V/m)
1	0.01	V	70	70
2	0.02	V	70	70
3	0.03	V	70	70
4	0.05	V	70	70
5	0.08	V	70	70
6	0.14	V	70	70
7	0.24	V	70	70
8	0.41	V	70	70
9	0.69	V	70	70
10	1.18	V	70	70
11	2.00	V	200	200
12	2.30	V	200	200
13	2.64	V	200	200
14	3.03	V	200	200
15	3.48	V	200	200
16	4.00	V	200	200
17	4.59	V	200	200
18	5.28	V	200	200
19	6.06	V	200	200
20	6.96	V	200	200
21	8.00	V	200	200
22	9.20	V	200	200
23	10.56	V	200	200
24	12.13	V	200	200
25	13.93	V	200	200
26	16.00	V	200	200
27	18.38	V	200	200

Table H-3. Sample Hero Unrestricted Frequency List (utilizing frequencies from MIL-STD-464).

Item #	Frequency (MHz)	Polarization	Peak (V/m)	Continuous Wave Average (V/m)
28	21.11	V	200	200
29	24.25	V	200	200
30	27.86	V	200	200
31	32.00	V/H	90	61
32	34.00	V/H	90	61
33	36.00	V/H	90	61
34	38.00	V/H	90	61
35	40.00	V/H	90	61
36	42.85	V/H	90	61
37	45.00	V/H	90	61
38	48.00	V/H	90	61
39	49.99	V/H	90	61
40	53.00	V/H	90	61
41	57.00	V/H	90	61
42	60.00	V/H	90	61
43	63.00	V/H	90	61
44	67.00	V/H	90	61
45	71.00	V/H	90	61
46	75.50	V/H	90	61
47	80.00	V/H	90	61
48	84.00	V/H	90	61
49	88.70	V/H	90	61
50	94.10	V/H	90	61
51	100.10	V/H	90	61
52	107.70	V/H	90	61
53	138.02	V/H	90	61
54	152.25	V/H	90	61
55	174.10	V/H	90	61
56	200.00	V/H	90	61
57	230.00	V/H	70	70
58	264.15	V/H	70	70
59	303.00	V/H	70	70
60	348.05	V/H	70	70
61	400.00	V/H	1940	260
62	438.00	V/H	1940	260
63	480.00	V/H	1940	260

Table H-3. Sample Hero Unrestricted Frequency List (utilizing frequencies from MIL-STD-464).

Item #	Frequency (MHz)	Polarization	Peak (V/m)	Continuous Wave Average (V/m)
64	527.00	V/H	1940	260
65	577.00	V/H	1940	260
66	632.00	V/H	1940	260
67	693.00	V/H	1940	260
68	760.00	V/H	290	95
69	805.00	V/H	2160	410
70	867.49	V/H	2160	410
71	912.00	V/H	2160	410
72	1000.00	V/H	3300	460
73	1155.00	V/H	3300	460
74	1335.00	V/H	3300	460
75	1543.00	V/H	3300	460
76	1783.00	V/H	3300	460
77	2000.00	V/H	3300	490
78	2380.00	V/H	4500	490
79	2757.00	V/H	27460	2620
80	2950.00	V/H	27460	2620
81	3178.00	V/H	27460	2620
82	3672.00	V/H	9710	310
83	4243.00	V/H	7200	300
84	4902.00	V/H	27460	300
85	5665.00	V/H	15970	300
86	5950.00	V/H	320	320
87	6545.00	V/H	1100	390
88	7563.00	V/H	1100	390
89	7950.00	V/H	860	860
90	8200.00	V/H	860	860
91	8500.00	V/H	1100	390
92	9300.00	V/H	13380	1760
93	10098.00	V/H	13380	1760
94	11668.00	V/H	2800	390
95	13482.00	V/H	2800	390
96	15578.00	V/H	2800	350
97	18000.00	V/H	7060	420
98	26500.00	V/H	7060	420
99	33000.00	V/H	7060	420

Table H-3. Sample Hero Unrestricted Frequency List (utilizing frequencies from MIL-STD-464).

Item #	Frequency (MHz)	Polarization	Peak (V/m)	Continuous Wave Average (V/m)
100	39000.00	V/H	7060	420
101	43000.00	V/H	570	570

b. Prior to testing, the SUT operators will perform system checks to ensure that all the EIDs and subsystems are electrically intact (continuity exists).

c. The instrumented EID (s) configured in the applicable SUT ordnance phase (s) will be positioned in the test area.

d. The sample test frequencies, field intensities and modulation used for the test are provided in Table H-3 (HERO frequencies similar to those specified in MIL-STD-464 and MIL-HDBK-240).

e. The SUT will be exposed at critical orientations taking into consideration placement of communication, electronics, harness cabling, shielded apertures and points of entry (POE). At least two antenna placement aspect angles should be considered for a very small system (less than 1m X 1m). All other items should have a minimum of four head on aspect angles. Also, a 45 degree aspect angle should be considered dependent on the worse case orientation for POEs. Additionally, any system with a turret or rotating gun should also be exercised and considered in the test item orientations.

f. The following sequence will be observed for each exposure:

(1) The EID configuration will be placed in the test area initially in one of the system phase configurations and test item orientation to the antenna.

(2) The environment will be adjusted to generate a peak pulsed power or continuous wave (CW) field (see Table H-3). Transmitter power will be increased until either the criterion field is reached, or facility limitation is reached.

(3) If an anomaly or effect is observed (safety margin below 16.5 dB or 6 dB as appropriate for safety assurances and reliability) an additional test exposure will be conducted to ensure that the EMR was the cause of the effect. Data will be collected for every test exposure.

(4) Procedure c and d will be repeated for each test frequency, polarization, and test item orientation.

(5) The illumination period shall not exceed one minute unless an operational test sequence to monitor firing circuitry, or ordnance related operation is performed in conjunction with the HERO test data collection.

(6) SUT operational checkouts will be performed in conjunction with the handling/loading procedures as they apply or daily as SUT limitations allow, and at the conclusion of the HERO test.

g. Although MIL-STD 464A recommends a minimum of 100 test frequencies, additional consideration should be taken for system inherent frequencies. The HERO test facilities will be capable of generating the peak fields shown in Table 4A for firing circuits and operational performance, as well as a minimum of 10 percent of the average field intensity or 100 V/m (whichever is higher) for instrumented linear response electrically initiated devices (EIDs) testing (see Mil-Hdbk-240).

6. DATA PRESENTATION.

Table H-4. Data Collection Table Example.

<table>
<tr><th colspan="7">HERO DATA</th></tr>
<tr><td colspan="5">System: JDAM</td><td colspan="2">DODIC: Not Yet Assigned</td></tr>
<tr><td colspan="5">Platform: F/A 18</td><td colspan="2">HERO Phase: Staged and Storage</td></tr>
<tr><td>Freq Range</td><td>Frequency (MHz)</td><td>Test EME (V/m)</td><td>Criteria EME (V/m)</td><td>EID ID</td><td>Firing Consequence</td><td>Safety Margin</td></tr>
<tr><td>2-30</td><td>18</td><td>194</td><td>200</td><td>MK40</td><td>Safety</td><td>29.54</td></tr>
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</table>

Table H-5. Data Collection Table Example.

Sample HERO Induced Current Test Data																						
CHAN	START	STOP	RUN	FREQ	MOD	POL	HAG	DIST	CONFIG	ORIENT	SIG LEV	FWD PWR	REV PWR	FI	B. TEMP	E. TEMP.	DELTA	Imax	Icri	MAE	S.F.	REL/ SAFETY
1	122345	122456	1	30	CW	V	6	10	SYSTEM OFF	FRONT	-2.1	10000	200	50	32.4	36.6	4.2	50	10	450	8.5	0.15
2	122345	122456	1	30	CW	V	6	10	SYSTEM OFF	FRONT	-2.1	10000	200	50	32.5	32.5	0	7	80	32154	28.6	0.15
3	122345	122456	1	30	CW	V	6	10	SYSTEM OFF	FRONT	-2.1	10000	200	50	32.2	33.1	0.9	15	80	27150	24.1	0.45
4	122345	122456	1	30	CW	V	6	10	SYSTEM OFF	FRONT	-2.1	10000	200	50	32.1	32.2	0.1	7	80	30123	27.8	0.45

7. DATA ANALYSIS PROCEDURE.

a. Data from the External EME test environment measurements will be scored against the criteria levels set forth in MIL-STD 464, to determine the extent to which the test environment criteria and margins (if applicable), as well as equipment specification were met. Deficiencies will be identified and discussed with respect to criteria compliance and effects on the test results.

b. The environment data will be compared and evaluated against the systems required criteria.

c. Maximum No Fire Stimulus (MNFS). All EIDs will be tested using applicable military standards and statistical test methods to determine the MNFS levels. The test results will be shown along with the applicable margin or factor (safety assurance or reliability) and the MNFS requirement for the HERO test.

(1) For EIDs where the MNFS is current (or voltage):

$$\text{Safety Margin (dB)} = 20\ \text{Log}_{10}\ (\text{MNFC}/I_{emr})$$

Where I_{emr} = the measured induced EMR current or the minimum detectable current (MDC) of the instrumentation (or V_{emr} = the measured induced voltage or the minimum detectable voltage (MDV) of the instrumentation).

Where MNFC = the Minimum No Fire Current from the bare EID qualification test data

(2) For EIDs where MNFS is energy:

$$\text{Safety Margin (dB)} = 10\ \text{Log}_{10}\ (\text{MNFE}/E_{emr})$$

Where E_{emr} = the measured induced EMR energy or the minimum detectable energy (current) (MDC) of the instrumentation.

Where MNFE = the Minimum No Fire Energy from the bare EID qualification test data

Ideally the instrumentation MDC is small such that it can detect I_{emr} at any frequency and criteria. This HERO measurement is accomplished when the MDC is smaller than I_{emr}. In most cases, however, I_{emr} is too small to be observed. The safety margin calculation is then based on instrumentation MDC (I_{MD}), not I_{emr}. Replacing a measurement of I_{emr} with MDC limits the validity of the safety margin calculation, but it errs on the conservative side by calculating a lower safety margin than is actually the case. The calculated safety margin would be compared to the required safety margin to determine if the EID is acceptable. The MDC of the FISO sensors is assumed to be 10 mA (I_{MD}). The actual value will be measured before start of test.

If the E-field available during the test is less than the criteria then the measured (EMR induced) current or energy will be extrapolated analytically to the required criteria and the data then calculated. This assumes a linear relationship between the applied E-field and the induced current. The extrapolated value for current or voltage is then used in place of the measured induced EMR current value to calculate the safety margin. The extrapolated level is defined as follows:

$$I_{ext} = I_{emr} (E_{crit}/E_{test})$$

Where I_{ext} = the extrapolated value of the induced EMR current (A),
I_{emr} = the measured value for the induced EMR current (or MDC) (A),
E_{crit} = the required (criteria) E-field intensity (V/m), and
E_{test} = the E-field intensity available during the test (V/m)

If the E-field available during the test is less than the criteria, then the FISO sensor MDC limits the maximum allowable E-field extrapolation. The maximum allowable extrapolation factor is calculated per the HERO Test Guide:

$$\text{Fmax} = I_{crit}/I_{MD}$$

Where I_{crit} = the EID critical current to meet the required margin (A),
I_{MD} = the FISO MDC (A)

I_{crit} (or V_{crit}) is calculated with the following equation:

I_{crit} (or V_{crit}) = $\text{MNFS}/10^{(SM/20)}$ for current (or voltage) measurements, or

$E_{crit} = \text{MNFS}/10^{(SM/10)}$ for energy measurements

Where SM is the Safety Margin (16.5 dB for safety or 6 dB for reliability)

To meet test requirements, each test field must equal or exceed the ratio of the Criteria Test Field and the Maximum Allowable Extrapolation Factor (Fmax).

d. The test data will be compared to the applicable criteria set forth in the SUT specification, and SUT test plan and the pre-event baseline measurements to determine the extent to which the test criteria are met and the effects of the HERO test environment on the SUT. Test anomalies will be assessed to determine if they should be classified as SUT failures and if so, further assessed with regards to causes, test parameters at which they occurred, mission impact and safety.

APPENDIX I. TEMPEST.

1. APPLICABILITY.

The objective of this subtest is to determine if National Security Information (NSI) has the potential of being compromised by unintentional emanations from information processing equipment. Areas that fall under the TEMPEST umbrella are TEMPEST, and NONSTOP.

2. REQUIREMENTS.

MIL-STD-464A, Paragraph 5.12, TEMPEST: “National security information shall not be compromised by emanations from classified information processing equipment. Compliance shall be verified by test, analysis, inspections or a combination thereof.
(NSTISSAM TEMPEST/1-92 and CNNS Advisory Memorandum TEMPEST 01-02 provide testing methodology for verifying compliance with TEMPEST requirements.)”

Emanations Analysis

NSTISSAM TEMPEST/2-91	Compromising Emanations Analysis Handbook Equipment/System Testing
NSTISSAM TEMPEST/1-92	Compromising Emanations Laboratory Test Requirements, Electromagnetics
NSTISSAM TEMPEST/1-93	Compromising Emanations Field Test Requirements, Electromagnetics
CNSSAM TEMPEST 01-02	NONSTOP Evaluation Standard
NSTISSAM TEMPEST/2-00	Rationale NONSTOP Evaluation Techniques
KAG-30 ()/TSEC	Compromising Emanations Standard for Cryptographic Equipment
NSTISSAM TEMPEST/2-93	Rationale for Compromising Emanations Laboratory and Field Test Requirements, Electromagnetics

3. TEST PROCEDURE.

The first step in the testing process should be that the Program Manager of the SUT should contact the Certified TEMPEST Technical Authority (CTTA) very early on in the project and start a dialog to determine what TEMPEST requirements should be in the specifications and what TEMPEST testing will have to be done. Information that the CTTA will require at some point will be the following:

a. A discussion of the system to include.

(1) System description

(2) A functional system description how specific circuits are handling information

(3) How the system is fielded, i.e. setup, lay out, tent equipment, SWLANS, external cabling etc

(4) How the system is to be deployed and integrated into the system of systems, i.e. standalone (autonomous), in a TOC or in a shelter.

(5) Detailed block diagram of all signals and ID's of RED (classified) signals. This should include any keyboards, monitors, printers that process classified. Where fiber optics to Brigade commanders position, to NTDR then to adjacent brigade TOC, map information to server, etc

(6) Size of Control Space (How big will the perimeter around the vehicle be that is controlled?)

(7) Type of power (How is the system going to be powered worst case, external power, from generator or shore power, on board generator or alternator, type of power i.e. 50/60/400 Hz, 240 single phase, 100 Amp that uses 3 conductors with ground, 4 “O” cable)

b. Type of transmission media exiting the system to include.

(1) Type of radios, SINCGARS, EPLRS, HF, GBS, JTRS, NTDR, SPITFIRE, SOTM, Blue Force Tracking, etc

(2) Wireless LAN (Secure or unsecure)

(3) Fiber optics

(4) Twisted pair (26/50/100 pair hocks)

(5) Coax

(6) Coax 10 base-T

(7) CATV

c. Type of communications within system to include.

(1) Voice, i.e. VIC-3, TOCNET, etc.

(2) Video

(3) Data - Type of data transfer (serial or parallel).

Rate the data is transferred on each data path (time or frequency).
If data path carries classified data or not.
If data path carries classified, percent of total data across this path that is classified.
Highest classification.

(4) Data flow diagrams of all communication types and logic to determine those routings

(5) Any external communications or data transfer capability using land wires. (Type and distance)

d. Computer systems (All computers and peripherals addressed and classified computers and peripherals identified as such)

(1) Monitors – refresh rates, scan rates, interleaved/non-interleaved

(2) Keyboards – polling rate

(3) CPU – clock rates, data rate on the internal bus, single/dual processor

(4) Routers/HUBs/Switches/firewalls that process information

(5) Printers

(6) Plotters

(7) Overhead projectors (ones tied to a computer)

(8) External storage

e. The better the information the more accurate the cost estimate and test plan. Any further discussion beyond what is discussed above would require a higher classification of this document. Once the CTTA has determined what testing is required U.S. Army Electronic Proving Ground should be contacted to develop the RED signals matrix and testing performed.

4. DATA ANALYSIS PROCEDURE

The test data will be compared to the applicable criteria set forth in the SUT specification, and SUT test plan and the pre-event baseline measurements to determine the extent to which the test criteria are met and the effects of the TEMPEST test environment on the SUT. Test anomalies will be assessed to determine if they should be classified as SUT failures and if so, further assessed with regards to causes, test parameters at which they occurred, mission impact and safety.

APPENDIX J. HIGH POWER MICROWAVE (HPM)

1. APPLICABILITY.

a. This test method is applicable to equipment at the system level IAW the equipment specification. To provide the methods to assess the survivability of the system to the effects produced by a HPM environment.

b. To determine whether the system's operational performance requirements are met when subjected to the specified HPM.

Omission the extracted levels are omitted from this document to maintain an unclassified status.

2. REQUIREMENTS.

a. To assess the operational survivability and identify susceptibilities to the system when exposed to the HPM environment, as specified in MIL-STD-464 and the current requirements documents as developed.

b. The system shall remain combat effective without component replacement.

c. The system must operate and meet mission requirements after introduction of the HPM environment.

3. PURPOSE.

The purpose of this test procedure is to verify the ability of the system to operate without degradation, or component replacement when exposed to the specified HPM environment

4. TEST SETUP.

4.1 Test Equipment.

Table J-1 is a listing of typical equipment used. Test equipment should encompass bandwidth to allow for Nyquist analog value of 4 GHz and a digital value of up to 8 GHz so that the frequency content can be captured.

Electromagnetic environment source with the ability to deliver a system with the current requirements as developed.

Table J-1. List of HPM Test Equipment.

Hardware	Comments
HPM Simulator	Specially designed and procured
Power Supply	High voltage power supply used to charge
Current Probe	Used to measure current coupled to SUT cable or SUT EIDs (a clamp type probe - used only when the wire cannot be cut) Need several in different physical sizes and current handling capabilities
Surface Current Probe	Used to measure currents on the surface of the SUT Need several in different physical sizes and current handling capabilities
Fiber Optic Telemetry Unit	Takes input from probes & drives fiber optic output Need several in different physical sizes and current/voltage handling capabilities
Digital Oscilloscope	Used to record and display current and voltage measurements. Scope should meet nyquist requirement and digital requirement As well as all data links should have adequate bandwidth
Portable Computer	For data reduction (e.g. calculates safety margins, creates data plots for display, stores data)
HPM Test Software	For data reduction / presentation
E and H Field Probes or Sensors	Probes required for calibration and real time field monitoring
Signal recording and digitizer	Scope should meet nyquist requirement and digital requirement As well as all data links should have adequate bandwidth

4.2 Pre-Test Evaluation.

a. A pre-test evaluation will be performed to determine the primary current paths, ports of entry, test orientations and configurations, test conditions for the SUT, and bulk current measurement points. Energy coupling analysis will identify the type and capability requirements for the data acquisition system to include the bulk current probes. Usually, clamp-on non-obtrusive current probes are used so as to not affect the inherent shielding integrity of the cable or the SUT shielding integrity. For hardening evaluation and corrective recommendations, the HPM, Electromagnetic Pulse (EMP), and Near Strike Lighting (NSL) test points should remain the same as or be a subset there of.

b. The SUT status is verified and documented before HPM testing, using baseline self-test checks, system operational performance checks, and functional performance measures.

c. The pretest analysis should also address the system inherent frequencies. These should include at a minimum; the system frequencies of transmission as well as associated modulation parameters, frequencies associated with data rates, computer processors and generator power.

d. The pre-exposure and post-exposure operational and system check data, along with the environmental exposure data and specification requirements, will form the basis of the analysis to assess the effects of the HPM environment on the system mission and performance capabilities.

e. All equipment / system must be in operational, fielded and documented modes.

f. All normal fielded POEs must be attached to the equipment / system. As examples, the input ports to a Shelter System panel or a shore / external generation power configuration.

4.3 Setup.

a. Prior to testing, the HPM facility will be calibrated in order to establish the distances required to receive the specified field strengths. This measurement is a free field calibration. During the environmental illumination, the field strength is monitored at the specified environment mapping/calibration point (distance and height above ground). The transmission antenna and field measurement device placement will be no lower than 1.5 - 2 meters above ground. It is suggested to make measurements at mid and max height of the SUT.

b. The SUT is instrumented. Care must be taken so that the installation of the Data Acquisition System (DAS), especially the current probes does not compromise or reduce the inherent shielding of the SUT. It may also be necessary to leave a vehicle POE open to allow for the instrumentation cabling.

c. The SUT is illuminated by the simulated HPM environment. If no anomalies occur, the SUT is illuminated at least three times per orientation (as well as field amplitude), or until data from all the data acquisition test points have been collected. Induced anomalies may require additional illuminations.

d. Throughout each HPM illumination, the SUT will be fully operational, in accordance with SUT operating procedures, or be easily corrected by crew intervention (i.e., power reset).

e. The system will be tested in the parallel and perpendicular to the radiating antenna configurations. The antenna two polarizations will also be tested, as applicable.

f. A minimum of two testing levels are required for all UWB / HPM tests; based on current requirements as developed. Additional test levels will be performed based upon customer requirements and engineering judgment.

5. TEST PROCEDURE.

a. The SUT will be tested in two orientations with respect to the poynting vector, i.e., longitudinal (vertical) axis parallel to electric field vector, and 90 degrees clockwise or perpendicular to the poynting vector. In each of the two orientations, an HPM EME will illuminate the SUT. If no failures occur, an additional two illuminations will be conducted (per configuration) or until all data acquisition has been completed.

b. During each illumination, the SUT will be fully operational with main power ON, system idling and all electronic equipment powered ON and functional.

c. Perform detailed bulk current probe data measurements. The number of illuminations is dependent on how many cable/harness shields are monitored for HPM induced currents.

d. The following sequence will be observed for each exposure:

(1) The environment will be adjusted to generate the HPM field.

(2) If an anomaly or effect is observed an additional test exposure will be conducted to ensure that the HPM was the cause of the effect. Testing shall not continue until the problem is understood and its effects on the SUT are assessed. Should an upset occur, the effected equipment(s) and/or component(s) must be identified and the power cycled (OFF/ON) in an attempt to re-establish normal operation and record the recovery time. Testing must be repeated at the same level and orientation to determine whether the upset is attributable to the specific HPM environment.

(3) Procedures will be repeated for each test amplitude requirement.

(4) TIRs will be prepared to document anomalies.

(5) All test setups should be photographed.

6. DATA PRESENTATION.

Example data is shown in Table J-2 and Figure J-1.

Table J-2. Typical HPM Data Table.

Test Point ID	Orientation	Shot #	Units	Peak Field	Rise Time	Fall Time	Pulse Width	Primary Freq (Hz)
field	Front	23	(kV/M)	10.726	1.14E-10	2.83E-10	1.78E-10	4.49E+08
field	Front	24	(kV/M)	9.91252	6.55E-11	2.62E-10	1.71E-10	4.48E+08
field	Front	25	(kV/M)	9.97416	1.19E-10	1.25E-10	1.88E-10	4.48E+08
field	Front	62	(kV/M)	8.73883	1.65E-10	1.10E-10	2.39E-10	4.49E+08
field	Front	63	(kV/M)	9.83161	1.68E-10	1.15E-10	2.02E-10	4.49E+08
field	Front	65	(kV/M)	10.3802	7.75E-11	6.81E-11	2.12E-10	4.48E+08

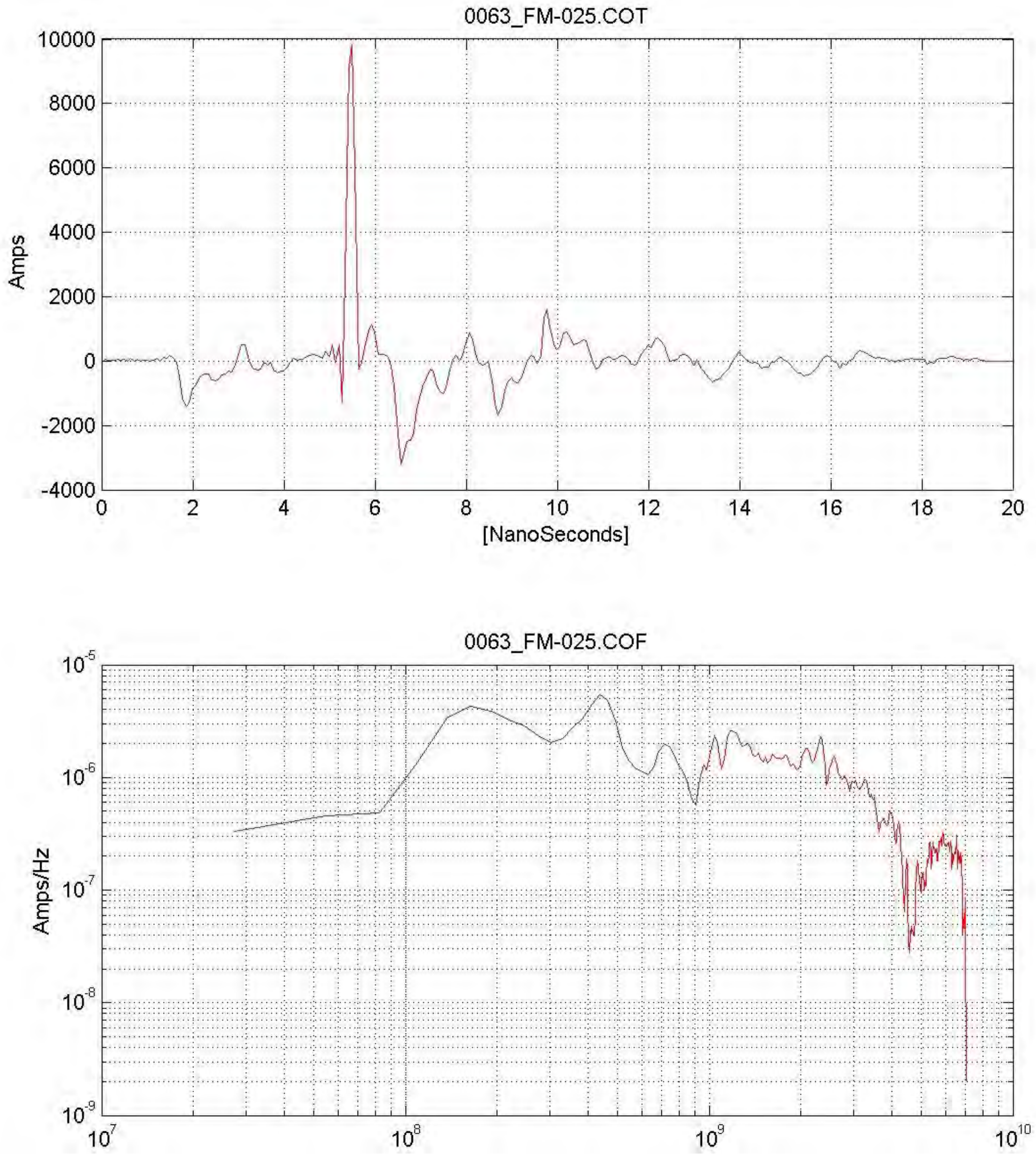


Figure J-1. Typical HPM Data Plots.

7. DATA ANALYSIS.

The test data will be compared to the applicable criteria set forth in the SUT specification, and SUT test plan and the pre-event baseline measurements to determine the extent to which the test criteria are met and the effects of the HPM test environment on the SUT. Test anomalies will be assessed to determine if they should be classified as SUT failures and if so, further assessed with regards to causes, test parameters at which they occurred, mission impact and safety.

APPENDIX K. INTRA SYSTEM ELECTROMAGNETIC COMPATIBILITY, SYSTEM EMISSIONS, ELECTRIC FIELD, 10 kHz to 40 GHz.

1. APPLICABILITY.

This requirement applies to all radiated emissions from equipment and subsystem enclosures, interconnecting cables, and antennas designed to be permanently mounted to the SUT (receivers and transmitters in standby mode). This requirement does not apply at the transmitter fundamental frequencies. The requirement is applicable from 10.0 kHz to 40.0 GHz (depending on the procuring agency). At a minimum, testing is required either up to 1.0 GHz or at ten times the highest intentionally generated frequency within the SUT, whichever is greater. It should be noted that there are differences between some of the MIL-STD-461E and MIL-STD-461F test set up and those specific procedure should be followed for each. This test procedure addresses those of MIL-STD-461E, but will show sample set ups for MIL-STD-461F as well.

2. PURPOSE.

This test procedure is used to verify that the radiated electric field emissions from the SUT and associated cabling do not exceed specified requirements.

3. TEST SETUP.

3.1 Test Equipment.

The test equipment shall be as follows:

a. Measurement Receivers for example;

(1) Electrometrics EMC-30.

(2) Electrometrics EMC-60.

(3) Rohde & Schwarz ESIB-40 or a spectrum analyzer that meets the characteristics specified in MIL-STD-461E paragraphs 40.3.10.2 through 40.3.10.4.

b. Data Recording Device. Any computer with appropriate RE software, Tile Version 3.4.k.4, ESK1 Version 1.71, or EMC32 Version 5.10.99 to drive the receivers and to record the data.

c. Antennas, for example

(1) 10.0 kHz to 30.0 MHz, 104 cm rod with impedance matching network, Electrometrics RVA-30 or similar

(a) Since the impedance matching network includes a preamplifier (active rod), observe the overload precautions.

(b) Use a square counterpoise measuring at least 60 cm on a side.

(2) 30.0 MHz to 200.0 MHz, Biconical, 137 cm tip to tip, Electrometrics BIA-30, EMCO 3104C or similar

(3) 200.0 MHz to 1.0 GHz, double ridge horn, 69.0 by 94.5 cm opening, Electrometrics RGA-30 or similar

(4) 1.0 GHz to 18.0 GHz, double ridge horn, 24.2 by 13.6 cm opening, Electrometrics RGA-50, Electrometrics RGA-60, Electrometrics RGA-180 or similar.

(5) 18.0 GHz to 26.5 GHz, Waveguide Horn, 1.51 by 1.16 in. opening, Loral Narda or similar.

(6) 26.5 GHz to 40.0 GHz, Waveguide Horn, 1.06 by 0.82 in. opening, Loral Narda or similar

d. Signal Generators for example:

(1) Hewlett Packard 83640B, 83623A

(2) Fluke 6080A.

(3) Rohde & Schwarz SML-01.

(4) Anritsu 68369A/NV.

e. Stub Radiator.

f. Capacitor, 10 microfara, Solar Electronics 6512-106R, 7113-106R, or similar.

g. LISNs, Solar Electronics 9233-50-TS-50-N, 8116-50-TS-100-N, or similar.

3.2 Setup.

The test setup is as follows:

a. Maintain a basic test setup for the SUT as shown and described in the general section of this guide, in the approved test plan, and in Figure K-1 at a distance of 1 m. Ensure that the SUT is oriented such that the surface that produces the maximum radiated emissions is toward the front edge of the test setup boundary.

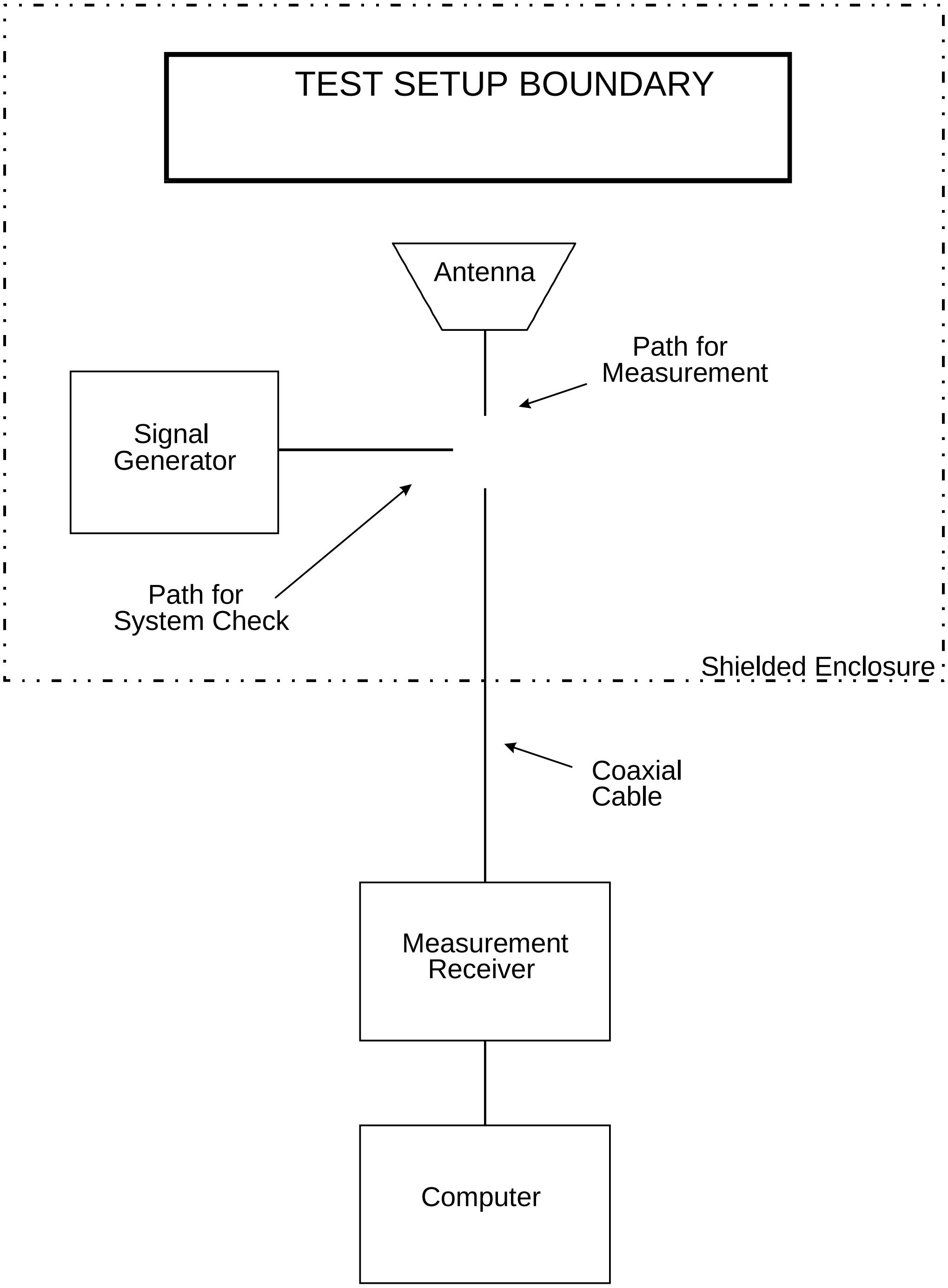


Figure K-1. System Emissions Basic Test Setup.

b. Calibration. Configure the test equipment as shown in Figure K-1.

c. SUT Testing.

(1) For shielded room measurements, electrically bond the rod antenna counterpoise to the ground plane using a solid metal sheet that is greater than or equal to the width of the counterpoise. The maximum DC resistance between the counterpoise and the ground plane shall be 2.5 milli ohms. For bench top setups using a metallic ground plane, bond the counterpoise to this ground plane. Otherwise, bond the counterpoise to the floor ground plane. For measurements outside a shielded enclosure, electrically bond the counterpoise to earth ground.

(2) Antenna positioning.

(a) Determine the test setup boundary of the SUT and associated cabling for use in positioning of antennas.

(b) Use the physical reference points on the antennas shown in Figure K-2 for measuring heights of the antennas and distances of the antennas from the test setup boundary.

(1) Position antennas 1 m from the front edge of the test setup boundary for all setups.

(2) Position antennas other than the 104 cm rod antenna 120 cm above the floor ground plane.

(3) Ensure that no part of any antenna is closer than 1 m from the walls and 0.5 m from the ceiling of the shielded enclosure.

(4) For test setups using bench tops, additional positioning requirements for the rod antenna and distance above the bench ground plane are shown in Figure K-3.

(5) For free standing setups, electrically bond and mount the 104 cm rod antenna matching network to the floor ground plane without a separate counterpoise.

(c) The number of required antenna positions depends on the size of the test setup boundary and the number of enclosures included in the setup.

(1) For testing below 200.0 MHz, use the following criteria to determine the individual antenna positions.

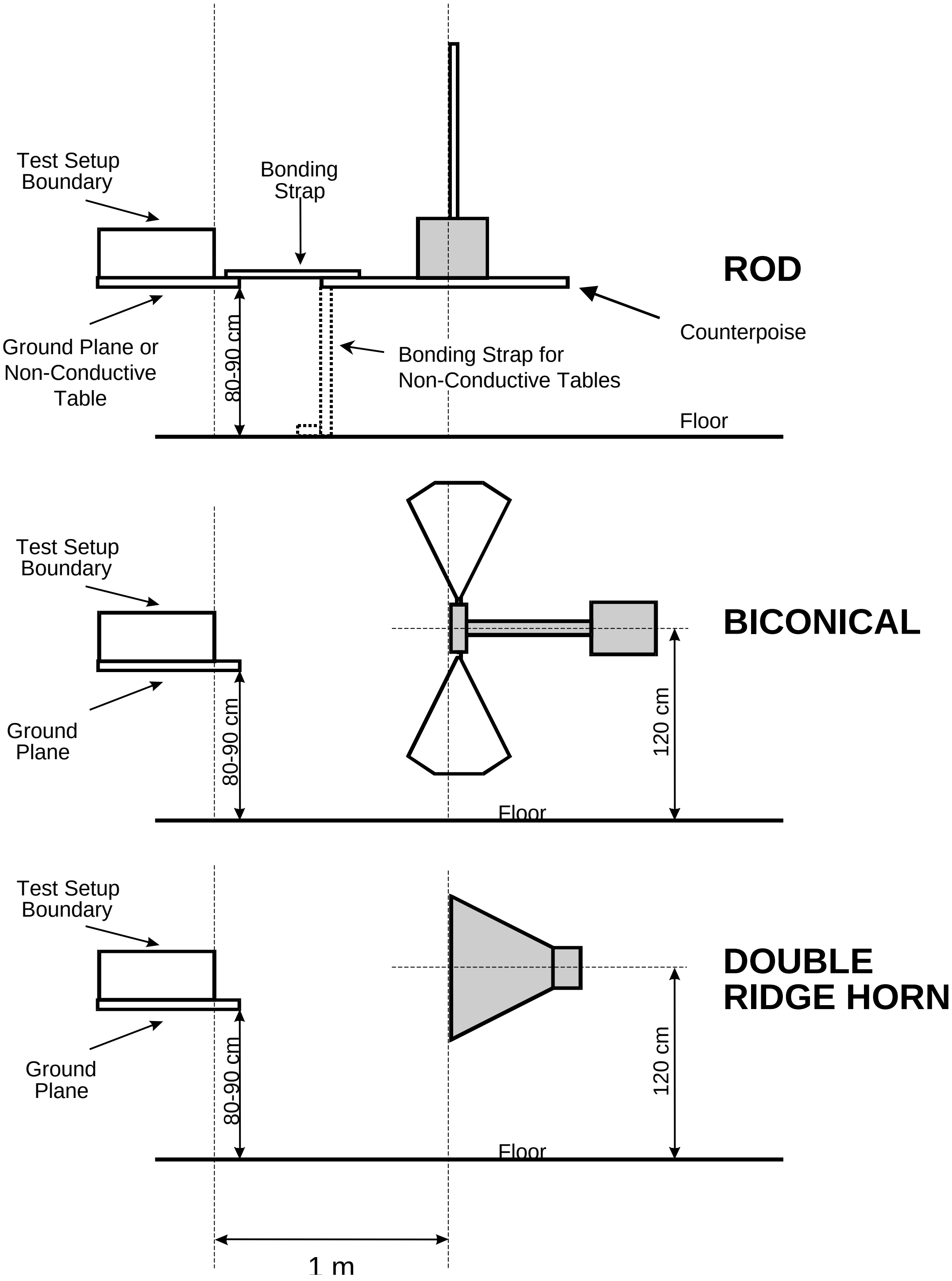


Figure K-2. System Emissions Antenna Positioning.

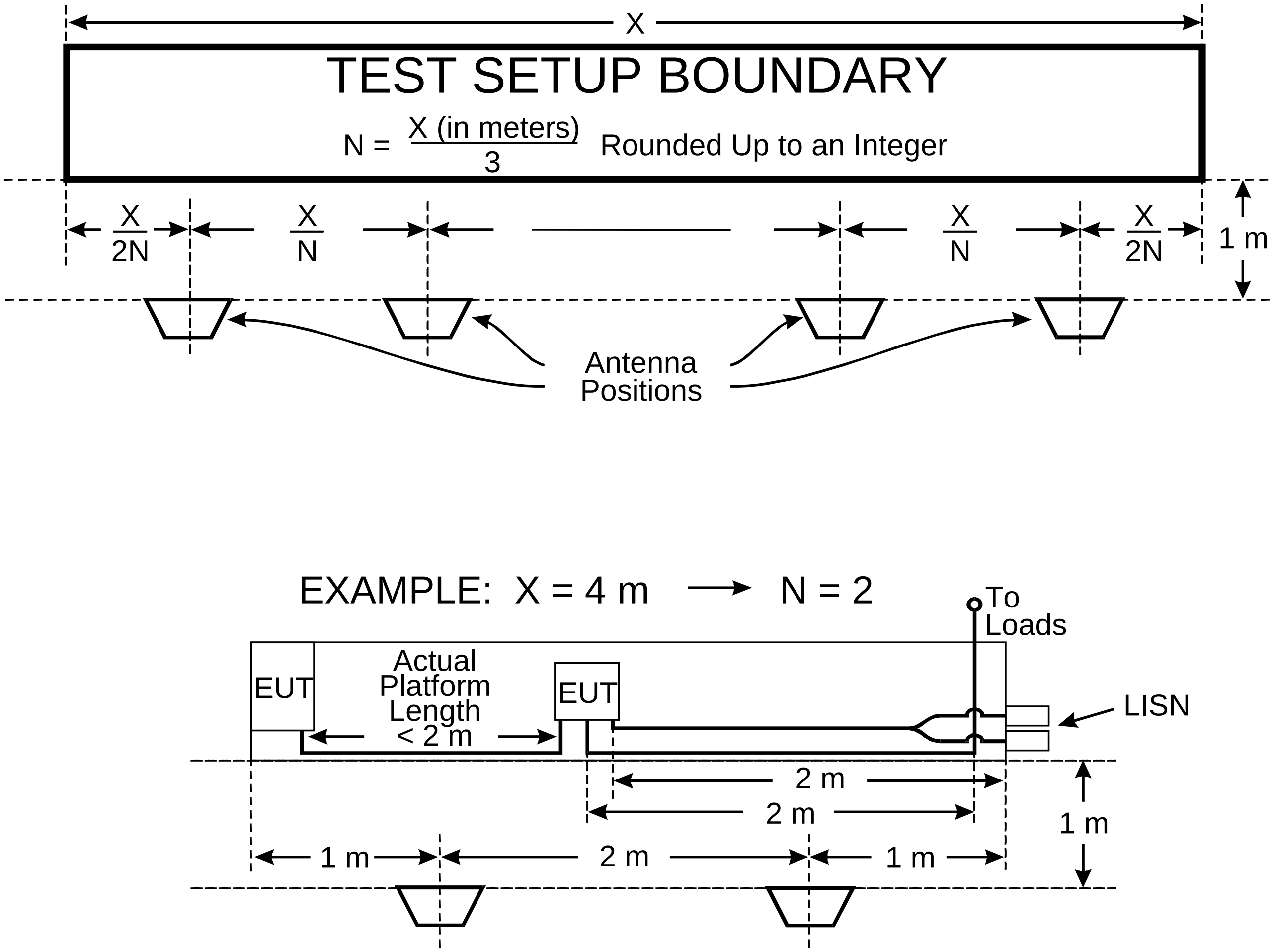


Figure K-3. System Emissions Multiple Antenna Positions.

(2) For setups with the side edges of the boundary 3 m or less, one position is required and the antenna shall be centered with respect to the side edges of the boundary.

(3) For setups with the side edges of the boundary greater than 3 m, use multiple antenna positions at spacing as shown in Figure K-3. Determine the number of antenna positions (N) by dividing the edge-to-edge boundary distance (in meters) by three and rounding up to an integer.

(4) For testing from 200.0 MHz through 1.0 GHz, place the antenna in a sufficient number of positions such that the entire width of each SUT enclosure and the first 35 cm of cables and leads interfacing with the SUT enclosure are within the 3 dB beam width of the antenna.

(5) For testing at 1.0 GHz and above, place the antenna in a sufficient number of positions such that the entire width of each SUT enclosure and the first 7 cm of cables and leads interfacing with the SUT enclosure are within the 3 dB beam width of the antenna.

4. TEST PROCEDURE.

a. Choose the appropriate radiated emission limit that is applicable to the specification from MIL-STD-461E, Figures RE102-1 through RE102-4.

b. Turn on the measurement equipment and allow a sufficient time for stabilization.

c. Conduct a radiated emission ambient to verify that the ambient requirements of the facility are met.

d. Using the system check path of Figure K-1, perform the following evaluation of the overall measurement system from each antenna to the data output device at the highest measurement frequency of the antenna. For rod antennas that use passive matching networks, the evaluation shall be performed at the center frequency of each band. For active rod antennas, the evaluation shall be performed at the lowest frequency, at a mid-band frequency, and at the highest frequency of the test.

(1) Apply a calibrated signal level, which is at least 6 dB below the limit (limit minus antenna factor), to the coaxial cable at the antenna connection point.

(2) Scan the measurement receiver in the same manner as a normal data scan. Verify that the data recording device indicates a level within ±3 dB of the injected signal level.

(3) For the 104 cm rod antenna, remove the rod element and apply the signal to the antenna matching network through a 10 pF capacitor connected to the rod mount.

(4) If readings are obtained which deviate by more than ±3 dB, locate the source of the error and correct the deficiency prior to proceeding with the testing.

(5) Using the measurement path of Figure K-1, perform the following evaluation for each antenna to demonstrate that there is electrical continuity through the antenna.

(6) Radiate a signal using an antenna or stub radiator at the highest measurement frequency of each antenna.

(7) Tune the measurement receiver to the frequency of the applied signal, and verify that a received signal of appropriate amplitude is present.

Note: This evaluation is intended to provide a coarse indication that the antenna is functioning properly. There is no requirement to accurately measure the signal level.

(8) Turn on the SUT and allow sufficient time for stabilization.

e. Using the measurement path of Figure K-1, determine the radiated emissions from the SUT and its associated cabling.

(1) Scan the measurement receiver for each applicable frequency range, using the bandwidths and minimum measurement times in the General section of this manual or in the approved test plan.

(2) Above 30.0 MHz, orient the antennas for both horizontally and vertically polarized fields.

(3) Take measurements for each antenna position determined under 2.3c (2) (c) above.

5. DATA PRESENTATION.

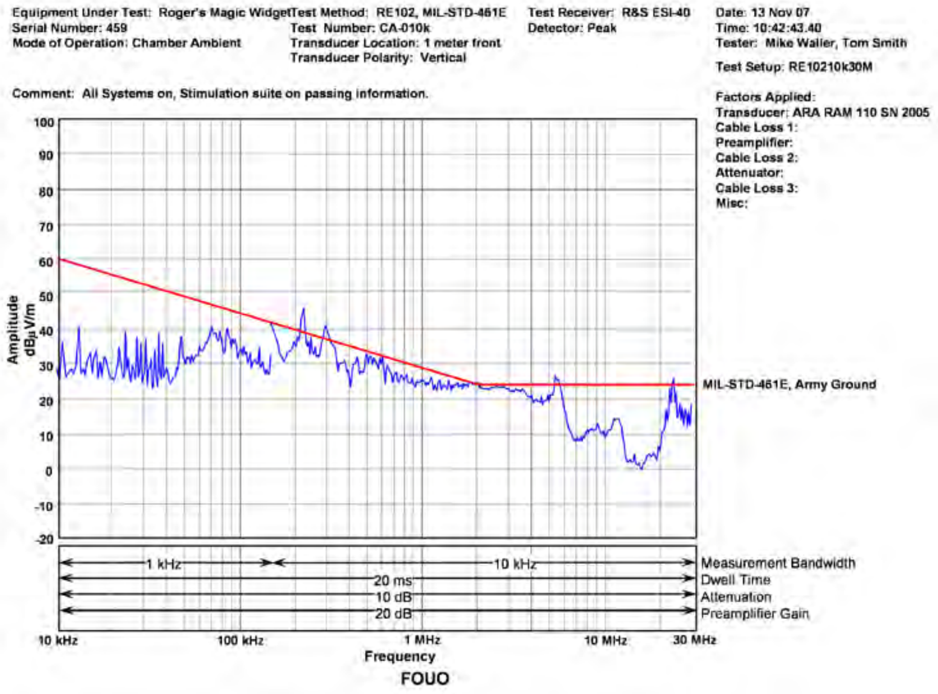
a. Continuously and automatically plot amplitude versus frequency profiles. Manually gathered data is not acceptable except for plot verification. Vertical and horizontal data for a particular frequency range shall be presented on separate plots or shall be clearly distinguishable in black or white format for a common plot.

b. Display the applicable limit on each plot.

c. Provide a minimum frequency resolution of 1 percent or twice the measurement receiver bandwidth, whichever is less stringent, and a minimum amplitude resolution of 1 dB for each plot.

d. Provide plots for both the measurement and system check portions of the procedure.

e. Provide a statement verifying the electrical continuity of the measurement antennas as determined in 2.4d.



Equipment Under Test: Roger's Magic Widget
Serial Number: 459
Mode of Operation: Chamber Ambient

Test Method: RE102, MIL-STD-461E
Test Number: CA-010k
Transducer Location: 1 meter front
Transducer Polarity: Vertical

Test Receiver: R&S ESI-40
Detector: Peak

Date: 13 Nov 07
Time: 10:42:43.40
Tester: Mike Waller, Tom Smith

Test Setup: RE10210k30M

Comment: All Systems on, Stimulation suite on passing information.

Factors Applied:
Transducer: ARA RAM 110 SN 2005
Cable Loss 1:
Preamplifier:
Cable Loss 2:
Attenuator:
Cable Loss 3:
Misc:

Figure K-4. Sample Emissions Data Plot.

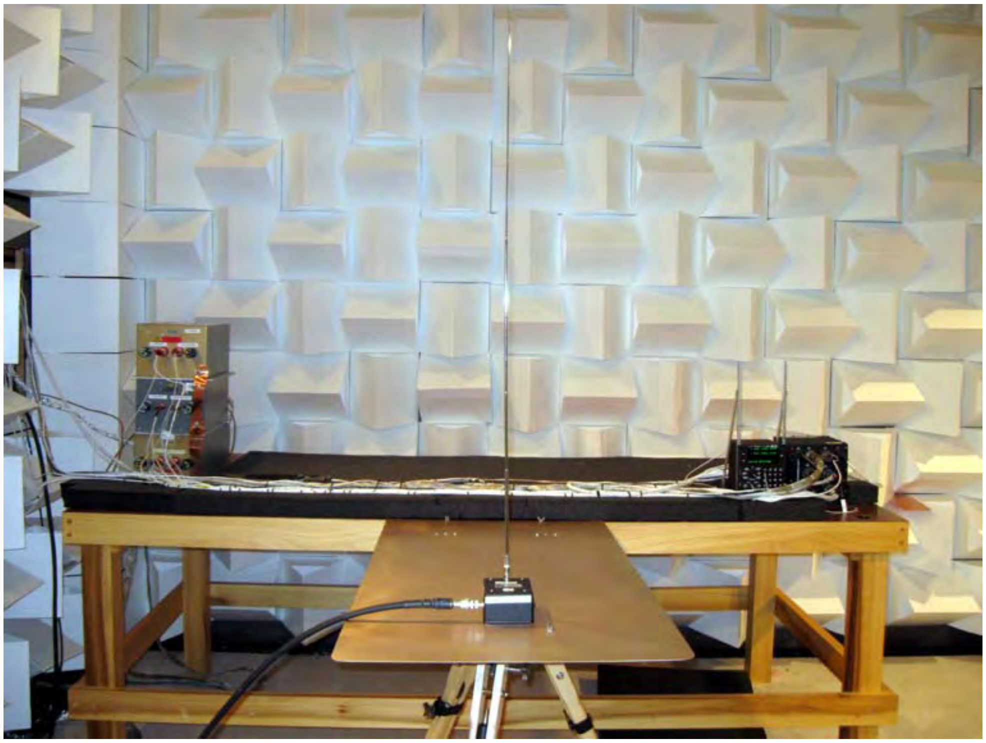


Figure K-5. Sample Emissions Set-up Photo for MIL-STD-461E.

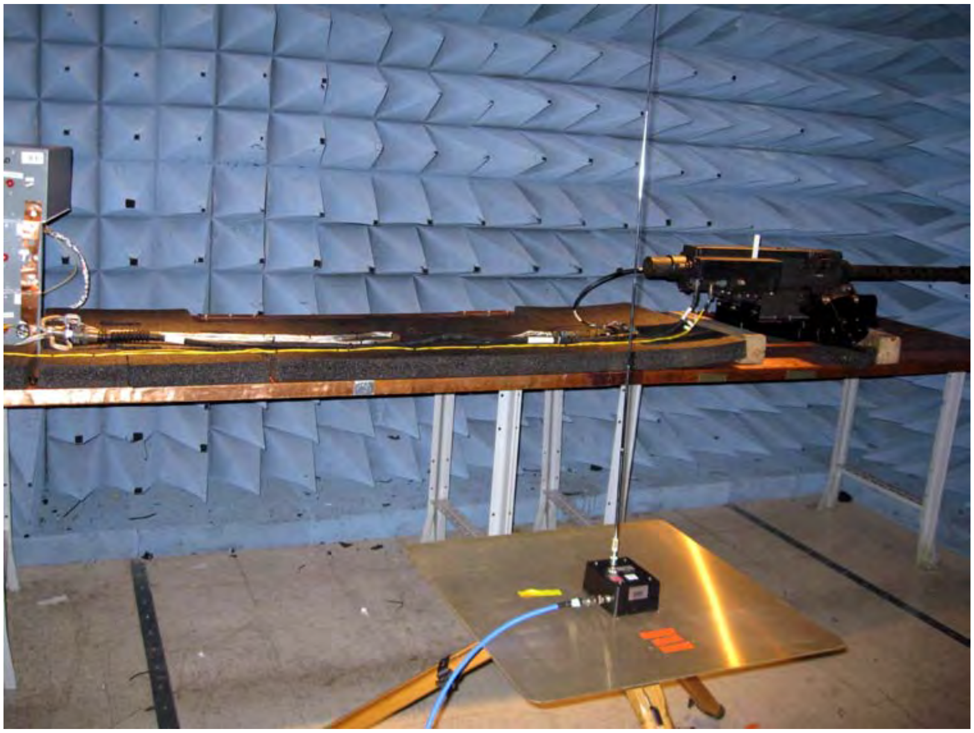


Figure K-6. Sample Emissions Set-up Photo for MIL-STD-461F.

6. DATA ANALYSIS.

The test data will be compared to the applicable criteria and the pre-event baseline measurements to determine the extent to which the test criteria are met and the effects of the test. Facility criteria compliance should be addressed to ensure that any deficiencies due to size of the chamber/shielded enclosure are documented. Pre-existing analyses and test data from previous tests may also be used as a comparison for the new test data. Failures or degradation resulting in SUT performance outside specifications, will be addressed with regards to causes, test level at which they occurred, allowable downtime, and mission impact. Vehicle/platform measurement data may require additional data consideration to account for application of the subsystem test methodology.

APPENDIX L. INTRA SYSTEM ELECTROMAGNETIC COMPATIBILITY (EMC) SOURCE/VICTIM.

1. APPLICABILITY.

This test method is applicable to equipment at the system/sub-system level. This procedure provides the methods to evaluate the system/sub-systems in support of Electromagnetic Compatibility (EMC). This Appendix is meant to act as a guide and is not a replacement for a test plan.

2. REQUIREMENTS.

The system shall be electromagnetically compatible within itself such that system operational performance requirements are met. Compliance shall be verified by system-level test, analysis, or a combination thereof.

3. PURPOSE.

The purpose of this test is to determine if there are any adverse iterations to subsystems and equipment with respect to performance and safety when additional subsystem or combinations of sub-systems on a platform are operated.

4. TEST SETUP.

4.1 Test Equipment.

The following is a list of typical equipment used for this test:

a. Baseband stimulation for transceiver systems i.e. Bit Error tester, SINAD meter, Signal generator, antenna systems

b. Antenna check equipment i.e.directional coupler, loads, spectrum analyzer, signal generator, VSWR meter or power/watt meter

c. Network checking equipment i.e.LAN taps, network analyzer

d. Weapons system diagnostics

4.2 Set Up.

a. It is recommended that the EMC test is performed in an electromagnetically quiet area as in an anechoic chamber, shielded enclosure, or an open area test site to minimize interference.

b. A pre-test evaluation shall be performed to determine whether all of the SUT subsystems noted in the intrasystem compatibility matrix are operational.

c. As part of the pre-test verify that the SUT onboard transmitter and antenna are functioning as required IAW manufactures specs. It is recommended that a transmission at a low, mid and high frequency is conducted.

5. PROCEDURES.

a. The system can be divided into multiple categories for the purposes of EMC testing as an example: non-C4ISR vehicle/platform systems, C4ISR computer and local area network (LAN) systems, C4ISR communications systems and weapons systems.

(1) The vehicle/platform and communications are independent systems and can be operated and tested as individual components; i.e., Remote Weapons Station (RWS), Voice Intercom System (VIS), Single Channel Ground and Airborne Radio System (SINCGARS), and Enhanced Position Location Reporting System (EPLRS).

(2) The computer and LAN system components are codependent items and must be treated as a one-victim group for the EMC testing. The Battlefield Functional Area Control System (BFACS), Force XXI Battle Command Brigade and Below (FBCB2), routers, hubs, switches, etc, are considered components of the computer and LAN system.

b. During the source/victim portion of EMC testing, the computer and LAN will be treated as a single-victim entity; however, the computer and LAN system components will be treated as individual source entities when testing for interference to the vehicle/platform and communications systems. The reasoning is that the computer and LAN components have individual power supplies and the greatest possibility of interference to the vehicle/platform and communications systems can be created by simply powering the computer and LAN components on. They do not have to be netted with other computer and LAN components to create interference potential. However, as a victim, the computer and LAN system must be netted with other components to establish a baseline performance level against which to check for interference-caused degradation.

c. Calibration consists of system operation verification

d. SUT Testing

Each subsystem will be operated (sources of possible interference) and any effect on the other subsystems or victim group (victims of possible interference). Specific procedures will vary depending on the type of systems installed in the vehicle/platform.

(1) Normal test operations will be as follows:

(a) Turn on a selected subsystem, designated as the victim.

(b) Turn on one of the other subsystems (source) after the victim sub¬system or group has achieved stable operation.

(c) Check the victim to determine whether any interference is being caused by operation of the source.

(d) Turn off the source after results are noted and turn on the next source.

(e) Repeat steps 2, through 4 until each source for that victim has been tested.

(f) For receiver system perform a desensitization test starting with an all sources off condition to an all sources on condition.

(2) Testing the SUT Transmitters as sources will be conducted as follows:

(a) Turn off all equipment except the selected transmitter.

(b) Turn on the selected victim subsystem and allow it to stabilize.

Note: The victim will be operated in its normal mode of operation. If the victim has more than one mode of operation, it will be tested in all modes, or known worst case.

(c) Set the transmitter to its normally used mode. (If more than one transmit mode is available do all modes, or worst case.) Set the transmitter to maximum transmitter output power.

(d) Key the transmitter and allow sufficient amount of time to allow the victim to react to the presence of the electromagnetic energy.

(e) Note on a data/record sheet any anomalous operation found. Record any information that will help to accurately describe the incompatibility.

(f) Proceed to the next victim in the test matrix after the current victim is tested and repeat steps 2 through 7.

(3) A final test of the sources can be conducted by powering on all sources and monitoring the victims. If an anomalous operation is found power OFF the sources until the victim is found.

6. DATA PRESENTATION.

Typical data collection sheets are shown in Tables L-1 and L-2.

Table L-1: Typical Intra-System Electromagnetic Compatibility Data Sheet.

Intra System EMC VICTIM/SOURCE DATA SHEET

Configuration: Vehicle 1 | **Serial No: 05** | **3/1/2006**

KEY: **G** is Good (No Anomaly Detected) **F(#)** is Anomaly Detected (See Note) ☐ / N/A to this configuration or equipment, not installed at time of test, or not evaluated.. ■ Test not required

■	System	Voice Radios				C4ISR						Vehicle						Mission														
System	VICTIM SOURCE	SINCGARS AN/VRC 92 (1A)	SINCGARS AN/VRC 92 (1B)	SINCGARS AN/VRC 92 (2A)	FHMUX	EPLRS	FBCB2 ANUYK-128	PLGR (FBCB2)	Squad Leader Display (SLD)	Lightweight Laser Printer	Embedded Training Module	Vehicular Intercom (VIS)	Engine Control	Driver's Vision Enhancment (DVE)	Ration Heater (MWRH)	Smoke Grenade Countermeasures	Remote Weapons Station (RWS) Block 1	Drivers Alert Panel (DAP)	Clim Ctrl Over Pres Sys (CCOPS)	NBC Sensor Proc Grp (NBCSPG)	CDR's workstation	Surveyor's workstation	Koolatron Sample Cooler / Warmer	Auto Chem Agent Det (M88 ACADA)	Radiac Set UDR-13	Radiac set VDR-2	Chem Bio Mass Spec (CBMS-II)	Chem Vapor Sampler Sys(CVSS)	Dbl Wheel Sampler Sys (DWSS)	J Bio Pnt Detect Sys (JBPDS)	JSL Standoff Chem Agent Detect (JSLSCAD)	Meteriorological Sensor (METSMAN)
Voice Radios	SINCGARS AN/VRC 92 (1A)	■	G	G	G	G	G	G	G	G	G	G	G	G	G	/	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
	SINCGARS AN/VRC 92 (1B)	G	■	G	G	G	G	G	G	G	G	G	G	G	G	/	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
	SINCGARS AN/VRC 92 (2A)	G	G	■	G	G	G	G	G	G	G	G	G	G	G	/	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
	FHMUX	F1	F1	F1	■	G	G	G	G	G	G	G	G	G	G	/	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
C4ISR	EPLRS	F1	F1	F1	G	■	G	G	G	G	G	G	G	G	G	/	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
	FBCB2 ANUYK-128	F1	F1	F1	G	G	■	G	G	G	G	G	G	G	G	/	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
	PLGR (FBCB2)	F1	F1	F1	G	G	G	■	G	G	G	G	G	G	G	/	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
	Squad Leader Display (SLD)	F1	F1	F1	G	G	G	G	■	G	G	G	G	G	G	/	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
	Lightweight Laser Printer	F1	F1	F1	G	G	G	G	G	■	G	G	G	G	G	/	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
	Embedded Training Module	F1	F1	F1	G	G	G	G	G	G	■	G	G	G	G	/	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
Vehicle	Vehicular Intercom (VIS)	F1	F1	F1	G	G	G	G	G	G	G	■	G	G	G	/	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
	Engine Control	F1	F1	F1	G	G	G	G	G	G	G	G	■	G	G	/	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
	Driver's Vision Enhancment (DVE)	F1	F1	F1	G	G	G	G	G	G	G	G	G	■	G	/	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
	Ration Heater (MWRH)	F1	F1	F1	G	G	G	G	G	G	G	G	G	G	■	/	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
	Smoke Grenade Countermeasures	/	/	/	/	/	/	/	/	/	/	/	/	/	/	■	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
	Remote Weapons Station (RWS) Block 1	F1	F1	F1	G	G	G	G	G	G	G	G	G	G	G	/	■	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
Mission	Drivers Alert Panel (DAP)	F1	F1	F1	G	G	G	G	G	G	G	G	G	G	G	/	G	■	G	G	G	G	G	G	G	G	G	G	G	G	G	G
	Clim Ctrl Over Pres Sys (CCOPS)	F1	F1	F1	G	G	G	G	G	G	G	G	G	G	G	/	G	G	■	G	G	G	G	G	G	G	G	G	G	G	G	G
	NBC Sensor Proc Grp (NBCSPG)	F1	F1	F1	G	G	G	G	G	G	G	G	G	G	G	/	G	G	G	■	G	G	G	G	G	G	G	G	G	G	G	G
	CDR's workstation	F1	F1	F1	G	G	G	G	G	G	G	G	G	G	G	/	G	G	G	G	■	G	G	G	G	G	G	G	G	G	G	G
	Surveyor's workstation	F1	F1	F1	G	G	G	G	G	G	G	G	G	G	G	/	G	G	G	G	G	■	G	G	G	G	G	G	G	G	G	G
	Koolatron Sample Cooler / Warmer	F1	F1	F1	G	G	G	G	G	G	G	G	G	G	G	/	G	G	G	G	G	G	■	G	G	G	G	G	G	G	G	G
	Auto Chem Agent Det (M88 ACADA)	F1	F1	F1	G	G	G	G	G	G	G	G	G	G	G	/	G	G	G	G	G	G	G	■	G	G	G	G	G	G	G	G
	Radiac Set UDR-13	F1	F1	F1	G	G	G	G	G	G	G	G	G	G	G	/	G	G	G	G	G	G	G	G	■	G	G	G	G	G	G	G
	Radiac set VDR-2	F1	F1	F1	G	G	G	G	G	G	G	G	G	G	G	/	G	G	G	G	G	G	G	G	G	■	G	G	G	G	G	G
	Chem Bio Mass Spec (CBMS-II)	F1	F1	F1	G	G	G	G	G	G	G	G	G	G	G	/	G	G	G	G	G	G	G	G	G	G	■	G	G	G	G	G
	Chem Vapor Sampler Sys(CVSS)	F1	F1	F1	G	G	G	G	G	G	G	G	G	G	G	/	G	G	G	G	G	G	G	G	G	G	G	■	G	G	G	G
	Dbl Wheel Sampler Sys (DWSS)	F1	F1	F1	G	G	G	G	G	G	G	G	G	G	G	/	G	G	G	G	G	G	G	G	G	G	G	G	■	G	G	G
	J Bio Pnt Detect Sys (JBPDS)	F1	F1	F1	G	G	G	G	G	G	G	G	G	G	G	/	G	G	G	G	G	G	G	G	G	G	G	G	G	■	G	G
	JSL Standoff Chem Agent Detect (JSLSCAD)	F1	F1	F1	G	G	G	G	G	G	G	G	G	G	G	/	G	G	G	G	G	G	G	G	G	G	G	G	G	G	■	G
	Meteriorological Sensor (METSMAN)	F1	F1	F1	G	G	G	G	G	G	G	G	G	G	G	/	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	■

ACADA - Alarm, Chemical, Agent Detection, Automatic; DVE – Driver Vision Enhancement; EPLRS – Enhanced Position Location Reporting System; FBCB2 – Force XXI Battle Command Brigade and Below; GPFU – Gas Particle Filter Unit; GPS – Global Positioning System; MWRH – Mounted Water Ration Heater; SINCGARS – Single Channel Ground and Airborne Radio System; SLD – Squad Leader Display; TSCP-Targeting Station Control Panel; VDR-2 – AN/VDR-2 Sensor; VIS – Voice Intercom System; PLGR - Percision Lighweight GPS Receiver.

F1 - C4 Performance and EMI was not perfrormed on this RWS Block 1 configuration.

Table L-2 Typical Weapons Solenoid Worksheet.

WEAPONS SOLENOID CHECK SHEET

		NOTES
SUT	Vehicle 1	
SN	5	
Weapon Type	50 Cal / M2	
Weapon SN	Mock Up	
Solenoid Model # and Serial #	M2, 0733	

	BOND	Static	Cocking	Firing	Weapon Activity
	m/ohm	Voltage (DC) mV			NOTES
Solenoid to RWS	332.5	0.92	0.98	1.78	
Solenoid to Vehicle chassis	413.6	1.15	1.57	2.49	

Monitor Solenoid while creating the following conditions	Intentional Actuation	Intentional deactuation	Un intentional Actuation	Unintentional Deactuation	NOTES
	Yes - Denotes Anomaly Observed No - Denotes No Anomaly Observed				
All systems off, engine off			NO		
Power on RWS			NO		
Engine Starting			NO		
Power on each NON-FBCB2 COM systems			NO		
Power on SINCGARS			NO		
Power on FBCB2-EPLRS			NO		
Establish EPLRS radio link (420 - 450 MHz) FBCB2 messages sent over EPLRS			NO		
All SINCGARS Transmit simultaneously, 50 Watts FH mode	NO	NO	NO	NO	
Send FBCB2 message over EPLRS while SINCGARS transmits	NO	NO	NO	NO	SC Freqs 30, 40, 50, 60, 70 80 MHz

NAME OF TESTER(s)
Mike Waller
Connie Bennett

DATE/S TESTED
3/2/2006

7. DATA ANALYSIS PROCEDURE.

The test data will be compared to the applicable criteria set forth in the SUT specification, and SUT test plan and the pre-event baseline measurements to determine the extent to which the test criteria are met and the effects of the EMC test environment on the SUT. Test anomalies will be assessed to determine if they should be classified as SUT failures and if so, further assessed with regards to causes, test parameters at which they occurred, mission impact and safety.

APPENDIX M. PERSONNEL-BORNE ELECTROSTATIC DISCHARGE (PESD).

1. APPLICABILITY.

a. This Appendix provides general test methods to assess the safety and survivability of the SUT to the effects produced by a Personnel-borne Electrostatic Discharge (PESD). This Appendix is meant to act as a guide and is not a replacement for a test plan.

b. The PESD environment is applicable to all subsystems, equipment, ordnance EIDs and firing circuits, including those installed external to aircraft IAW the equipment specification.

c. PESD environment testing may be applicable at either or both the equipment system level and the component level IAW the equipment specification. The PESD environment is applied to points on the SUT which may be contacted by personnel during the different configurations / modes of operation including operations, shipping, storage, loading/un-loading and maintenance.

2. REQUIREMENTS.

a. When exposed to the PESD environment, the SUT (and its platform, if any) shall meet the performance requirements detailed in their equipment specifications and test plan. A typical SUT PESD requirement is as follows. When the SUT is not flight or safety critical, often the “during and” is removed from the performance part of the requirement.

b. The SUT, when in the ground handling, storage, transport, and operational configurations, shall remain safe during and after exposure to the PESD environment, and meet its performance requirements during and after exposure to the PESD environment, with parameters specified by MIL-STD-464A, Paragraph 5.7.3. Discharges shall be to any point on the SUT that may be contacted by personnel during operation, transport, storage, and maintenance.

c. The simulated PESD environment is defined in MIL-STD-464A, Paragraph 5.7.3 for Ordnance Systems. The PESD test pulse parameters, detailed in Table M-1, standardize the PESD pulse and simulate the equivalent circuit of a person from which the electrostatic discharge may take place.

Table M-1. PESD Environment Parameters.

Voltage	Capacitance	Series Resistance
± 25,000 ± 500 Volts	500 ± 5% pF	500 ± 5% Ω

d. When the SUT contains ordnance or safety critical circuits / functions (e.g. EIDs, ESADs), the SUT ordnance and safety critical circuits / functions shall meet the safety margin requirements during and after exposure to the PESD specification environment or the test will be conducted GO-NO-GO on live EIDS as agreed upon by the Joint Service E3 Safety Testing Workshop held November 7-9 2007. The SUT EIDs, if any, will be considered to have passed when subjected to the PESD environment, if they exhibit sufficient safety margins. There are two classifications of EIDs, safety and reliability. In accordance with MIL-STD-464A, safety (hazardous) EIDs shall maintain a 16.5 dB safety factor below the Maximum No Fire Energy (MNFE) (based on not exceeding 15% of the EID MNFE) and reliability (non-hazardous) EIDs shall maintain a 6 dB safety factor below the MNFE (based on not exceeding 50% of the MNFE). When empirical MNFE for a specific, qualified, one-Watt no-fire EID is lacking, the Army may use a level of 17.6 mJ based on previous testing of a series of Stinger launch/flight motor EIDs providing the 16.5 dB safety factor is necessary and when approved by the Army Electromagnetic Environmental Effects (E3) Board. MIL-STD-1316 specifies a minimum firing voltage of 500 volts for an ESAD.

3. PURPOSE.

a. The purpose of this testing is to verify the ability of the SUT to withstand the PESD environment IAW its specification performance requirements detailed in the test plan. A typical test plan purpose follows.

b. The purpose of PESD testing is to determine if exposure of the subsystem, equipment or ordnance to the PESD environment due to personnel handling (e.g. operating, transporting, loading, unloading, assembly, disassembly, maintenance) results in a safety hazard (e.g. fuel and/or ordnance / EID / firing circuit initiation / degradation / duding, shocks to personnel), subsystem or equipment damage or subsystem or equipment degraded performance (malfunctions, undesirable & unacceptable responses).

4. TEST SETUP

4.1 Test Equipment.

a. A listing of the typical equipment used during PESD testing is provided in Table M-2. The test report shall include the actual test equipment used along with their serial numbers and calibration dates, if applicable.

(a) The test measurement equipment is required to operate in the PESD environment frequency range (100 kHz to 200 MHz) as a minimum.

(b) Unless otherwise stated, test equipment tolerances shall meet the following minimum requirements:

(1) Distance: ± 5 %.

(2) Frequency: ±2 %.

Table M-2. PESD Typical Test Equipment.

Hardware	Comments
PESD Generator / Simulator	Both tabletop and hand-held versions are available
Current Probe	Used to measure current coupled to SUT or SUT EIDs (preferred – a closed type current probe - requires a break in the line being monitored to attach the probe) Need several in different physical sizes and current handling capabilities
Current Probe	Used to measure current coupled to SUT cable (a clamp type probe - used only when the wire cannot be cut) Need several in different physical sizes and current handling capabilities
Differential Voltage Probe	Used to measure voltage across ESAF capacitor. Need several in different physical sizes and current handling capabilities
Telemetry Unit	Takes input from probes & drives fiber optic output Need several in different physical sizes and current/voltage handling capabilities
Fiber Optic Converter	Converts telemetry fiber optic signal back to an analog signal for input to oscilloscope
Digital Storage Oscilloscope	Used to record and display current and voltage measurements. Must operate in the 100 kHz to 200 MHz frequency range.
Laptop PC	For data reduction (e.g. calculates safety margins, creates plots from data for display, stores data)
ESD Test Software	For data reduction / presentation
Plotter	To plot out data

(3) Amplitude, measurement receiver: ± 2 dB

(4) Amplitude, measurement system (receiver, cables, etc): ± 3 dB

(5) Time (waveforms): ± 5 %

(6) Resistors: ± 5 %

(7) Capacitors: ± 20 %

(c) Test software used, including measurement system software, SUT software, instrumentation and test set software shall be documented as to dates, developer, version number, etc.

4.2 Instrumentation.

SUT instrumentation is permissible but it shall not influence test results. To minimize the possibility of instrumentation influencing test results or instrumentation susceptibility:

a. Use fiber-optic based instrumentation whenever possible.

b. Use twisted, shielded pair wiring when conductive leads are required.

c. Instrumentation equipment and its leads should be buried inside the SUT with only the fiber optic leads exiting the SUT.

4.3 Instrumentation may include the following:

a. Current probes to measure the stimulus current waveforms to determine the adequacy of the simulated PESD environment.

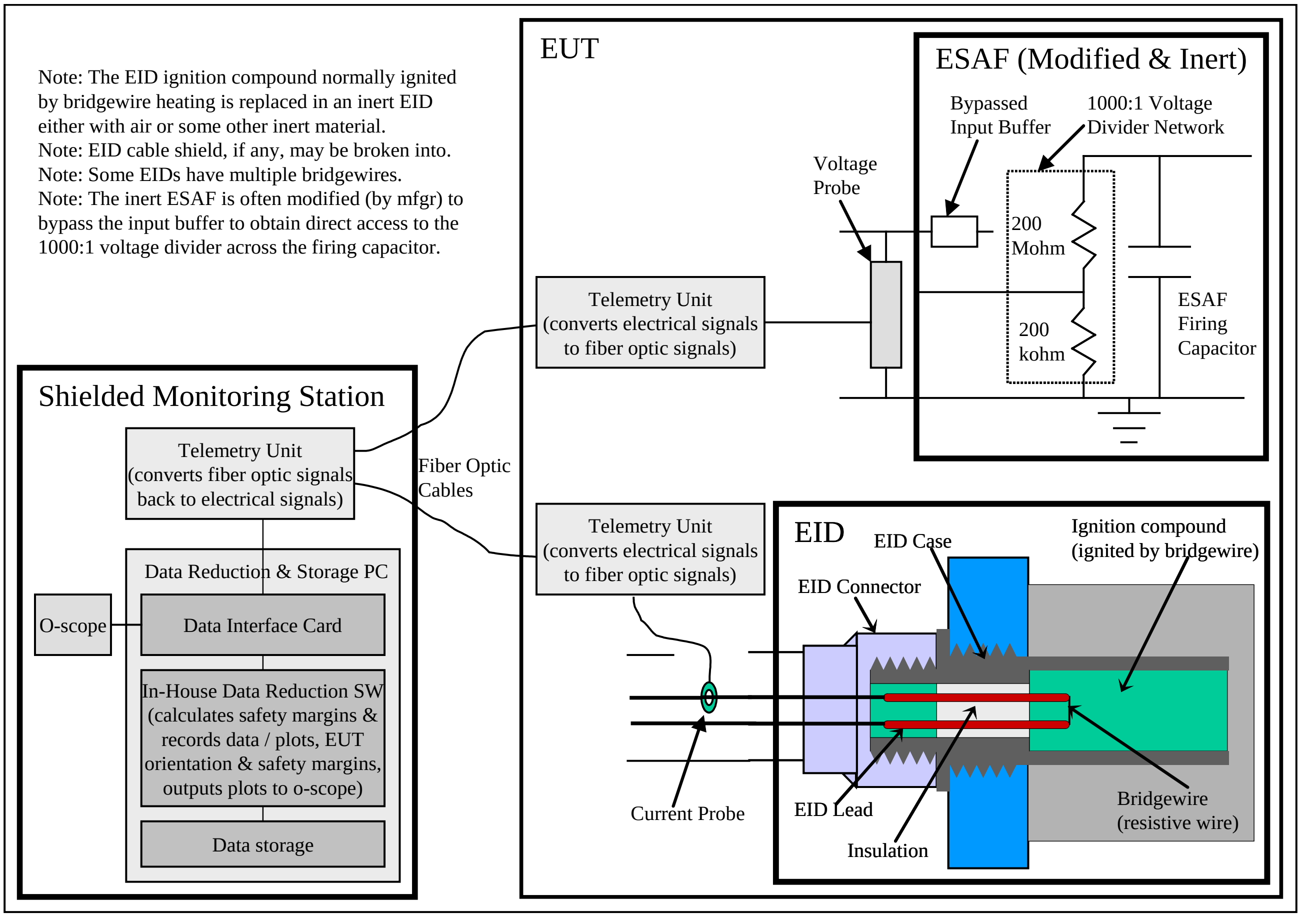
b. Cameras connected to monitors in a shielded instrumentation room using fiber optic lines. The cameras may be placed within shielded enclosures.

c. Test sets may be used to check out the SUT before and after each test event but should be removed from the test setup for PESD testing (if not used during the test event). If required during testing, test sets should be protected from the test environment and placed as far away from the strike point as possible. Any test set interface cabling should be well shielded and emplaced radially away from the strike point to minimize coupling.

d. SUT instrumentation typically consists of current probes to measure the current coupled to one or more SUT wires / cables due to the PESD environment and/or voltage probes to measure a firing capacitor voltage.

e. EIDs & ESAFs may be instrumented to determine safety margins (see Figure M-1) using current and voltage probes.

f. PESD testing is typically performed using ordnance items that have been modified to remove all explosives, pyrotechnic, and combustible materials, including the EIDs or the test will be conducted GO-NO-GO on live EIDS as agreed upon by the Joint Service E3 Safety Testing Workshop held November 7-9 2007.. Test personnel instrument and install inert EIDs / ESAFs (a typical EID / ESAF description table is shown in Table M-2). The instrumented EIDs / ESAFs are installed in the ordnance item at precisely the same location as the original EIDs / ESAFs.



Note: The EID ignition compound normally ignited by bridgewire heating is replaced in an inert EID either with air or some other inert material.
Note: EID cable shield, if any, may be broken into.
Note: Some EIDs have multiple bridgewires.
Note: The inert ESAF is often modified (by mfgr) to bypass the input buffer to obtain direct access to the 1000:1 voltage divider across the firing capacitor.

Figure M-1. Typical Instrumentation Block Diagram.

Table M-2. Typical Instrumented EID Description.

EID	EID Type	MNFC / MNFE	Required Safety Margins	Bridgewire Resistance (Ω)	Comments
Control Battery	304-JTM-050	17.6 mJ	6.0 dB for reliability	0.5 (two 1± 0.1 BWs in parallel)	Used Pearson 2877 probe.
Electronics Battery	MIS-40737A	17.6 mJ	6.0 dB for reliability	0.5 (two 1± 0.1 BWs in parallel)	Used Pearson 2877 Probe.
Rocket Motor Igniter	PN: 2-101400-1 Dwg: 13287151	17.6 mJ	16.5 dB for safety	1.0	Used Pearson 2877 Probe.
Short Delay Fuze Detector	2-400020-1	3.4 mJ	16.5 dB for safety	2.5	2 tested. Used Pearson 2877 Probe.
Long Delay Fuze Detector	2-400020-3	3.4 mJ	16.5 dB for safety	2.5	2 tested. Used Pearson 2877 Probe.
2AW4E3 cable harness	The cable harness was instrumented to measure the current induced on it by the environments for contractor EMP analysis. Used a Pearson 91550-2 probe.				

g. Also, EIDs are tested live with no instrumentation; GO-NO-GO. The live EID bridgewire resistances are checked before and after each discharge and the measurements compared to check for degradation and firing. With this method the test is repeated a minimum of 10 times (22 is statistically preferable) with a fresh EID each time to provide some measure of confidence that the EIDs will remain safe.

4.4. Pre-Test Evaluation.

a. A pre-test evaluation is performed to include the following. This evaluation is used for test planning and can often reduce the amount of testing required.

(1) Determine / select PESD test points (points contacted by personnel).

(2) Determine the primary PESD current paths.

(3) Determine the most / least susceptible SUT configurations.

(4) Determine the most / least susceptible SUT modes of operation.

(5) Determine the probable Ports of Entry (POEs).

(6) Determine the bulk current measurement points.

(7) Perform an energy coupling analysis to identify the type and capability requirements for the data acquisition system. Usually, clamp-on non-obtrusive current probes are used to not affect the inherent shielding integrity of the cable or the SUT shielding integrity.

(8) Determine critical SUT data required to be instrumented and monitored.

(9) Determine which EIDs are to be instrumented and measured and how.

(10) Determine SUT/platform critical functions and circuits.

(11) Determine SUT PESD protection features and their predicted performance and whether they are repairable or replaceable.

(12) Determine verification and pass/fail criteria and required safety margins.

(13) Determine the SUT operating and check-out procedures.

b. Pre-existing analyses and test data from previous tests may be evaluated and incorporated into the test planning and pre-test analysis in order to enhance and reduce the scope of the new testing.

4.5 Setup.

Test setups vary. Some typical test setup photographs are shown in Figures M-2 and M-3. Following are general / typical test setup guidelines.

a. PESD testing utilizes a PESD charge generator designed to discharge IAW the required test parameters. The PESD environment is generated by discharging the voltage on a capacitor through a resistor onto the SUT test points.

b. Fast response probes are used to monitor current, voltages, and the test energy. Telemetry units are used to convert the electrical signals to optical signals and transmit them over fiber optic lines to a receiver in a shielded area where they are converted back to electrical signals, processed, observed (monitored on a digitizing oscilloscope), and recorded on a PC laptop for data reduction. Test data reduction software extracts the desired test parameters, calculates the EID safety margins, plots the data and creates plots.

Figure M-2. Typical PESD Test Setup Component Level.

Figure M-3. Typical PESD Test Setup – Sling Loaded.

c. The PESD environment is verified by testing at the equipment level or at the platform level. The SUT may be tested in several different setups (e.g. SUT components on test bench, SUT installed on aircraft, or SUT hanging in an isolated sling). The SUT may be tested in several different modes (e.g. storage, transport, operating, loading). Testing is usually performed with the SUT un-powered. The SUT may be tested in several different configurations and modes. For example, tested first with the SUT un-powered in the storage configuration and then with the SUT powered and operating a mission.

d. The discharge test points shall be points that may be contacted by the crew during operation or handling personnel during operations such as transport, assembly, loading/unloading and maintenance. Each test location will be tested with both positive and negative polarity ESD transients. Each test location will be documented and photographed for test report clarity.

e. After each test discharge, the SUT is checked for proper operation and damage. If damage occurs, it will be documented and assessed. Testing will not be continued until the problem and its effect on the SUT has been assessed as well as potential impacts on the SUT if testing is continued.

f. The SUT and EIDs may be instrumented tested GO-NO-GO with live EIDs. EID bridgewire resistances should measured before and after each discharge to check for degradation and firing (or each test level set of discharges).

g. Allow sufficient time for test equipment to stabilize prior to calibration and testing. Periodically check for receiver or transducer overload conditions.

h. Test equipment (e.g. oscilloscopes) are calibrated regularly by calibration labs using procedures traceable to the National Institute of Standards and Technology (NIST). The typical PESD instrumentation system (e.g. Nanofast) has a self-calibration feature.

5. TEST PROCEDURES.

The specific test procedures will be conducted IAW the test plan. The exact order of testing may be altered for test efficiency with the approval of the test manager. Any changes to the procedures will be noted in the test report. PESD testing is potentially hazardous to personnel. Safety procedures must be initiated IAW the test facility ESD Standard Operating Procedures (SOP).

5.1 Calibration.

a. Test Equipment Calibration:

Calibration of the test equipment shall be traceable to the NIST.

b. PESD Test Setup Calibration (to verify specification waveform parameters):

(1) Set up the PESD simulator with settings that past experience has shown to discharge per the specification waveform parameters.

(2) Secure the test area and insure personnel are at a safe distance.

(3) Charge up the PESD simulator to the positive specification level.

(4) Discharge the PESD simulator to the ground return line. Repeat, adjusting the PESD simulator until the PESD criteria is obtained.

(5) Record the PESD simulator calibration settings.

(6) Repeat calibration for the negative specification level.

(7) Verify that the PESD simulator is in a safe configuration.

5.2 EID Instrumentation Calibration.

a. Check instrumentation operation for the SUT, EIDs, ESAFs, etc.

b. Test EIDs and their associated firing circuit continuity and operation.

c. Exercise instrumentation self-calibration features, if available.

5.3 Test.

a. Set up the SUT for PESD testing using the same test equipment and settings used during calibration. Set up the instrumentation equipment (e.g. to monitor EID current / energy coupling), if applicable. Electrically isolate the SUT.

b. Connect the instrumentation to the data processing/collection system (oscilloscope and PC) using the telemetry system and fiber optic cables.

c. Place the SUT in a test plan matrix specified configuration and mode.

d. Verify data acquisition and instrumentation equipment operation.

e. Power the SUT ON, run pre-test baseline functional checks.

f. Secure the test area and insure that personnel are at a safe distance.

g. Charge PESD probe to the positive specification level using the settings determined during calibration.

h. Move the PESD probe toward a test point until discharge occurs.

i. Verify PESD simulator is in a safe configuration.

j. After each discharge, examine the data to ensure that the PESD criteria were simulated, the test data is adequate, and the data is within pass/fail criteria. Calculate safety margins or, measure live EID bridgewire resistance as required.

k. After each discharge, perform a visual check for PESD induced SUT damage.

l. After each discharge, repeat SUT operational checks and compare to baseline.

m. If there are susceptibilities, determine the SUT components affected the required steps to recovery (e.g. cycling power) and the recovery time. If possible (if SUT not damaged), verify the repeatability of the susceptibility and determine the threshold and safety margins, if necessary.

n. Record the following for each discharge and mark on plots.

(1) Stimulus waveform parameter data / plots.

(2) Test configuration / test mode.

(3) Test discharge point.

(4) Post-discharge functional check pass/fail results.

(5) Visual damage inspection results.

(6) SUT responses (e.g. components affected, wire/cable currents, EID currents, SUT upsets, recovery times, etc.).

(7) EIDs monitored their calculated SMs and whether they met requirements.

(8) EID bridgewire resistance and determination of degradation, if required.

(9) Date, time, location.

o. Repeat the test procedure for the negative PESD transient.

p. Repeat the test procedure for all test discharge points.

q. Repeat the test procedure for all test modes and configurations.

6. DATA PRESENTATION.

A sample tabular data sheet is provided in Table M-3. Note: data should be reported at the level of accuracy of the test equipment. Sample test photographs and test data plots are provided in Figures M-4 and M-5.

Table M-3. Example PESD Test Run Data Sheet.

Test Config	**Test Mode**	**Discharge Location**	**Shot #**	**EID Name**	**Test Pulse Parameters**	**EID level (J) /Cable Current (mA)**	**Safety Margins (dB)**	**EID BW Resist. (Ω) Pre/Post**	**Pass / Fail**
In Storage Container	Un-powered Not operating	Bottom Left corner		Missile Motor EID #1	+25 kV				Visual chk: Funct chk: EID SM: BW resist:
					-25 kV				Visual chk: Funct chk: EID SM: BW resist:
				Missile Motor EID #2	+25 kV				Visual chk: Funct chk: EID SM: BW resist:
					-25 kV				Visual chk: Funct chk: EID SM: BW resist:

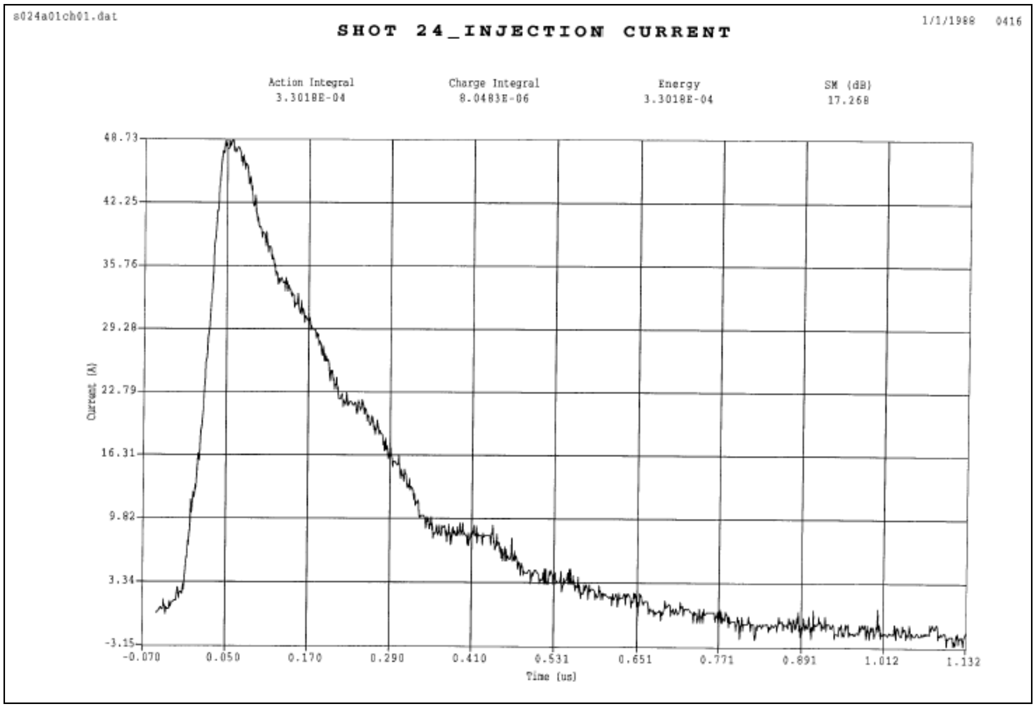


Figure M-4. Typical Injection Current Data Plot.

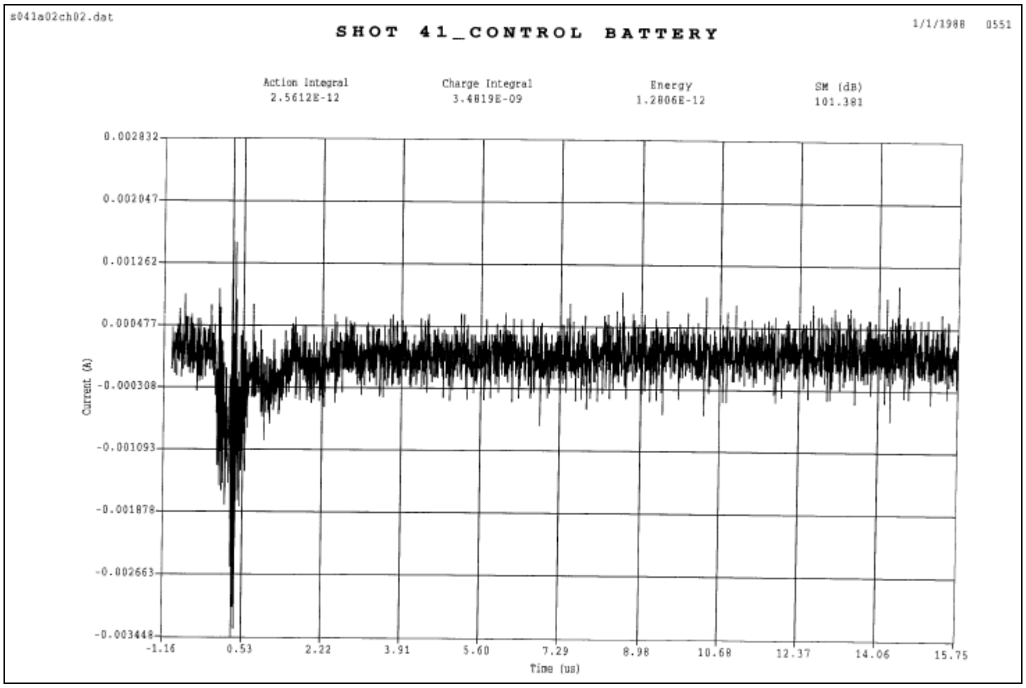


Figure M-5. Typical EID Data Plot.

7. DATA ANALYSIS.

a. Test data will be compared and evaluated against the criteria set forth in MIL-STD 464, the SUT specification, and SUT test plan to determine if the SUT met the criteria. Deficiencies will be identified, and discussed.

b. The safety margins are calculated using the following formulas:

ENERGY: $\text{SM (dB)} = 10 \log_{10} (E_{MNF} / E_{Induced})$

where E_{MNF} = Max No-Fire energy of EID. Typically 17.6 milli-Joules[1]
$E_{induced}$ = measured energy induced in the EID circuit (J)

CURRENT: $\text{SM (dB)} = 20 \log10 (I_{MNF} / I_{Induced})$

where I_{MNF} = Maximum No-Fire current of EID (A)
$I_{induced}$ = measured value for the induced EID current (A)
(or Minimum Discernable Current, MDC, if signal below MDC)

VOLTAGE: $\text{SM (dB)} = 20 \log10 (MFV / V_{Induced})$

where MFV = Min ESAD capacitor FiringVoltage. Typically 500 Volts[2]
$V_{induced}$ = measured value for the induced ESAD cap firing voltage
(or Minimum Discernable Voltage, MDV, if signal below MDV)

NOTE (1) - Previous test programs have used 17.6 milli-Joules as the MNFE for safety margin calculations for MIL-I 23659 qualified, one watt, no-fire initiators. The MNFE value was established during testing of a series of Stinger Launch/Flight motor EIDs. The EID testing evaluated 72 initiators tested with a one amp per millisecond current ramp. The data was used to derive the MNFE and is documented in technical document RD-TE-87-4, MLRS AT2 Lightning Test Report.

NOTE (2) - MIL-STD-1316 requirement for minimum firing voltage = 500 volts. Most initiators have minimum firing voltages in the 1000 to 2000 volt range.

NOTE (3) - or the test will be conducted GO-NO-GO on live EIDS as agreed upon by the Joint Service E3 Safety Testing Workshop held November 7-9 2007.

c. The test data will be compared to the applicable criteria set forth in the SUT specification, and SUT test plan and the pre-event baseline measurements to determine the extent to which the test criteria are met and the effects of the PESD test environment on the SUT. Test anomalies will be assessed to determine if they should be classified as SUT failures and if so, further assessed with regards to causes, test parameters at which they occurred, mission impact and safety.

APPENDIX N. DIRECT STRIKE LIGHTNING (DSL).

1. APPLICABILITY.

a. This Appendix provides general test methods to assess survivability of the SUT to the effects produced by a Direct Strike Lightning (DSL). This Appendix is meant to act as a guide and is not a replacement for a test plan.

b. This Appendix is usually applicable at the equipment system level IAW the equipment specification with the SUT integrated into its platform (if any). The environment may apply to the SUT in multiple configurations including shipping.

2. REQUIREMENTS.

a. When exposed to the DSL environment, the SUT (and its platform, if any) shall meet their applicable performance requirements. A typical SUT DSL requirement is as follows.

The SUT shall remain safe during and after exposure to the DSL environment and meet its operational performance requirements after exposure to the DSL environment when in its operational configurations & modes and shall remain safe during and after exposure to the DSL environment when in its storage and transportation configurations & modes.

b. The simulated DSL environment is defined in MIL-STD-464. The standardized DSL test pulse parameters are detailed in Table N-1 and Figure N-1.

c. When the SUT contains ordnance or safety critical circuits / functions (e.g. EIDs,), the SUT ordnance and safety critical circuits / functions shall meet the safety margin requirements during and after exposure to the DSL specification environment. The SUT EIDs, if any, will be considered to have passed when subjected to the DSL environment, if they exhibit sufficient safety margins. There are two classifications of EID situations, safety and reliability. In accordance with MIL-STD-464, safety (hazardous) EIDs shall maintain a 16.5 dB safety factor below the Maximum No Fire parameter (MNF) (based on not exceeding 15% of the EID MNF) and reliability (non-hazardous) EIDs shall maintain a 6 dB safety factor below the MNF (based on not exceeding 50% of the MNF). When empirical MNFE for a specific, qualified, one-Watt no-fire EID is lacking, the Army may use a level of 17.6 mJ based on previous testing of a series of Stinger launch/flight motor EIDs providing the safety factor is necessary, and when the methodology is approved by the Army Electromagnetic Environmental Effects (E3) Board. MIL-STD-1316 specifies a minimum firing voltage of 500 volts for an ESAD. In some cases, EIDs are tested live with no instrumentation; GO-NO-GO. This is the preferred method as agreed upon by the Joint E3 Safety Testing Workshop on 7-9 November, 2007. Testing in a tactical full up live configuration also applies as part of the Joint E3 Safety Testing Workshop for specific ordnance configurations.

Table N-1. DSL Environment Parameters.

Parameter	**Cloud-to-Ground**
Number of strokes	24 (max)
Time intervals between strokes (msec)	60
Peak current (first stroke) (kA)	200 (Comp A)
Time to peak (all strokes)(μsec)	6.4 (Comp A) 3.2 (Comp D)
Max dI/dt (A/sec)	1.4E11
Action integral $\int i^2\, dt$ (A^2 sec)	2E6
Peak current (subsequent strokes) (kA)	100 (Comp D)
Action integral $\int i^2\, dt$ (subsequent strokes) (A^2 sec)	0.25E6
Amplitude of continuing current (avg) (A)	400 (Comp C)
Duration of continuing current (msec)	500 (Comp C)
Charge passing in continuing current (coulombs)	200 (Comp C)
Charge per stroke (coulombs)	228
Total charge in flash (coulombs)	223
Flash duration (sec)	2 (max)

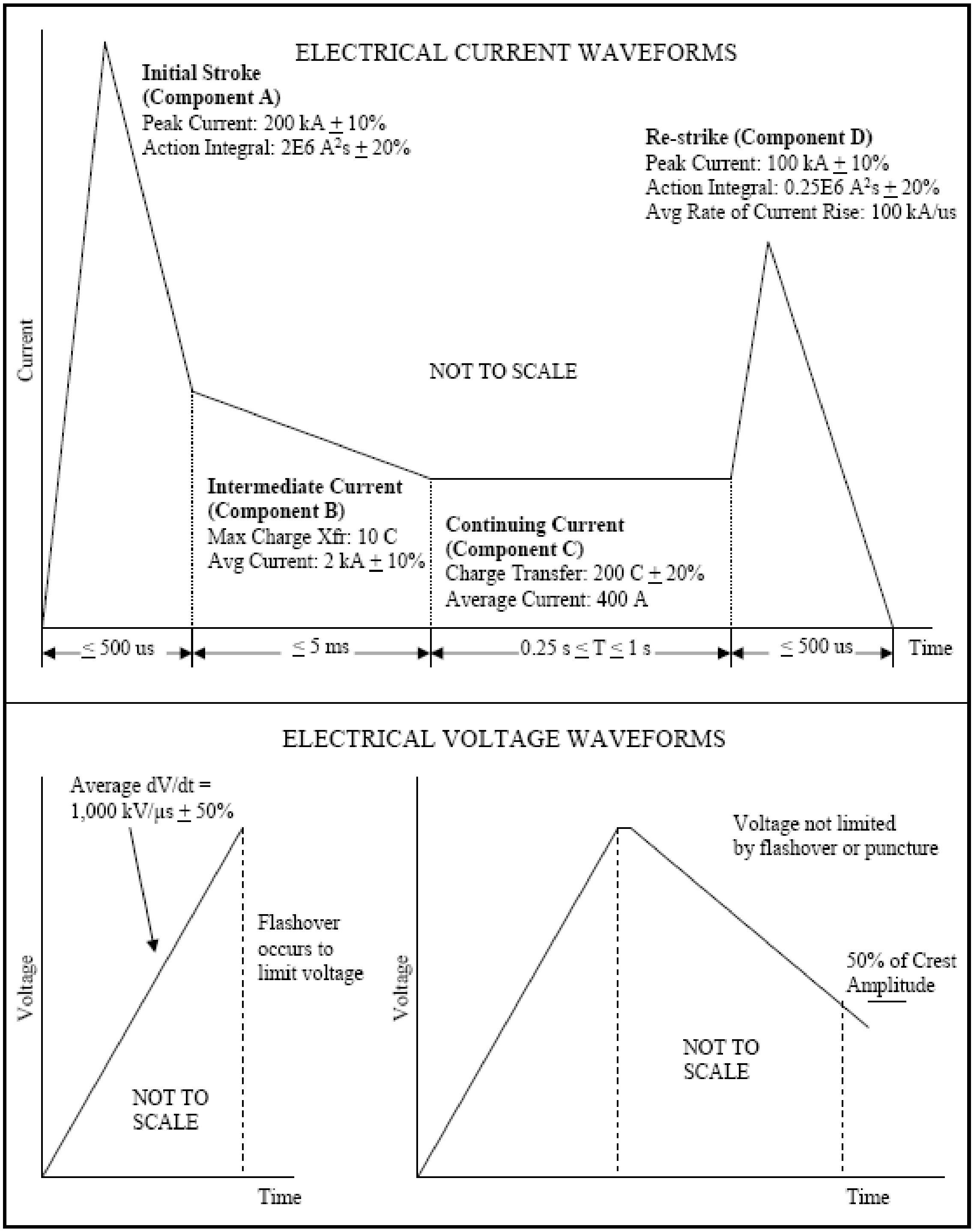


Figure N-1. DSL Component Description.

3. PURPOSE.

a. The purpose of this testing is to verify the ability of the SUT to withstand the DSL environment IAW its specification performance requirements detailed in the test plan. A typical test purpose follows:

The purpose of DSL testing is to demonstrate that the SUT remains safe and meets its operational performance requirements during and after being subjected to the DSL environment when in a stored configuration and that the SUT remains safe during and after being subjected to the DSL environment when in an operational condition.

4. TEST SETUP.

4.1 Test Equipment.

a. A listing of the typical equipment used during DSL testing is provided in Table N-2. The test report shall include the actual test equipment used along with their serial numbers and calibration dates, if applicable.

b. The test measurement equipment is required to operate in the DSL environment frequency range (dc to 2 MHz) as a minimum.

c. Unless otherwise stated, test equipment tolerances shall meet the following minimum requirements:

(1) Distance: ± 5 %

(2) Frequency: ± 2 %

(3) Amplitude, measurement receiver: ± 2 dB

(4) Amplitude, measurement system (receiver, cables, etc): ± 3 dB

(5) Time (waveforms): ± 5 %

(6) Resistors: ± 5 %

(7) Capacitors: ± 20 %

d. Test software used, including measurement system software, SUT software, instrumentation and test set software shall be documented as to dates, developer, version number, etc.

Table N-2. DSL Typical Test Equipment List.

Hardware	Description
DSL Generator / Simulator	Often a custom, in-house design and build Marx generator type design, usually in four parts to simulate each of the four DSL components
HV DC Power Supply	High Voltage power supply used to charge up capacitor charge storage bank
Voltage Divider Network	Used to measure charge voltage
Down Conductor	(discharge probe)
Current Probe	Used to measure injection current Placed around down conductor
Current Probe	Used to measure current coupled to SUT or SUT EIDs (preferred – a closed type current probe - requires a break in the line being monitored to attach the probe)
Current Probe	Used to measure current coupled to SUT cable (a clamp type probe - used only when the wire cannot be cut) Need several in different physical sizes and current handling capabilities
Differential Voltage Probe	Used to measure voltage across the ESAF capacitor. Need several in different physical sizes and current handling capabilities
Field Probe	E and H field probes real time field calibration and monitoring
Telemetry Unit	Takes input from probes & drives fiber optic output Need several in different physical sizes and current/voltage handling capabilities
Fiber Optic Converter	Converts telemetry fiber optic signal back to an analog signal for input to oscilloscope
Fiber Optic lines	To send the sensor data back to the data acquisition units
Digital Storage Oscilloscope	Used to record and display current and voltage measurements Must operate in the dc to 2 MHz range minimum, Typical setting: 2 µs/div
Portable Computer	For data reduction (e.g. calculates safety margins, creates plots from data for display, stores data)
Lightning Test Software	For data reduction / presentation
Plotter	To plot out data

4.2 Instrumentation.

SUT instrumentation is permissible but it shall not influence test results. To minimize the possibility of instrumentation influencing test results or instrumentation susceptibility:

a. Use fiber-optic based instrumentation whenever possible.

b. Use twisted, shielded pair wiring when conductive leads are required.

c. Instrumentation equipment and its leads should be buried inside the SUT with only the fiber optic leads exiting the SUT.

4.3 <u>Instrumentation may include the following</u>:

a. Current probes to measure the stimulus current waveforms to determine the adequacy of the simulated DSL environment.

b. Cameras connected to monitors in a shielded instrumentation room using fiber optic lines. The cameras may be placed within shielded enclosures.

c. Test sets may be used to check out the SUT before and after each test event but should be removed from the test setup for DSL testing (if not used during the test event). If required during testing, test sets should be protected from the test environment and placed as far away from the strike point as possible. Any test set interface cabling should be well shielded and run radially away from the strike point to minimize coupling.

d. SUT instrumentation typically consists of current probes to measure the current coupled to one or more SUT wires / cables due to the DSL environment and/or voltage probes to measure a firing capacitor voltage.

e. EIDs s may be instrumented to determine safety margins (see Figure N-2) using current and voltage probes, or the test will be conducted GO-NO-GO on live EIDS as agreed upon by the Joint Service E3 Safety Testing Workshop held November 7-9 2007.

f. DSL testing is typically performed using ordnance items that have been modified to remove all explosives, pyrotechnic, and combustible materials, including the EIDs. Test personnel instrument and install inert EIDs (a typical EID description table is shown in Table N-3). The instrumented EIDs are installed in the ordnance item at precisely the same location as the original EIDs.

g. In some cases, EIDs are tested live with no instrumentation. The live EID bridgewire resistances are checked before and after each discharge and the measurements compared to check for degradation and firing. With this method the test is repeated a minimum of 10 times (22 is statistically preferable) with a fresh EID each time to provide some measure of confidence that the EIDs will remain safe. If the SUT is small, all samples can be tested at the same time. This is the preferred method as agreed upon by the Joint E3 Safety Testing Workshop on 7-9 November, 2007.

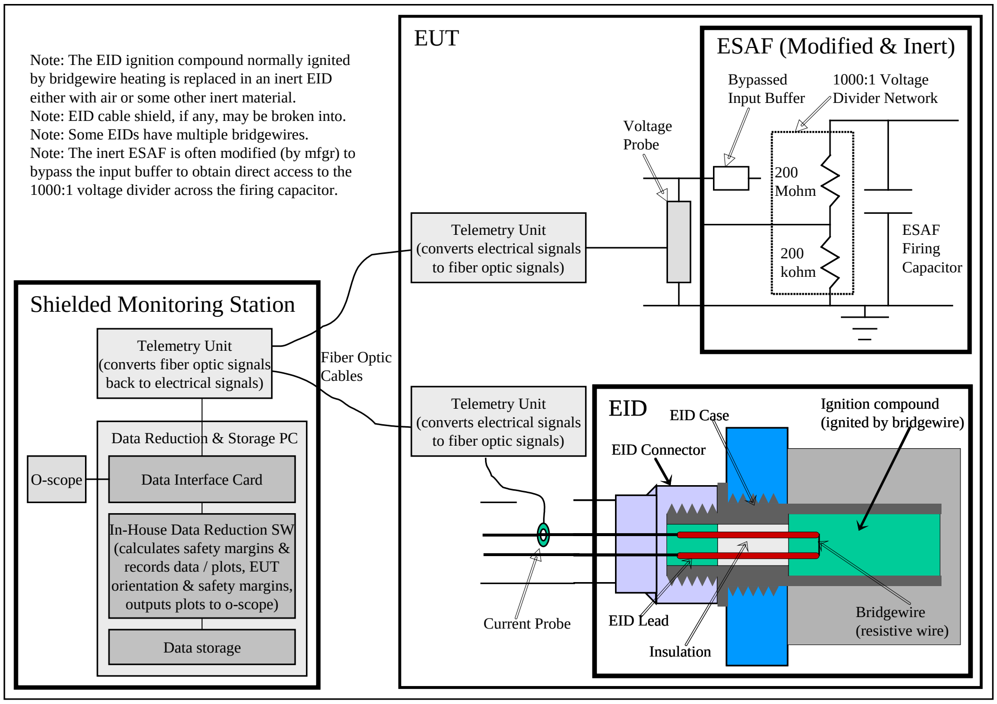


Figure N-2. Typical Instrumentation Block Diagram.

Table N-3. Typical Instrumented EID Description.

EID	EID Type	MNFC / MNFE	Required Safety Margins	Bridgewire Resist. (Ω)	Comments
Control Battery	304-JTM-050	17.6 mJ	6.0 dB for reliability	0.5 (two 1±0.1 BWs in parallel)	Used Pearson 2877 probe.
Electronics Battery	MIS-40737A	17.6 mJ	6.0 dB for reliability	0.5 (two 1±0.1 BWs in parallel)	Used Pearson 2877 Probe.
Rocket Motor Igniter	PN: 2-101400-1 Dwg: 13287151	17.6 mJ	16.5 dB for safety	1.0	Used Pearson 2877 Probe.
Short Delay Fuze Detector	2-400020-1	3.4 mJ	16.5 dB for safety	2.5	2 tested. Used Pearson 2877 Probe.
Long Delay Fuze Detector	2-400020-3	3.4 mJ	16.5 dB for safety	2.5	2 tested. Used Pearson 2877 Probe.
2AW4E3 cable harness	The cable harness was instrumented to measure the current induced on it by the environments for contractor DSL analysis. Used a Pearson 91550-2 probe.				

4.4 Pre-Test Evaluation.

a. A pre-test evaluation is performed to include the following. This evaluation is used for test planning and can often reduce the amount of testing required.

(1) Determine / select DSL test points (points contacted by personnel).

(2) Determine the primary DSL current paths.

(3) Determine the most / least susceptible SUT configurations.

(4) Determine the most / least susceptible SUT modes of operation.

(5) Determine the probable Ports of Entry (POEs).

(6) Determine the bulk current measurement points.

(7) Perform an energy coupling analysis to identify the type and capability requirements for the data acquisition system. Usually, clamp-on non-obtrusive current probes are used to not affect the inherent shielding integrity of the cable or the SUT shielding integrity.

(8) Determine critical SUT data required to be instrumented and monitored.

(9) Determine which EIDs are to be instrumented, monitored, measured and how.

(10) Determine SUT/platform critical functions and circuits.

(11) Determine SUT DSL protection features and their predicted performance and whether they are repairable or replaceable.

(12) Determine verification and pass/fail criteria and required safety margins.

(13) Determine the SUT operating and check-out procedures.

b. Pre-existing analyses and test data from previous tests may be evaluated and incorporated into the test planning and pre-test analysis in order to enhance and reduce the scope of the new testing.

4.5 Setup.

Test setups vary. Some typical test setups and photographs are shown in Figures N-3 through N-7. Following are general / typical test setup guidelines.

a. The DSL environment is generated by discharging the energy in several capacitor banks through low resistance cables onto the SUT attachment points. The different capacitor banks are set up to produce different components of the lightning waveform (A through D). The SUT / platform will be grounded to the return side of the lightning generator. The return path should be less than 1.0 Ω resistance and less than 20 μH of inductance.

b. Fast response current probes are used to monitor current and to measure the test energy. Telemetry units are used to convert the electrical signals to optical signals and transmit them over fiber optic lines to a receiver in a shielded area where they are converted back to electrical signals, processed, observed (monitored on a digitizing oscilloscope), and recorded on a PC laptop for data reduction. Test data reduction software extracts the desired test parameters, calculates the EID safety margins, plots the data and creates plots.

c. Testing usually consists of two phases at each test point. The first phase consists of a simultaneous Component A and Component C attachment. The second phase consists of a Component D attachment. The effects of Component B are often considered negligible compared to the other components since all the components are being subjected to the SUT at the same test points (the components would normally track across a fast moving SUT / platform). Component A has a peak current of 200,000 Amperes compared to a peak current of 2000 Amperes for Component B and Component C has a charge transfer of 200 Coulombs compared to a charge transfer of 10 Coulombs for Component B.

d. The DSL test points are typically selected to be the sharp edges and/or the highest points on the test article as these are the most likely locations for the lightning to attach to, or worst-case safety-related test points may be chosen.

e. The SUT may be tested in several different configurations and modes. For example, tested first with the SUT un-powered and in the storage configuration and then with the SUT powered and operating in a fire mission. All SUT cabling is terminated. Dummy loads are typically used on un-connected SUT interface cables to increase simulation fidelity.

f. After each test event, the SUT, EIDs & platform are checked for proper operation and damage. If damage occurs, it will be documented and assessed. Testing will not be continued until the problem and its effect on the SUT has been assessed as well as potential impacts on the SUT if testing is continued.

g. The SUT and EIDs may be instrumented. EID bridgewire (live and inert) resistances should be measured before and after each discharge to check for degradation and firing.

h. Allow sufficient time for test equipment to stabilize prior to calibration and testing. Periodically check for receiver or transducer overload conditions.

i. Test equipment (e.g. oscilloscopes) is calibrated regularly by calibration labs using procedures traceable to the National Institute of Standards and Technology (NIST). The typical DSL instrumentation system (e.g. Nanofast) has a self-calibration feature.

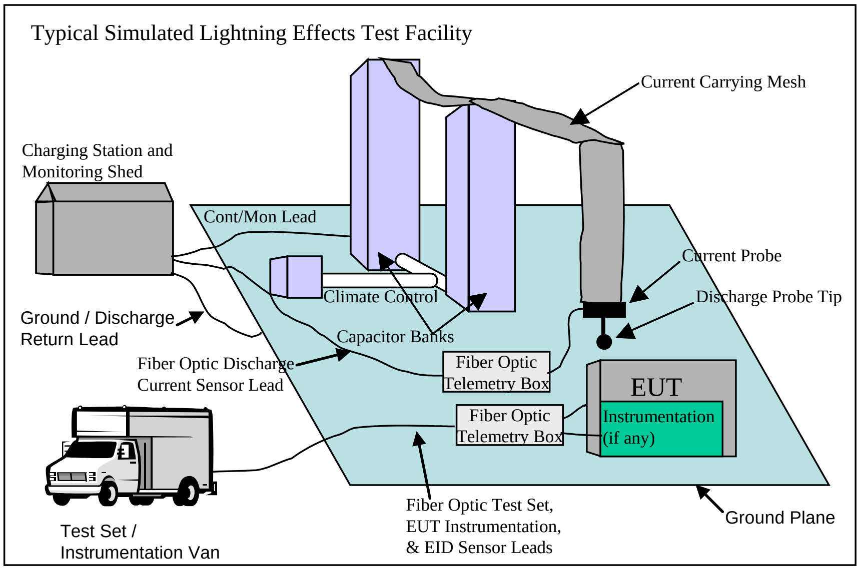


Figure N-3. Typical DSL Test Setup.

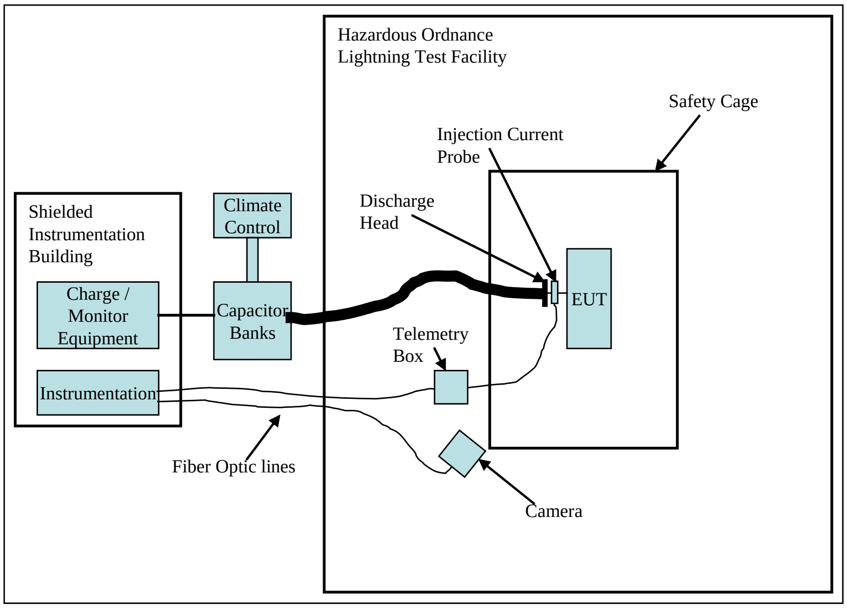


Figure N-4. DSL Test Facility Typical Test Setup for Testing Hazardous Ordnance.

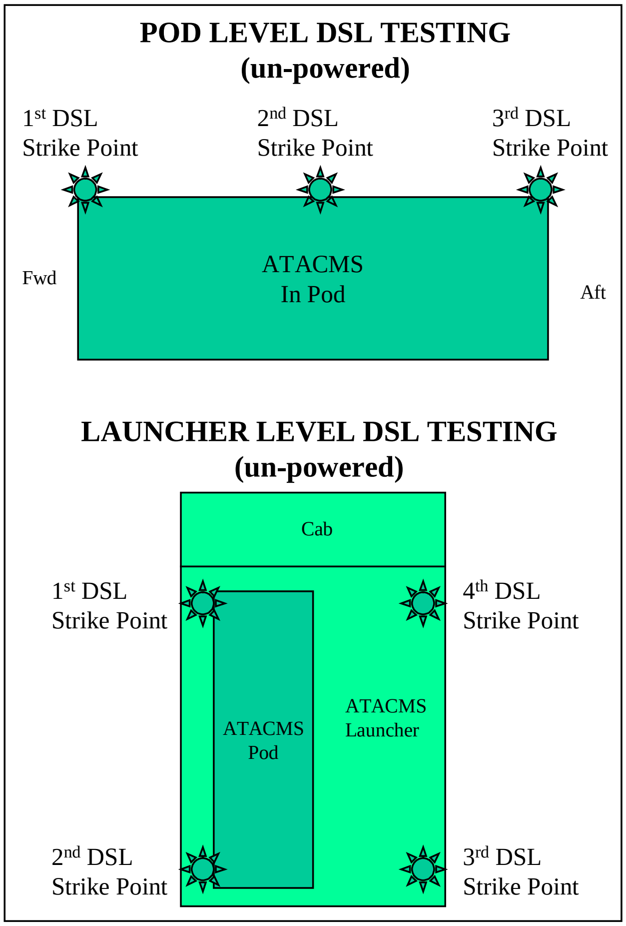


Figure N-5. Example DSL Attachment Point Diagram.

Figure N-6. System Level DSL Testing.

Figure N-7. Subsystem Level DSL Testing.

5. TEST PROCEDURES.

The specific test procedures will be conducted IAW the test plan. The exact order of testing may be altered for test efficiency with the approval of the test manager and test safety officer. Any changes to these procedures will be noted in the test report. Lightning testing is potentially hazardous to personnel. Safety procedures must be initiated IAW the test facility Standard Operating Procedures (SOP).

5.1 Calibration.

a. Test Equipment Calibration: Calibration of the test equipment shall be traceable to the NIST.

b. DSL Test Setup Calibration (to confirm proper operation of the instrumentation and capacitor banks and to verify specification waveform parameters):

(1) Set up the DSL simulator and discharge head IAW Figure N.3-1 without the SUT being in the setup.

(2) Place the current probe around the lightning simulator discharge conductor to measure the stroke current amplitude and waveform.

(3) Connect the current probe to the data collection system (oscilloscope and PC) through the telemetry system and fiber optic cables.

(4) Set the DSL simulator equipment to settings that past experience has shown to discharge per the specification waveform parameters.

(5) Secure the test area and insure that personnel are at a safe distance.

(6) Charge up Component A and C capacitor banks and discharge to the return.

(7) Repeat, adjusting the DSL simulator until the DSL criteria is obtained.

(8) Record the DSL simulator calibration settings.

(9) Verify DSL simulator is in a safe configuration.

(10) Repeat for each DSL component, as necessary.

5.2 EID Instrumentation Calibration.

a. Check instrumentation operation for the SUT, EIDs, ESAFs, etc.

b. Test EIDs and their associated firing circuit continuity and operation.

c. Exercise instrumentation self-calibration features, if available.

5.3 Test.

a. Set up the SUT for DSL testing IAW Figure N.3-1 using the same test equipment and settings used during calibration. Set up the instrumentation equipment (e.g. to monitor EID current / energy coupling), if applicable.

b. Connect the instrumentation (e.g. current probes) to the data collection system (oscilloscope and PC) using the telemetry system and fiber optic cables. If required, set up a camera to monitor the discharge.

(1) Set up the DSL simulator downlink at a selected SUT attachment point IAW the test plan matrix. Place a current probe around the lightning simulator downlink conductor to measure the stroke current amplitude and waveform.

(2) Power up the SUT and run a pre-test baseline functional check.

(3) Place the SUT in a test plan matrix specified configuration and mode.

(4) Verify data acquisition and instrumentation equipment operation.

(5) Secure the test area and insure that personnel are at a safe distance.

(6) Charge up the capacitor banks and discharge them to an SUT attachment point using the calibration settings.

(7) Verify that the lightning generator is in a safe configuration.

(8) After each discharge, examine the data to ensure that the DSL criteria were simulated, the test data is adequate, and the data is within pass/fail criteria.

(9) After each discharge, perform a visual check of the SUT for any lightning induced damage.

(10) After each discharge, repeat SUT operational checks and compare to baseline.

(11) If there are any susceptibilities, determine the SUT components affected the required steps to recovery (e.g. cycling power) and the recovery time. If possible (if SUT not damaged), verify the repeatability of the susceptibility and determine the threshold and safety margins, if necessary.

c. Record the following for each discharge and mark on plots.

(1) Stimulus waveform parameter data / plots.

(2) Test configuration / test mode.

(3) Test discharge point.

(4) Post-discharge functional check pass/fail results.

(5) Visual damage inspection results.

(6) SUT responses (e.g. components affected, wire/cable currents, EID currents, SUT upsets, recovery times, etc.).

(7) EIDs monitored their calculated SMs and whether they met requirements.

(8) EID bridgewire resistance and determination of degradation, if required.

(9) Date, time, location.

d. Repeat the test procedure for each lighting attachment point and DSL component, as necessary.

e. Repeat the test procedure for all test modes and configurations.

6. DATA PRESENTATION.

Sample data sheets are provided in Tables N-3 and N-4. Note: data should be reported at the level of accuracy of the test equipment. Sample test photographs and test data plots are provided in Figures N-8 through N-12.

Table N-3. Example DSL Test Run Data Sheet – Test without SUT Instrumentation.

Test Config	**Test Mode**	**Discharge Location**	**Shot #**	**Test Pulse Parameters**	**Observed Damage / Response Functional Check Results**	**Pass / Fail**

Table N-4. Example DSL Test Run Summary – Test with Instrumented SUT & EIDs.*

Test Config	Test Mode	Discharge Location	Shot #	EID Name	Test Pulse Parameters	EID level (J) / Cable Current (mA)	Safety Margins (dB)	EID BW Resistance (Ω) Pre/Post	Pass / Fail
In Storage Container	Un-powered Not operating	Bottom Left corner		Missile Motor EID #1	150 kA				Visual chk: Funct chk: EID SM: BW resist:
					149 kA				Visual chk: Funct chk: EID SM: BW resist:

* Should also include data sheet for live EID parameters; pre and post test.

Figure N-8. Example DSL Strike Damage.

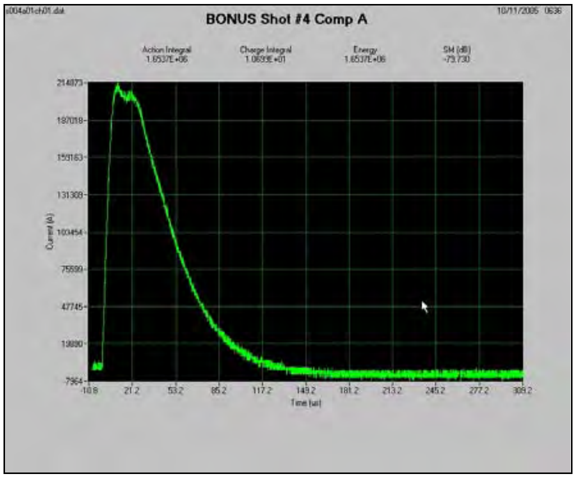


Figure N-9. Example component A Test Waveform.

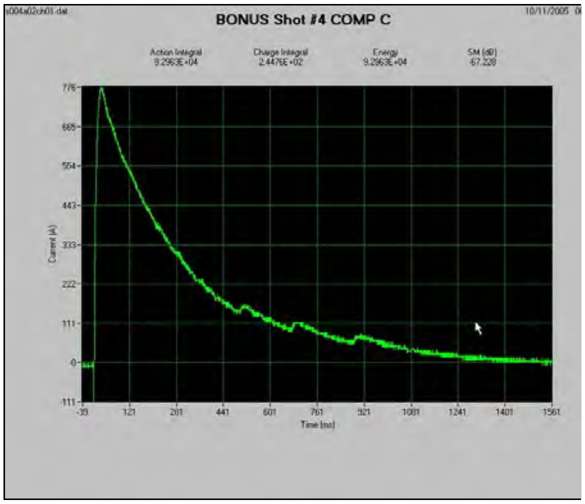


Figure N-10. Example component C Test Waveform.

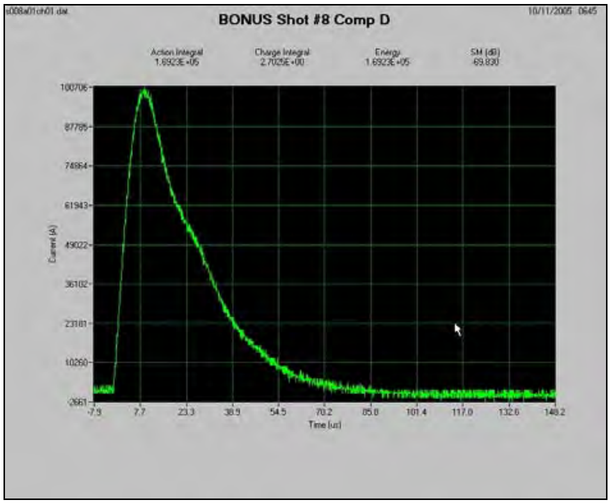


Figure N-11. Example component D Test Waveform.

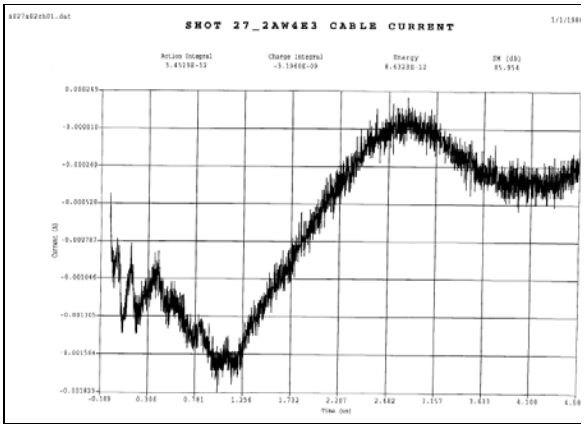


Figure N-12. Example Cable Current Data Plot.

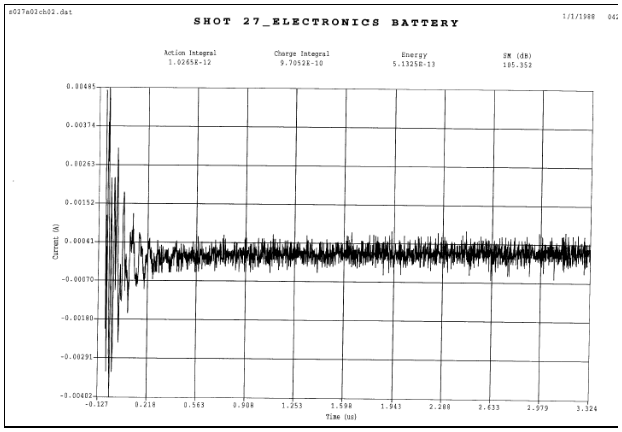


Figure N-13. Example EID Current Data Plot.

7. DATA ANALYSIS.

a. Test data will be compared and evaluated against the criteria set forth in MIL-STD 464, the SUT specification, and SUT test plan to determine if the SUT met the criteria. Deficiencies will be identified and discussed.

b. The safety margins are calculated using the following formulas:

ENERGY: $\text{SM (dB)} = 10 \log_{10} (E_{MNF} / E_{Induced})$

where E_{MNF} = Max No-Fire energy of EID. Typically 17.6 milli-Joules[1]
$E_{induced}$ = measured energy induced in the EID circuit (J)

CURRENT: $\text{SM (dB)} = 20 \log10 (I_{MNF} / I_{Induced})$

where I_{MNF} = Maximum No-Fire current of EID (A)
$I_{induced}$ = measured value for the induced EID current (A)
(or Minimum Discernable Current, MDC, if signal below MDC)

VOLTAGE: $\text{SM (dB)} = 20 \log10 (MFV / V_{Induced})$

where MFV = Min ESAD capacitor FiringVoltage. Typically 500 Volts[2]
$V_{induced}$ = measured value for the induced ESAD cap firing voltage
(or Minimum Discernable Voltage, MDV, if signal below MDV)

NOTE (1) - Previous test programs have used 17.6 milli-Joules as the MNFE for safety margin calculations for MIL-I 23659 qualified, one watt, no-fire initiators. The MNFE value was established during testing of a series of Stinger Launch/Flight motor EIDs. The EID testing evaluated 72 initiators tested with a one amp per millisecond current ramp. The data was used to derive the MNFE and is documented in technical document RD-TE-87-4, MLRS AT2 Lightning Test Report.

NOTE (2) - MIL-STD-1316 requirement for minimum firing voltage = 500 volts. Most initiators have minimum firing voltages in the 1000 to 2000 volt range.

NOTE (3) - or the test will be conducted GO-NO-GO on live EIDS as agreed upon by the Joint Service E3 Safety Testing Workshop held November 7-9 2007, or live tactical ordnance as specified in applicable requirement documents.

The DSL environmental data may require extrapolation to the 200 kA level. If the test discharge current level available during the test is less than the criteria, then the measured (DSL induced) current, voltage or energy will be extrapolated analytically to the required criteria. The extrapolation expressions are defined as follows:

<u>ENERGY:</u> $E_{extrapolated} = E_{induced} (I_{criteria} / I_{test})^2$

where $E_{extrapolated}$ = the extrapolated value of the induced energy (J)

The extrapolated value for energy can then used in place of the measured induced energy value to calculate the safety margin or the following expression can be used:

$$SM_{extrapolated} \text{ (dB)} = 10 \log_{10} \{(E_{MNF} / E_{induced}) \times K\}$$

where $K = (I_{criteria} / I_{test})^2$

<u>CURRENT:</u> $I_{extrapolated} = I_{induced} (I_{criteria} / I_{test})$

where $I_{extrapolated}$ = the extrapolated value of the induced current (A)
$I_{criteria}$ = the required (criteria) discharge current (A) (Table C.2-1)
I_{test} = the actual discharge current amplitude measured during the test (A)

The extrapolated value for current can then used in place of the measured induced current value to calculate the safety margin or the following expression can be used:

$$SM_{extrapolated} \text{ (dB)} = 20 \log_{10} \{(I_{MNF} / I_{induced}) \times K\}$$

where $K = (I_{criteria} / I_{test}) < 1$

<u>VOLTAGE:</u> $V_{extrapolated} = V_{induced} (I_{criteria} / I_{test})$

where $V_{extrapolated}$ = the extrapolated value of the induced voltage (V)

The extrapolated value for voltage can then used in place of the measured induced voltage value to calculate the safety margin or the following expression can be used:

$$SM_{extrapolated} \text{ (dB)} = 20 \log_{10} \{(MFV / V_{induced}) \times K\}$$

where $K = (I_{criteria} / I_{test}) < 1$

c. The test data will be compared to the applicable criteria set forth in the SUT specification, and SUT test plan and the pre-event baseline measurements to determine the extent to which the test criteria are met and the effects of the DSL test environment on the SUT. Test anomalies will be assessed to determine if they should be classified as SUT failures and if so, further assessed with regards to causes, test parameters at which they occurred, mission impact and safety.

APPENDIX O. GLOSSARY

1. ACRONYMS.

AAE -
ASW - antisubmarine warfare
AM - amplitude modulation

BIT - built-in test
BITE - built-in test equipment

CI - commercial item
CTTA - certified TEMPEST technical authority
CW - continuous wave

DC - direct current
DOD - Department of Defense
DODI - Department of Defense Instruction
DSL - direct strike lightning

E3 - electromagnetic environmental effects
EFI - exploding foil initiator
EID - electrically initiated device
EMC - electromagnetic compatibility
EMCON - emission control
EME - electromagnetic environment
EMI - electromagnetic interference
EMICP - electromagnetic interference control procedures
EMITP - electromagnetic interference test procedures
EMITR - electromagnetic interference test report
EMP - electromagnetic pulse
EMRADHAZ - electromagnetic radiation hazards
EPLRS - Enhanced Position Location and Reporting System
ERP - effective radiated power
ESAD - Electronic Safe/Arm Devices

FCC - Federal Communication Commission
FM - frequency modulation

GFE - government furnished equipment

HERF - hazards of electromagnetic radiation to fuel
HERO - hazards of electromagnetic radiation to ordnance
HERP - hazards of electromagnetic radiation to personnel
HESD - helicopter generated electrostatic discharge
HEMP - high altitude electromagnetic pulse

IMI - intermodulation interference
ISO - International Standards Organization
ISR - intelligence, surveillance, and reconnaissance
ISM - industrial, scientific and medical

KPP - key performance parameter

LISN - line impedance stabilization network

mA - milliampere
MDC - minimum discernable current
MDV - minimum discernable voltage
MIL-HDBK – military handbook
MIL-STD - military standard
MIL-I - military instruction
MNFC - maximum no-fire current
MNFE - Maximum No Fire Energy
MNFS - maximum no-fire stimulus
MOD - modulation

NDI - nondevelopmental item
NIST - National Institute of Standards and Technology
NSL - near strike

P-Static - precipitation - static
PEL - permissible exposure levels
PESD - personnel-borne electrostatic discharge
POE – probable point of entry
POL – polarization

RF - radio frequency
RMS - root mean square

SAD - safe/arm device
SINAD – signal, noise and distortion
SINGCARS – single channel ground and airborne radio system
SUT - system under test

TEM - transverse electromagnetic
TIR - test incident report
TPD - terminal protection device

2. DEFINTIONS.

Above deck. An area on ships, which is directly exposed to the external electromagnetic environment, and is not considered to be below deck as defined herein.

Below deck. An area on ships which is surrounded by a metallic structure or an area which provides an equivalent attenuation to electromagnetic radiation, such as the metal hull or superstructure of a surface ship, the hull of a submarine and the screened rooms in nonmetallic ships.

Compromising emanations. Unintentional intelligence-bearing signals which, if intercepted and analyzed, disclose the national security information transmitted, received, handled, or otherwise processed by any classified information processing system.

Electrically initiated device (EID). An EID is a single unit, device, or subassembly that uses electrical energy to produce an explosive, pyrotechnic, thermal, or mechanical output. Examples include: electro explosive devices (such as hot bridgewire, semiconductor bridge, carbon bridge, and conductive composition), exploding foil initiators, laser initiators, burn wires, and fusible links.

Electromagnetic environmental effects. The impact of the electromagnetic environment upon the operational capability of military forces, equipment, systems, and platforms. It encompasses all electromagnetic disciplines, including electromagnetic compatibility; electromagnetic interference; electromagnetic vulnerability; electromagnetic pulse; hazards of electromagnetic radiation to personnel, ordnance, and volatile materials; and natural phenomena effects of lightning and P-Static.

Launch vehicle. A composite of the initial stages, injection stages, space vehicle adapter, and fairing having the capability of launching and injecting a space vehicle or vehicles into orbit.

Lightning direct effects. Any physical damage to the system structure and electrical or electronic equipment due to the direct attachment of the lightning channel and current flow. These effects include puncture, tearing, bending, burning, vaporization, or blasting of hardware.

Lightning indirect effects. Electrical transients induced by lightning due to coupling of electromagnetic fields.

Margins. The difference between the subsystem and equipment electromagnetic strength level, and the subsystem and equipment stress level caused by electromagnetic coupling at the system level. Margins are normally expressed as a ratio in decibels (dB).

Maximum no-fire stimulus. The greatest firing stimulus which does not cause initiation within five minutes of more than 0.1 percent of all electric initiators of a given design at a confidence level of 95 percent. When determining maximum no-fire stimulus for electric initiators with a delay element or with a response time of more than five minutes, the firing stimulus is applied for the time normally required for actuation.

Mission critical. Unless otherwise defined in the procurement specification, a term applied to a condition, event, operation, process, or item which if performed improperly, may: 1) prohibit execution of a mission, 2) significantly reduce the operational capability, or 3) significantly increase system vulnerability.

Multipaction. Multipaction is a radio frequency (RF) resonance effect that occurs only in a high vacuum where RF field accelerates free electrons resulting in collisions with surfaces creating secondary electrons that are accelerated resulting in more electrons and ultimately a major discharge and possible equipment damage.

NONSTOP. An unclassified, short name referring to the investigation and study of compromising emanations.

Nondevelopmental item. Nondevelopmental item is a broad, generic term that covers material, both hardware and software, available from a wide variety of sources with little or no development effort required by the Government.

Ordnance. Explosives, chemicals, pyrotechnics, and similar stores (such as bombs, guns, and ammunitions, flares, smoke and napalm) carried on an airborne, sea, space, or ground system.

Safety critical. Unless otherwise defined in the procurement specification, a term applied to a condition, event, operation, process, or item whose proper recognition, control, performance or tolerance is essential to safe system operation or use; for example, safety critical function, safety critical path, or safety critical component.

Space vehicle. A complete, integrated set of subsystems and components capable of supporting an operational role in space. A space vehicle may be an orbiting vehicle, a major portion of an orbiting vehicle, or a payload of an orbiting vehicle which performs its mission while attached to a recoverable launch vehicle. The airborne support equipment, which is peculiar to programs utilizing a recoverable launch vehicle, is considered a part of the space vehicle being carried by the launch vehicle.

System operational performance. A set of minimal acceptable parameters tailored to the platform and reflecting top level capabilities such as range, probability of kill, probability of survival, operational availability, and so forth. A primary aspect of acquisition related to this definition are key performance parameters (KPPs), which are used in acquisition to specify system characteristics that are considered most essential for successful mission accomplishment and that are tracked during development to evaluate the effectiveness of the system. For the purposes of this document, the set of parameters under consideration would normally extend beyond this limited set of parameters to address other details of system performance that may be less critical but still have a substantial impact on system effectiveness.

TEMPEST. An unclassified, short name referring to the investigation and study of compromising emanations.

APPENDIX P. REFERENCES

1. MIL-STD-464A Interface Standard, Electromagnetic Environmental Effects Requirements for Systems.

2. ADS-37A-PRF, Aeronautical Design Standard Electromagnetic Environmental Effects (E3) Performance and Verification Requirements.

3. MIL -STD-2169 (Classified) High Altitude Electromagnetic Pulse Environment.

4. MIL-STD-461 Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment.

5. Army Technical Report TR-RD-TE-97-01, “Electromagnetic Environmental Effects Criteria and Guidelines for EMRH, EMRO, Lightning Effects, ESD, EMP, and EMI Testing of US Army Missile Systems

6. MIL-HDBK-240 Hazards of Electromagnetic Radiation to Ordnance (HERO) test Guide

7. DODI 6055.11 Protection of DOD Personnel from Exposure to Radio Frequency Radiation and Military Exempt Lasers.

8. MIL-STD-1316E Fuze Design, Safety Criteria For Fuze components

9. MIL-DTL-23659E Detailed Specification, Initiators, Electric, General Design specification for

10. RD-TE-87-4, MLRS AT2 Lightning Test Report

11. MIL-STD-1399-070 Interface Standard for Shipboard Systems, D.C. Magnetic Field Environment.

12. CNSS Advisory Memorandum, NONSTOP Evaluation Standard TEMPEST 01-02.

13. DODD 4650.1 Management and Use of the Radio Frequency Spectrum.

14. NSTISSAM Compromising Emanations Laboratory Test TEMPEST/1-92 Requirements, Electromagnetic.

15. NTIA Manual of Regulations and Procedures for Federal Radio Frequency Management.
MIL-STD-331 Fuze and Fuze Components, Environmental and Performance Tests for Fuze and
4.
16. ANSI/IEEE C95.1-2005 IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz.

17. ANSI/IEEE C63.14 Standard Dictionary for Technologies of Electromagnetic Compatibility (EMC), Electromagnetic Pulse (EMP), and Electrostatic Discharge (ESD).

Forward comments, recommended changes, or any pertinent data which may be of use in improving this publication to the following address: Test Business Management Division (TEDT-TMB), US Army Developmental Test Command, 314 Longs Corner Road Aberdeen Proving Ground, MD 21005-5055. Technical information may be obtained from the preparing activity: Survivability, Vulnerability & Assessment Directorate (TEDT-WSV-E), US Army White Sands Missile Range, White Sands Missile Range, NM 88002-5178. Additional copies can be requested through the following website: http://itops.dtc.army.mil/RequestForDocuments.aspx, or through the Defense Technical Information Center, 8725 John J. Kingman Rd., STE 0944, Fort Belvoir, VA 22060-6218. This document is identified by the accession number (AD No.) printed on the first page.