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14. ABSTRACT
This TOP provides methods for planning, providing instrumentation, and execution of testing of Army/DOD Materiel to determine the effects of Vertical Component High Altitude Electromagnetic Pulse (VHEMP) Environment on the safety and/or reliability of the DOD materiel and Commercial Infra-Structure. The content will include facilities, instrumentation setup, new testing procedures, actual environmental considerations, data recording and presentation of results, photos of recommended test equipment and test setups will be included along with some representative data plots. This document will incorporate the requirements of MIL-STD-464A and MIL-STD-2169 that provide DOD EMP guidance.

15. SUBJECT TERMS

High Altitude Electromagnetic Pulse, Vertical Electromagnetic Pulse, Nuclear Weapons Effect Testing and Environments.

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US ARMY DEVELOPMENTAL TEST COMMAND
TEST OPERATIONS PROCEDURE

*Test Operations Procedure 1-2-622 — 11 September 2009
DTIC AD No.:

VERTICAL ELECTROMAGNETIC PULSE TESTING

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1. SCOPE.

This Test Operations Procedure (TOP) is a general outline on test and analysis procedures required to determine the effects of a specified Vertical Electromagnetic Pulse (VEMP) environment on Army materiel. The purpose of these test and analysis procedures is to ascertain the degree to which the Operational Requirements Document (ORD), Capabilities Development Document (CDD), Army Regulation (AR) 70-75[1**], Independent Evaluation Plan (IEP)/Independent Assessment Plan (IAP) criteria, and Army Nuclear Hardening Criteria (NHC) are met. Army materiel can consist of complete end items, subsystems, Line Replaceable Units (LRUs), components or piece-parts of major systems. All materiel must be tested and analyzed to its NHC with respect to the performance of all its mission essential functions. Realistic hardware, and practical test configurations and scenarios must be tested and analyzed in order to achieve an accurate and complete VEMP Survivability Test and Assessment (STA). All VEMP STAs must include a three phase approach in order to meet the requirements of Department of Defense Instruction (DODI) 5000.1[2], AR 70-75 and its NHC[3]. This TOP adheres to an integrated set of test principles and procedures that will result in timely, reliable, and consistent data for VEMP survivability assessment. This document is encouraged for use by all VEMP survivability testers (government and contractor) for test planning, for test conducting, and for acquiring and analyzing data in technical and customer tests.

2. FACILITIES AND INSTRUMENTATION.

2.1 Facilities.

Acceptable VEMP test facilities can be categorized as radiating VEMP or bounded wave VEMP. Simulators in these categories will be vertically polarized. Vertically polarized simulators should be utilized on systems which response vertically such as missiles, aircraft or those possessing large vertical antennas.

Item	Requirement
Vertical Electromagnetic Pulse Simulator	To be able to provide test items, such as missiles, aircraft and high vertical antenna structures to the required Electric Field (E-Field) and Magnetic Field (H-Field) from 25 percent to 200 percent of the MIL-STD 2169B[4] requirement.

Examples of acceptable VEMP facilities are shown in Table 1 on the following page.

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

Table 1. Acceptable VEMP Facilities.

Facility	Type	Location	Comments
1. DNA ARES	Bounded Wave/Vertical	Kirtland Air Force Base (KAFB), NM	Max E-Field -97 kV/m Area -40 x 33 x 40h m QSTAG 244, Ed. 4 or MIL-STD 2169B System level **Mothball Status**
2. USA VEMPS	Bounded Wave/Vertical	WSMR, NM	Max E-Field - 70 kV/m Area - 35 m x 35 m x 35 m QSTAG 244, Ed. 4 MIL-STD-2169B System level **Operational during FY10**
3. USN – VPD	Radiating/Vertical	Patuxent River, MD	Max E-Field - 50 kV/m QSTAG 244, Ed. 4 MIL-STD-2169B **Limited Testing Volume at Higher Testing Levels**

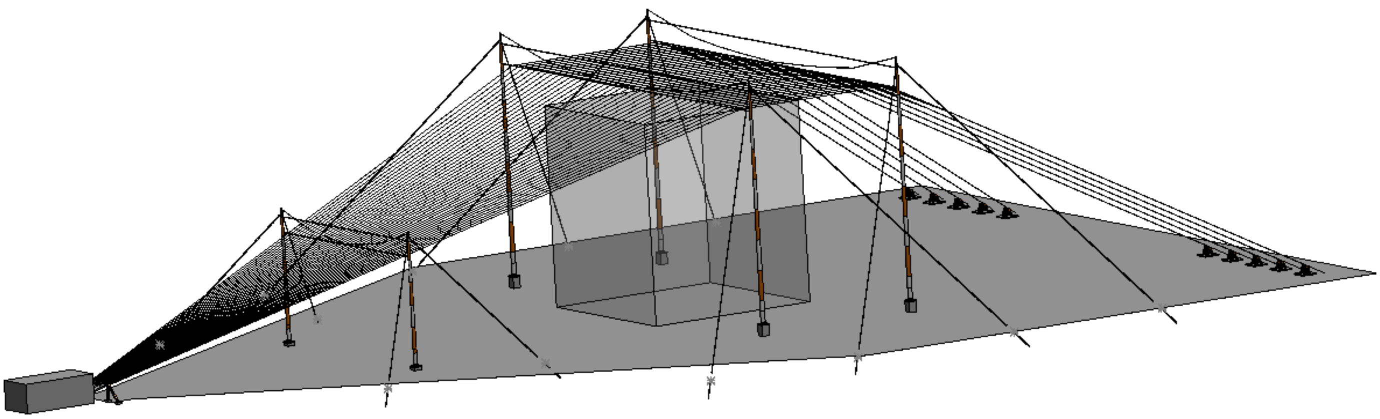


Figure 1. WSMR VEMPS Facility.

Figure 2. Patuxent River VPD Facility.

The Test Officer (TO) must ensure that the VEMP test facility utilized is the foremost facility to accurately simulate desired criteria and test system response in order to adequately test the system configuration. It is emphasized that available facilities will provide only a simulated VEMP environment. Therefore, in addition to good test data, adequate analysis must be performed to account for the facility deficiencies which must be known, quantified, and documented.

2.2 Instrumentation.

Devices for Measuring	Permissible Measurement Uncertainty
VEMP Environmental E-Field	2 kV/m or ±5 % (whichever is greater)
VEMP Environmental H-Field	5 Ampere-Turns/Meter or ±5 % (whichever is greater)
Current	Amperes ±5 %

Examples of acceptable instrumentation are shown in Table 2.2 on the preceding page.

Table 2. Acceptable VEMP Instrumentation.

Measurement Parameter	Preferred Device	Measurement Accuracy
Current	Current Probes	±5%
E-Field	D-Dot Probe	±5%
H-field	B-Dot Probe	±5%
Test Setup	Digital Camera	> 2 Megapixel

The data acquisition system for the free-field tests should consist of transient digitizers with an operating bandwidth of 750 MHz, with a 1 Giga-sample per second sampling rate. Fiber optic data transmission system must be equal to the operating bandwidth. All utilized probes must be responsive to at least 1 GHz.

Measurements of each illumination must be monitored by a B-dot probe (measures the time rate of change in the H-Field) or D-dot probe (measures the time rate of change in the E-Field) so that the magnitude of the E-field and pulse shape information is obtained. This information should be digitized, analyzed, and stored for later detailed analysis.

2.3 VEMP Test Controls.

These four criteria parameters and the SUT allowable down time must be thoroughly analyzed to ensure that acceptable facilities and appropriate instrumentation are utilized.

VEMP Parameter	Units	Parameter Tolerance
Electric Field - E-field	[volts/meter]	±5%
Magnetic Field - H-field	[amp-turns/meter]	±5%
Rise Time	[nanoseconds]	±5%
Pulse Width	[nanoseconds]	±5%
Allowable Downtime	[minutes]	±1 minute

Performance criteria requirements of the test system include allowable downtime and recovery procedures, operate through, acceptable damage and degradation, re-boot, and the availability of and time required to implement repair and replacement parts.

3. REQUIRED TEST CONDITIONS.

3.1 Test Preparation.

3.1.1 Scope of Testing.

Once a test program is initiated, the first concern of the TO is the establishment of the objectives and the scope of the VEMP program. In essence, the following questions must be addressed: What equipment and support items are required? How must the equipment be tested in order to maximize determination of its performance? What test environment levels and at what assembly levels must testing occur? What data are required and how it will be collected, how must the information be processed and analyzed in order to obtain an accurate and complete survivability analysis of the test system and ultimately the system configuration to the criteria environment?

The TO must thoroughly understand the operation of all mission essential functions, test criteria, test facility limitations, test objectives, operational and maintenance procedures, performance and operational checkouts, material composition, instrumentation, system integration, environmental considerations, induced current analyses, statistical processes, and safety considerations to adequately devise a realistic test scenario, test schedule, and performance analysis program.

3.1.2 Cost Estimates.

Upon devising an appropriate test scenario, a Developmental Test Command (DTC) cost estimate must be prepared in accordance with (IAW) DTC Pamphlet 73-1[5], Developmental Test Guide. The TO must ensure that the cost estimate adequately accounts for all reasonable expenditures of the proposed VEMP test and analysis program. These direct expenditures are for man-hours, material and supplies, travel, contractual service, equipment, minor construction, facilities, repair and replacement of test related consumables. IAW the National Defense Authorization Act 2003, only direct expenditures can be charged to DoD or DoD sponsored customers. Additionally, these cost estimates must be posted in the U.S. Army Test and Evaluation Command (ATEC) Decision Support System (ADSS) and Vision Digital Library (VDL).

3.1.3 Test Coordination.

From the initiation to the completion of the test program, test coordination is a constant and essential task. The TO must coordinate effectively with a multitude of various personnel in order to properly plan, resource, execute, and determine the VEMP survivability of a test system. Without proper and effective test coordination, a VEMP System Test and Assessment (STA) program will experience cost overruns, unnecessary test delays, inadequate test data, improper determinations, and improper usage of manpower. In conclusion, test coordination is one of the most important aspects to a TO and is essential to the conduct of a successful program.

3.1.4 Environmental Impact.

An important pretest requirement IAW AR 200-1, Environmental Protection and Enhancement[6], and AR 200-2, Environmental Effects of Army Actions[7], is an environmental analysis. This analysis will help alleviate environmental problems that could interfere with the test schedule and completion of the VEMP STA program. The proper system under test (SUT) documents must be completed and submitted to the environmental office and/or personnel who regulate and control environmental practices at the test execution site prior to start-of-test. The actual time requirement for document submission before test execution is dependent on the level of preparation required, type of system, and required documentation as well as the workload of the environmental office. Most of the required information can be obtained from the Project Manager's (PM's) office. Facility and test location specific environmental documents should be provided by the test facility.

3.1.5 Safety Analysis.

Another important pretest coordination task is the safety analysis, which must be prepared IAW AMC-R 385-100, Safety Manual[8]. Like the environmental analysis, it should be prepared, submitted, and approved as soon as possible (ASAP) to alleviate safety problems which could affect the completion of the VEMP STA program. The SUT safety analysis can usually be obtained from the PM's office or system's contractor. If a complete initial safety analysis is needed, extra time and funds must be allotted to identify the necessary safety procedures and prepare the documentation. Facility and test location specific safety documents and training should be provided by the test facility.

3.1.6 Preferred VEMP Environment Test Methodology.

The TO must ensure that sufficient analysis is performed to account for deficiencies in the simulated VEMP test environment versus the United States Army Nuclear and Combating Weapons of Mass Destruction Agency (USANCA) environments, variations between the test and production configuration, and the corresponding variations in hardware response. One must initially assume that neither the test environment nor hardware is accurate representations of the VEMP environment and system configuration, respectively. There will be differences which must be identified and quantified in order for a survivability assessment to be successfully performed. To accurately achieve compliance with the test objective, one must accomplish the following:

a. First, perform the pretest analysis to identify:

(1) Instrumentation for required response and environment data.

(a) Test hardware for each test setup.

(b) Location of instrumentation, for VEMP attention should include vertical cable runs and all external cabling.

(c) Test facilities and limitations.

(d) Test levels per environment.

(e) Test system's performance and operational checkouts to adequately analyze all mission essential functions.

(f) Required test data.

(g) Electromagnetic (EM) energy paths and port-of-entries. Analyze drawings and circuits to determine potentially harmful energy paths. The analysis should be concentrated on external unshielded cables and vertical cables of significant length and interface of these cables into subsystems of the test system.

(h) Identify test system's configuration.

(i) Analyze grounding scheme and shielded cables to include backshells and connectors to insure that the system is designed and manufactured with electromagnetic shielding.

(j) Analyze contractor's program documentation and operating modes.

(k) Analyze hardening and analysis performed by contractor.

(l) If required, fabricate Breakout Boxes (BOBs) for all cables of concern to enable actual pin measurements to be performed during testing and current injection.

(m) Test system's configuration with respect to each environmental exposure.

(n) Differences between test and production configuration.

b. Second, the TO must thoroughly document and analyze the test hardware which is to be utilized during the VEMP STA. This documentation and determination includes the test system's material composition, shape, size, mass, fastening schemes, shielding and attenuation characteristics, EMP hardening concepts and devices and Mission Essential Functions (MEFs). With all this information, the TO can identify and establish the test system and proposed system baseline configuration. This baseline will be utilized for the survivability analysis as well as a basis for analysis of all product improvements, Engineering Change Proposals (ECPs), and configuration changes to ensure that the test system remains VEMP survivable during production, maintenance, and deployment.

c. Lastly, the TO must analyze and determine the test system's performance with a detailed post-test analysis. This post-test analysis includes test environments and results of the pretest analysis, documentation and detailed determination of the test system's performance, determination of all shortcomings and failures, and determination of obtained environmental data against the USANCA criteria. In order to effectively determine criteria compliance, the TO must thoroughly understand the simulation fidelity of the test facility along with the test facility’s documentation and procedures to account for fidelity deficiencies. All test facilities have one or more parameter deficiencies. It is very important that these deficiencies be well understood and analysis performed to establish the effects of these parameter deficiencies on the results of the test. With this facility provided analysis, the TO can adequately determine the environmental test parameters against the desired USANCA criteria. In order to effectively analyze survivability of the system configuration, the TO must thoroughly understand the differences between the system's test configuration and the system's production configuration, and corresponding effects on the system assessment.

3.1.7 Test Plan.

The TO must incorporate all the factors and ideas presented in paragraphs 3.1.1 through 3.1.6 into a test plan that must be written IAW DTC Pamphlet (Pam) 73-1. It is critical that all required steps in DTC Pam 73-1 are followed. The test plan must be developed by the TO, submitted to DTC approximately sixty days prior to test execution, and approved by DTC approximately thirty days prior to test execution. Test plans should contain the following information:

I. Section 1: Introduction.
  1.1 System Description.
  1.2 Summary.
  1.5 Unique Test Personnel Requirements.

II. Section 2: Subtests. (for each test environment).
  2.1 Name of Subtest.
  2.1.1 Objectives.
  2.1.2 Criteria and Data Analysis/Procedure
  2.1.3 Test Procedures and Data Required.

III. Section 3: Appendices.
  A. Test Criteria.
  B. Test Schedule.
  C. Informal Coordination.
  D. References.
  E. Abbreviations.
  F. Distribution List.

Events are likely to occur during the test execution that causes the TO to utilize sound engineering judgment to deviate from the original test plan. Major deviations must be approved by Headquarters (HQ) DTC before being implemented. All deviations must be documented in the detailed test report.

3.2 Test Execution.

3.2.1 Pretest Analysis / Modeling.

Before the execution of any VEMP test program, a pretest analysis must be performed. During the pretest analysis, the TO must thoroughly examine the test system and manipulate engineering principles and VEMP effects responses to estimate where potential coupling and survivability problems exist. These estimations may include EM modeling techniques and sub-threat level test evaluations where appropriate. The TO must also determine appropriate test facility capabilities to ensure that the best facility (cost and schedule issues are paramount) is scheduled, adequate data acquisition is available, and required test configurations/orientations are tested. Sub-threat level test evaluations can be an efficient and reduced-cost approach for eliminating unnecessary configurations/orientations being performed in the threat level facility. In order to perform an adequate pretest analysis, the TO must have (if available) accurate schematics, parts lists, details of deliberate hardening methods/hardware, previous test (including all pertinent EM modeling studies and all sub-threat level evaluations) and/or analytical data, material composition, wiring diagrams, and cable shielding specifications. Based on the pretest analysis (including modeling/sub-threat evaluations) and system inspection, the TO can establish functional modes and system configurations where significant data can be obtained on the expected performance of the test system through the threat level VEMP environment.

3.2.2 Circuit Analysis Program.

One of the major limitations in VEMP STA programs is the difficulty of establishing survivability confidences on systems with extremely small sample sizes. To effectively establish confidence levels and the survivability of the baseline system, the TO is expected to implement an analysis program. For VEMP, this program will identify and analyze grounding schemes, cabling, cable shielding, transient and terminal protection devices. Only by having adequate design margins can an acceptable VEMP survivability analysis be performed on the system's baseline configuration.

3.2.3 Test Organization and Documentation.

The early formulation of a detailed test plan and effective test coordination is critical to test organization and execution, and cost effectiveness. Test organization consists of preset procedures for accomplishing specific test execution tasks. Proper test organization will result in superior test execution. The TO must assign and explain to test support personnel their specific tasks and schedules. Examples include test system placement and probe placement (incorporating sub-threat evaluation observations and measurements), test documentation, data acquisition, performance checkouts, maintenance procedures, etc. The most important of these specific tasks is test documentation including all observations, conclusions, and recommendations resulting from all previous modeling/sub-threat level testing. The TO must ensure that all aspects of the VEMP program are carefully, completely, and correctly documented. To achieve effective documentation, test specific control forms should be generated. In conclusion, careful organization and adequate documentation of the test is essential.

3.2.4 Sound Engineering Judgment.

During the entire execution of the VEMP test, the TO must utilize sound engineering judgment to effectively conduct testing, analyze the test data, and maintain schedules and costs. Sound engineering judgment becomes extremely critical when schedule impacts occur such as facility downtime, inclement weather, failures and/or re-prioritization. Under such conditions, the TO must determine the problem, deviate from the original test plan, and devise an alternate plan or set of procedures. The TO must also devise work a rounds that maximize the completion of testing and meet the test objectives. Any deviations from the test plan shall be recorded and documented in the test report.

3.3 Test Reporting and Life-Cycle.

3.3.1 Data Reduction and Analysis.

After the completion of all VEMP survivability testing, the TO must understand the data reduction and analysis on the raw data (recorded data reduction and correction should be provided by the facility). The raw test data are manipulated by the facility's data acquisition experts into an understandable format and documented in Appendix B and summarized in the Test Results section of the test report. The actual data reduction procedures selected is dependent upon the performance parameters, the test environment, and the criteria parameters. All facility data reduction procedures must be standardized for each individual test and documented. Clear and concise data reduction and analysis will enhance and enrich the final product; the survivability analysis.

3.3.2 Statistical and Error Analysis.

Other forms of analysis that should be performed on the test data are statistical and error analysis. The TO should use statistical analysis to obtain the criteria compliance between actual environment parameters and desired criteria. An error analysis should be performed to account for and eliminate sources of error present in the raw test data. Possible sources of error are: instrumentation and data acquisition, human, test setup, probe, and roundoff. The TO utilizes this error analysis to help predict how accurate the simulated test environment was to the specified USANCA environment and to ensure that the test system received its VEMP survivability criteria including the predicted error.

3.3.3 Test Record / Reports.

After the TO has completed all test execution, data analysis, and survivability analysis, a detailed test report or test record must be written IAW DTC Pam 73-1. It is critical that all required steps in DTC Pam 73-1 are followed. The test record/report must be completed and submitted to DTC no later than (NLT) the time frames specified in Table 6.2 (DTC Pam 73-1) after test completion and approved by DTC. Test Record / Reports should contain the following information:

Foreword.

I. Section 1: Executive Digest.
- 1.1 System Description.
- 1.2 Summary.
- 1.3 Conclusions.
- 1.4 Recommendations.

II. Section 2: Subtests. (for each test environment).
- 2.1 Name of Subtest.
- 2.1.1 Objectives.
- 2.1.2 Criteria and Analysis.
- 2.1.3 Test Procedure and Findings.

III. Section 3: Appendixes.
  A. Test Criteria.
  B. Test Data.
  C. Recommendation for Classification of Risk.

If no additional appendices are required to adequately quantify the test results and findings, the following appendixes are required to close the test report and will be lettered consecutively:

  D. References.
  E. Abbreviations.
  F. Distribution List.

The highlighted portions of the previous list (Summary, Test Findings, & Technical Analysis) are the most significant sections of the test report. The TO must give special consideration to ensure these sections are concise, detailed, complete, accurate and comprehensible.

3.3.4 Life-Cycle VEMP Survivability Program.

The production, operation, maturity, storage, maintenance, modification, and ambient environments must not introduce any form of susceptibilities or unacceptable levels of degradation into a VEMP survivable system. To ensure continued VEMP survivability, a Life-Cycle Nuclear Survivability (LCNS) program must be established IAW the NHC, AR 70-75, and the DODD 5000.1. The basic purpose of the LCNS program is to control all changes to the baseline configuration during production and product improvements, ensure that an acceptable hardness level is preserved during maintenance by using certified spare parts and procedures, and verifying that the hardness level is not degraded to an unacceptable level during fielding, storage, and operating in the ambient environments.

4. TEST PROCEDURES.

4.1 Test System.

Survivability of the test system when exposed to the simulated VEMP environment will be analyzed by:

a. Performing the detailed pretest analysis. (TO responsibility).

b. Calibrating required Data Acquisition Systems (DAS). (Facility responsibility).

c. Establishing the performance and operational baseline for the test system prior to testing. (TO responsibility).

d. Determining effects by repeating the performance and operational baseline checks or abbreviated checks after each illumination (TO responsibility).

e. Illuminating the test system in the pre-selected orientations, configurations, and modes at 0.5, 0.75, 1.0, 1.5, and 2 times (6 dB margin IAW MIL-STD 464A) its E-field criterion level as defined in the pretest analysis phase. Determining all upsets, failures, downtimes, mission performance impacts, and corrective actions, TO responsibility.

f. Analyzing response. (TO responsibility.)

g. Correcting the environmental data. (Facility responsibility).

h. If the system cannot be tested in an adequate simulated environment or exceeds the facilities physical dimension test capability, then current injecting at 1X, 3X, and 5X based upon simulator signals and/or damped sinusoidal waveforms obtained from CS115 and CS116 in Military Standard (MIL-STD) 461E[9] and 464A[10] references should occur. (TO responsibility).

i. Analyzing system induced current in both the time and frequency domains. (Facility responsibility).

The TO must ensure that accurate, consistent, and operational checks are performed and documented. Many of the problems induced by the illumination will be transient upsets and will be correctable by recycling power.

4.2 Baseline System.

The survivability of the baseline system configuration when exposed to the VEMP USANCA environments will be analyzed by:

a. Analyzing the differences between the test simulation and USANCA environments. (Facility responsibility).

b. Analyzing the differences between the SUT baseline and production configurations.

c. Determining the response of the SUT configuration to the USANCA environment.

4.3 Test Setup.

Prior to testing, the complete test system will be analyzed to ensure proper operation and establish the performance baseline. All problems identified will be documented and corrected if detrimental to the VEMP test program. The test facility will perform calibration and noise measurements on the DAS to ensure that accurate data acquisition will be achieved. The DAS utilized must account for all introduced error and be adequately protected against EM interference. The test system will be positioned in its first orientation in the facility's test volume based upon facility mapping data. Current and/or voltage probes will be positioned based on information obtained from the pretest analysis; breakout boxes will be installed if required. The baseline or abbreviated baseline checks will be performed. Test setup photographs will be taken. These procedures will be repeated for each test orientation and configuration at each test level.

4.4 Test.

The test system will be illuminated by simulated VEMP waveforms. After illumination, the test system will be analyzed to identify and quantify effects by using the pretest baseline checks and diagnostic checks, if necessary. Test probes will be repositioned if required, and the test system will be illuminated again. This procedure will be implemented until sufficient data are obtained for all functional modes and system configurations on all cables identified in the pretest analysis. At the completion of the first successful test system orientation, the system's orientation will be altered IAW the pretest analysis unless the test results dictate differently. Once adequate data are obtained for the initial test level, the test level will be incremented as specified in paragraph 4.1.e. The levels specified in paragraph 4.1 can be altered based on engineering judgments of the results/effects of the on-going test. Multiple illuminations or a substantial test sample size (seven test items is preferred) must be utilized to provide statistical confidence in the VEMP survivability of the test system. Failures and significant upsets will be diagnosed as to cause and impacts on mission accomplishment. Response and environment data will be processed, analyzed, and determined. All pertinent data will be analyzed. The four critical test environment parameters will be analyzed against the USANCA parameters to determine criteria compliance. These criteria compliances must be utilized in correcting induced and projected responses in the test system and baseline configuration, respectively.

5. DATA REQUIRED.

a. Detailed description of the method and facility for producing the VEMP environment to include photographs of the test facility setup, showing test system location relative to the VEMP source.

b. Complete set of pretest mapping data of the facility with the E-field expressed in volts/meter (±5%), risetime and pulsewidth expressed in nanoseconds (±5%), frequency expressed in Hertz (±5%), and H-field amplitude expressed in amp-turns/meter (±5%).

c. Results from the pretest analysis to include data from the contractor's VEMP test/analysis programs as well as other such programs performed on similar military systems.

d. Detailed description of system performance and operational checks utilized to baseline the system and determine its post-illumination operational status.

e. Complete list of all active electronic piece-parts to be utilized in the test system that supports EMP protection.

f. Complete set of electrical schematics and interconnect diagrams.

g. Detailed description, serial numbers, and dimensions of each subsystem of the test system.

h. Detailed description of all system cables to include type, composition, and dimensions.

i. Detailed description of all backshells and connectors to include attachment methodology, type, and composition.

j. Detailed description of the grounding scheme utilized on the test system.

k. Complete list of safety and environmental concerns.

l. Detailed description of all mission essential functions.

m. Detailed description of all deliberate EM hardening techniques/hardware to include manufacturer's specifications.

n. Detailed description of pretest selected system configurations, orientations, and modes utilized during the test.

o. Detailed description and documentation of all inspections, downtime (sec) (±10%), performance and operational checks, and maintenance procedures.

p. Detailed description of the facility's data acquisition system to include probe calibration data, noise measurements, hardware and software.

q. Detailed description of utilized current and voltage probes, breakout boxes (BOBs) and probe locations employed on the test system.

r. Results of all VEMP environment and test points measurements to include real time response and Fast Fourier Transforms (FFTs).

s. Results obtained from the pretest Current Injection tests (CI) (if required based on facility capabilities or test system size).

t. Detailed description of the method and facility producing the CIs (if required).

u. Detailed description of recovery procedures and time.

v. Results of all energy coupling and protection hardware analysis to include Design Margins (DMs).

6. PRESENTATION OF DATA.

6.1 Data Appropriation and Compliance.

a. Results from the pretest analysis and all other applicable VEMP survivability programs will be analyzed and, whenever possible, incorporated into all facets of the VEMP STA on the test system. The incorporation of all available analytical and test data will be used to enhance and reduce the overall scope of the test program.

b. Data from free-field environment measurements will be utilized to define the test environment and quantify the differences between the test and criterion environments. Differences greater than fifteen percent between the primary parameter values and the simulated parameter values will be analyzed to determine the effect on the test results. Procedures and analysis utilized will be clearly documented.

c. Results from the pretest analysis, system test and post-test determination/analysis, and environment compliance will be integrated into an assessment of the survivability of the test system's configuration to the test and then the USANCA environments. The final assessment of the test system may show different damage and mission impacts than the test results due to extrapolation and correction of environmental and test data to account for variances and differences.

d. The USANCA VEMP requirements are usually derived from the following documents:

(1) QSTAG 244, Edition 4: Nuclear Survivability Criteria for Military Equipment[11].

(2) QSTAG 620, Edition 2: Nuclear Survivability Criteria for Communications-Electronics Equipment[12].

(3) MIL-STD-2169B: High Altitude Electromagnetic Pulse (HEMP) Environment.

The final survivability analysis of the baseline system configuration to the USANCA requirements will utilize, incorporate, and integrate data and results of the test system survivability determination and analysis of the production configuration differences. This final survivability assessment of the baseline configuration may show results different than the test system analysis due to extrapolations and/or corrections for configuration differences.

6.2 Data Reduction.

a. All raw data collected during VEMP survivability testing must be processed to remove data acquisition error and to define simulation deficiencies. All analytical procedures and methods utilized to process these raw data must be documented along with example calculations in " Appendix B: Test Data" of a detailed test report. The entire collection of raw data should not be presented in the test report because of its excessive bulk. Reduced data that are pertinent to the analysis and support the determinations should be included in tabular form in the main body.

b. Quantitative and analytical techniques along with adequate response measurements must be utilized during all VEMP survivability testing. A simple GO-NO-GO test is not acceptable and will not enable the survivability of the system to be determined.

c. The data must demonstrate that the test hardware was adequately tested to its specified criteria. The VEMP environment parameters will then be processed and combined with the pretest results, along with the body of data analyzed, so that the survivability of the test configuration can be determined. Analytical techniques such as PSPICE, frequency analysis, and curve fitting must be discussed with constraints and inputs to enable the reader to determine adequacy. All analytical data reduction methods must be identified and presented in Appendix B of the test report and must include pertinent VEMP data in both the frequency and time domains.

d. Statistical analysis such as computing the mean, standard deviation, DMs, and criteria compliance percentages should be performed on all VEMP survivability system test data. Type and quality of data will determine the statistical methods to be employed.

e. Additional data reduction and analytical techniques can be found in TOP 1-2-612[13] Nuclear Environment Survivability

6.3 Data Presentation.

Data must be presented in a clear and concise manner, so they are easy to understand and support the conclusions regarding the VEMP survivability of test item/system hardware as depicted in Appendix G. To accomplish this, a combination of charts, graphs, drawings, tables, and photographs should be utilized.

a. Tables should be utilized to present the following data:

(1) Illumination Test Results Summary.

(2) Equipment Test Matrix.

(3) Criteria Compliance.

(4) Test Point Reduced Data.

(5) Statistical Analysis.

(6) Criteria and Test Standards.

(7) Test Comparisons.

b. Photographs should be utilized to present the following data:

(1) Test Configurations, Orientations, and Set-ups.

(2) Test Facility's Data Acquisition Set-up.

(3) Locations of Other Utilized Measuring Devices.

(4) Test Facility Layout.

(5) Visible Damage.

c. Drawings should be utilized when photography is not available or inadequate to display critical data supporting the results and/or conclusions.

d. Charts and Graphs should be utilized to present the following data:

(1) Test Schedules.

(2) Criteria Compliance.

(3) Previous Test Comparisons.

(4) Comparisons of Test Point Data with the Test Item in Different Configurations, Orientations, or Modes.

(5) Test Program Status.

APPENDIX A: ELECTROMAGNETIC ENVIRONMENT AND EFFECTS.

The electromagnetic environment produced by a nuclear weapon consists of the ionization of the atmosphere and generation of an EMP. The gamma rays, neutrons, beta particles, X-rays, and positive ions emitted from the nuclear detonation causes electrons to be ejected from their perspective atoms, thus ionizing the atmosphere in the burst vicinity. This increase in electron density attenuates or refracts all electromagnetic signals from a few seconds to several hours depending on weapon yield and HOB. Radio communications depend on propagation of transmitted waves through the atmosphere. Depending on the specific frequency, this propagation occurs in one of two paths, ground or sky waves. Low frequencies utilize the ground wave path, while the high frequency band utilizes the sky wave path which is reflected back to earth by the ionosphere. Very High Frequency (VHF) and Ultra High Frequency (UHF) penetrate the ionosphere; therefore, any disturbance in the ionosphere does not affect communications in these frequency bands. See Table A-1 for frequency band effects caused by atmosphere ionization.

Table A-1. Frequency Band Effects Caused by Atmosphere Ionization.

BAND	FREQUENCY RANGE	EFFECTS ON COMMUNICATIONS
VLF	3 - 30 kHz	Limited Effects
LF	30 - 300 kHz	Drastic Reduction of Sky Wave Path, but No Effects on Ground Wave Path
MF	300 - 3000 kHz	Same as LF
HF	3 - 30 MHz	Considerable Effects
VHF	30 - 300 MHz	Limited Effects, but Propagation Enhancement Possible
UHF	300 - 3000 MHz	Limited Effects
RADAR	3000 - 10000 MHz	Attenuated and Refracted

A nuclear detonation distributes approximately one millionth of its energy in the form of an intense EMP with a frequency content of a few hertz (Hz) to several hundred megahertz (MHz). The area affected by EMP and the characteristics of the pulse, is a function of burst altitude and weapon design and yield. Typical EMP intensity is in the order of tens of thousands of volts/meter. This compares with the order of 200 volts/meter for nearby radars, 10 volts/meter for communication equipment, and 0.01 volts/meter for typical metropolitan area ambient. Two characteristics of EMP which result in a threat to electrical equipment are field amplitude and broad frequency spectrum. There are three basic mechanisms for EM coupling to a conducting structure: electrical induction, the basic mechanism for linear conductors; magnetic induction, the principal mechanism when the conducting structure forms a closed loop; and earth transfer impedance for buried conductors. Devices which may be susceptible to functional damage due to electrical transients include active electronic devices, passive electronic components, semiconductor devices, squibs and pyrotechnic devices, meters, and power cables. Operational upset can be expected in digital processing systems, memory units, guidance systems, and power distribution systems. Damage mechanisms include dielectric breakdown, thermal effects and interconnection failures. The two EMP situations which are based upon burst altitude are (Endo-Atmospheric) Source Region Electromagnetic Pulse (SREMP) and (Exo-Atmospheric) High Altitude Electromagnetic Pulse (HEMP).

The first EMP situation, SREMP, occurs within the atmosphere at an altitude of less than 40 km above sea level, and possesses an extremely large electric and magnetic field over the burst vicinity. Of particular concern are events at or within 1 km of the surface. Only within these limits are tactical surface systems close enough to the event to have the potential to be adversely affected by SREMP. SREMP is generated by collisions between photons from gamma radiation and molecules of the atmosphere. These highly energetic photons eject electrons from the surrounding air molecules, producing ionized air molecules. This immense separation of charge creates an intense E-Field of several 100,000 volts/meter and a large associated H-Field of 500 ampere-turns/meter. Ninety percent of its energy is contained in the 100 Hz to 10 kHz range. See Figure A-1 for an example of the SREMP waveform and Figure A-2 for relative energy versus frequency for an Endo-Atmospheric Burst on the following page.

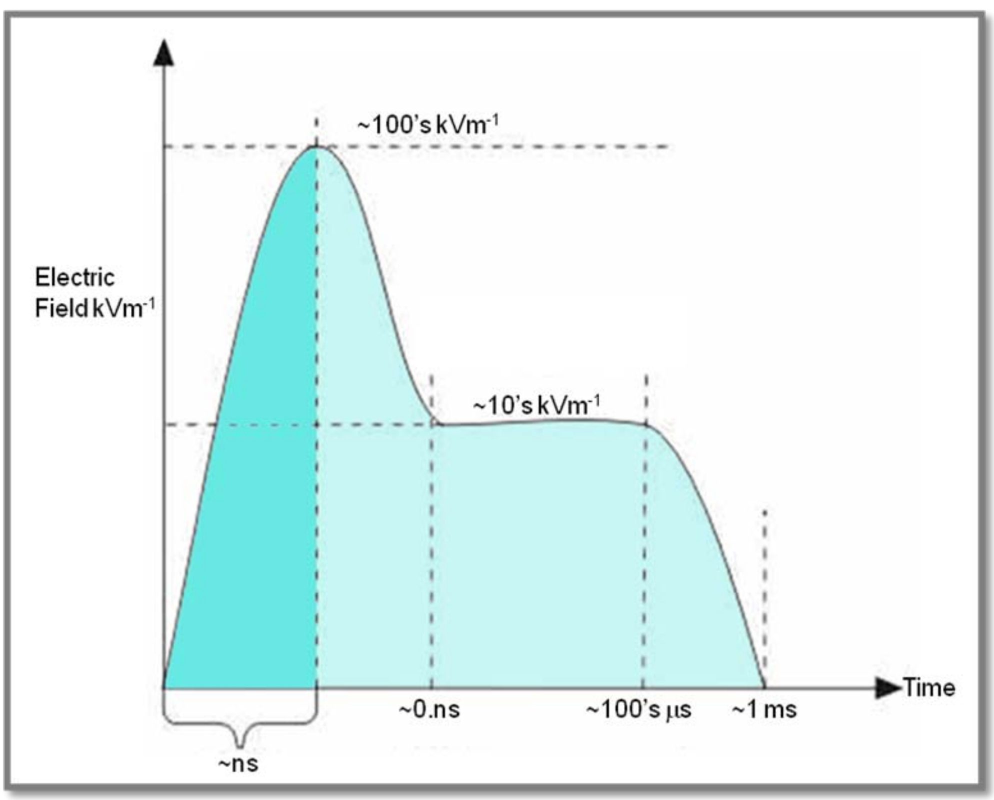


Figure A-1. Endo-Atmospheric EMP Waveform.

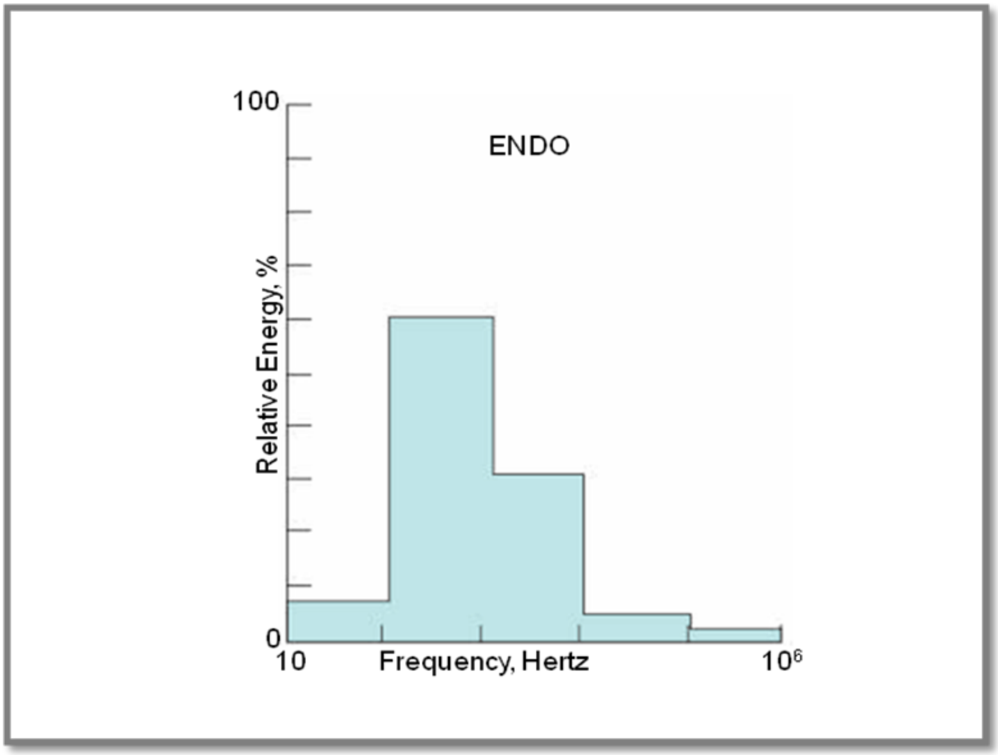


Figure A-2. Endo-Atmospheric Relative Energy Versus Frequency.

The second EMP situation, HEMP, occurs at an altitude greater than 40 km above sea level, and possesses a large electric and magnetic field over a diverse area. This tremendous area of effects is the reason HEMP is considered militarily significant and the more damaging of the two EMP situations. The HEMP is generated by gamma photons being absorbed by the atmospheric molecules at altitudes from 20 to 40 kilometers. This absorption causes electrons to be deflected by the earth's magnetic field into a spiral path about the field lines, causing them to radiate electromagnetic energy. See Figure A-3 for formation of HEMP and Figure A-4 on the next page for the detailed geometry of this phenomenon.

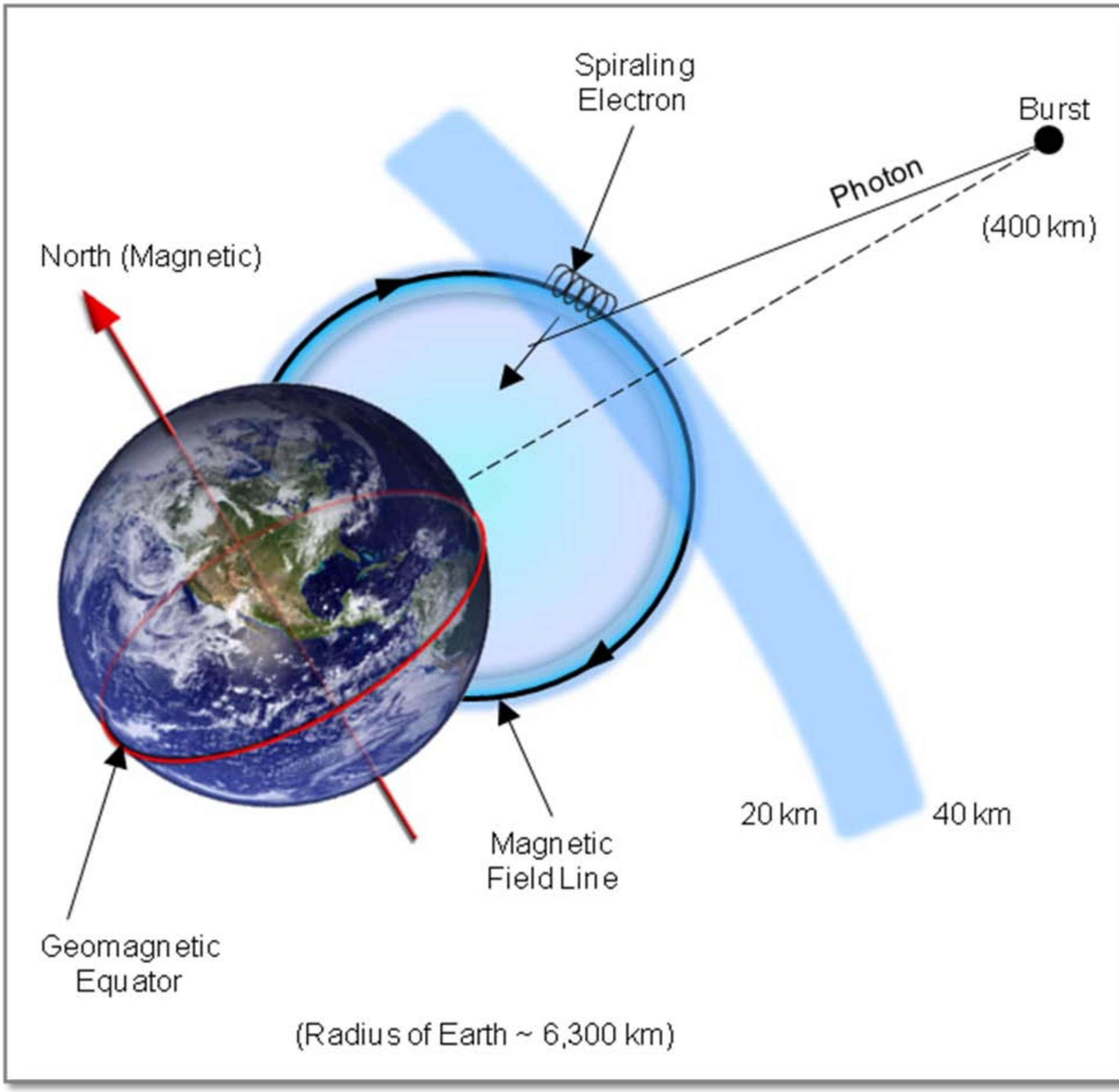


Figure A-3. Formation of Exo-Atmospheric EMP.

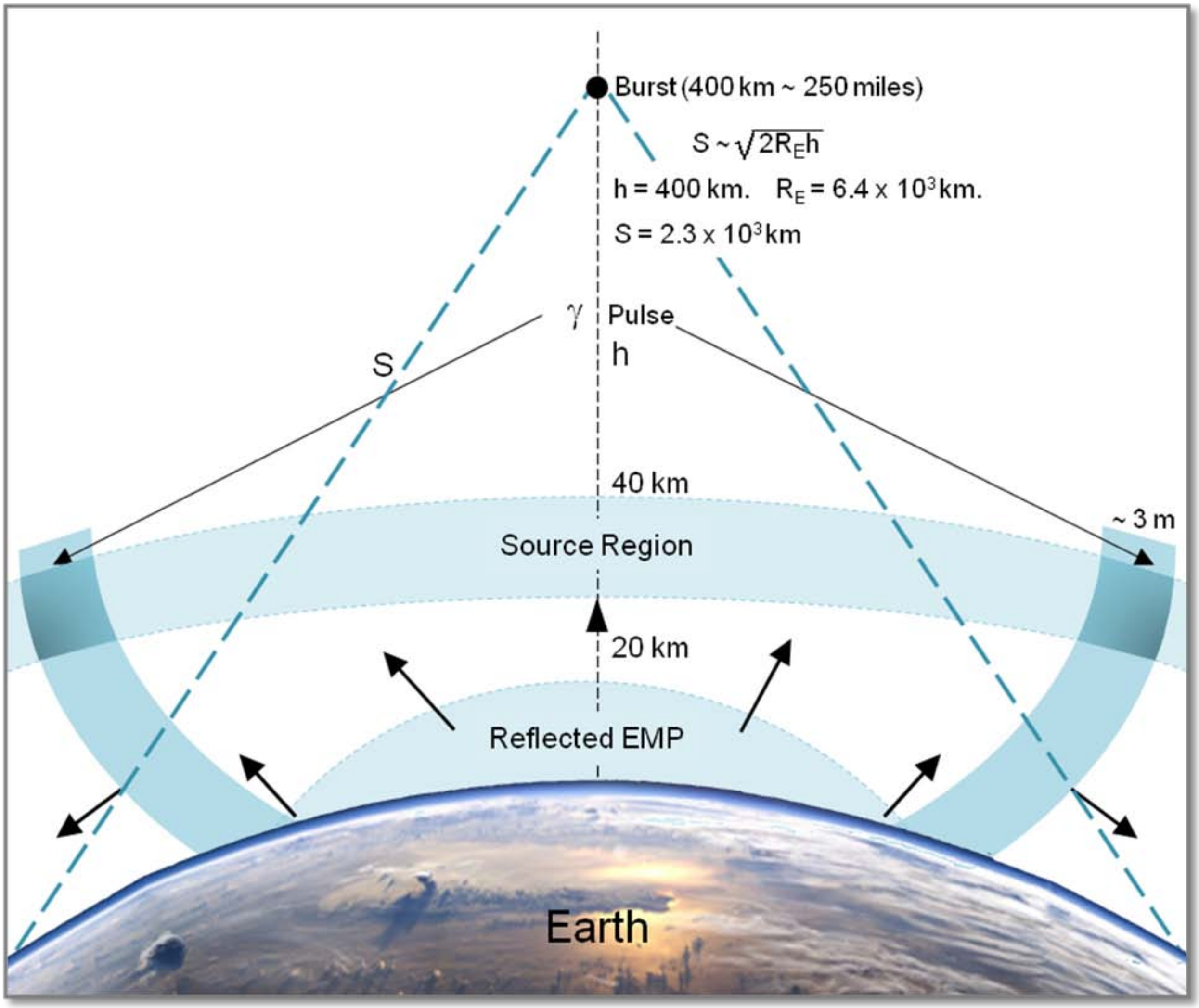


Figure A-4. Detailed Geometry for Exo-Atmospheric Burst.

The waveform and frequency content of HEMP is drastically different from its SREMP counterpart. This electron radiated energy creates a large, diverse E-Field in the range of tens of kilovolts/meter and an associated H-Field in the range of 10 to 100 ampere-turns/meter. Ninety percent of its energy is contained in the 100 kHz to 10 MHz range. See Figure A-5 for an example of the HEMP waveform and Figure A-6 for relative energy versus frequency for an Exo-Atmospheric Burst on the following page.

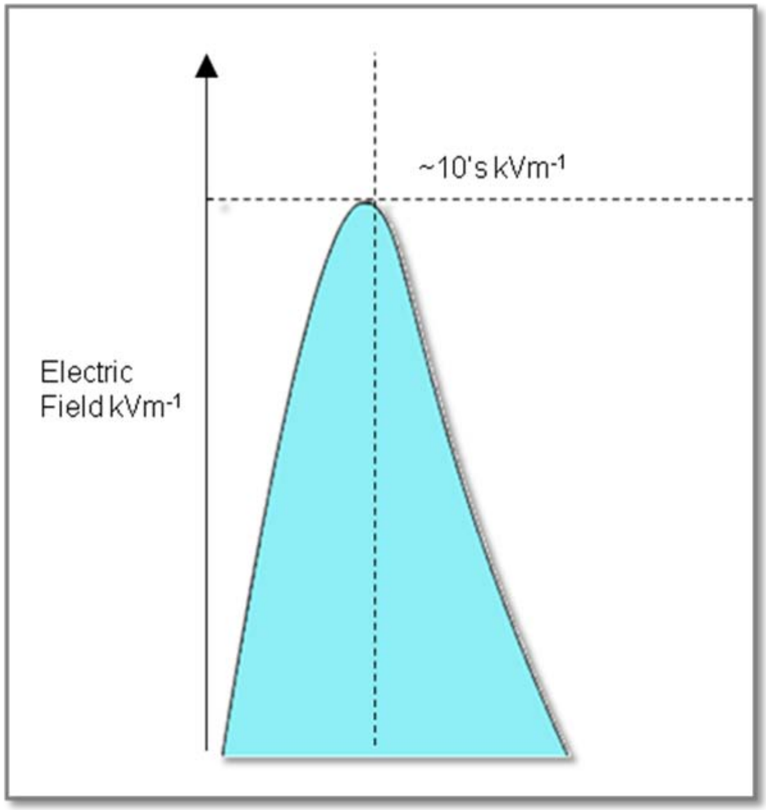


Figure A-5. Exo-Atmospheric EMP Waveform.

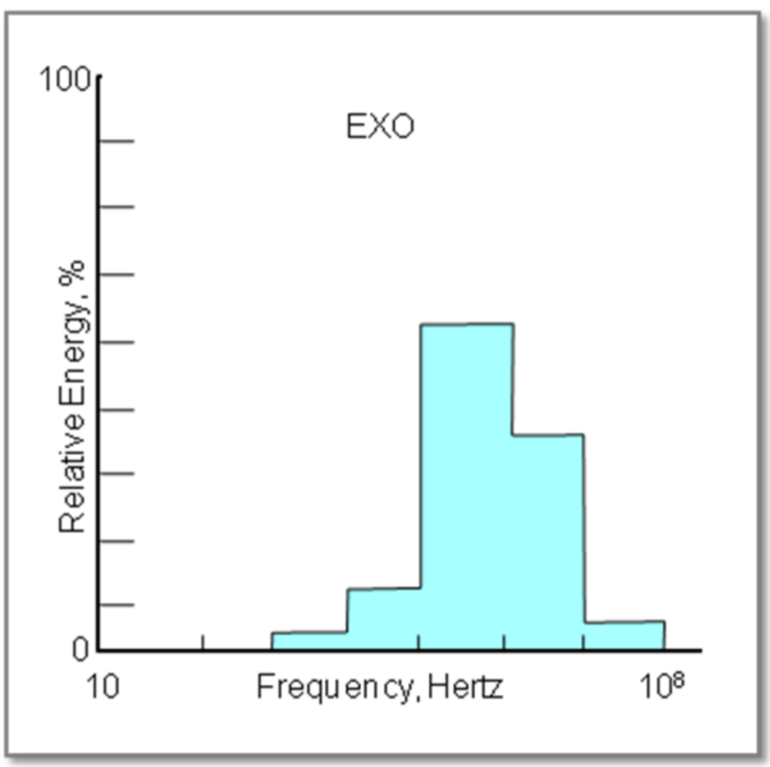


Figure A-6. Exo-Atmospheric Relative Energy Versus Frequency.

See Figure A-7 for an example of the diverse coverage in area and corresponding generate E-Field contours by an Exo-Atmospheric burst.

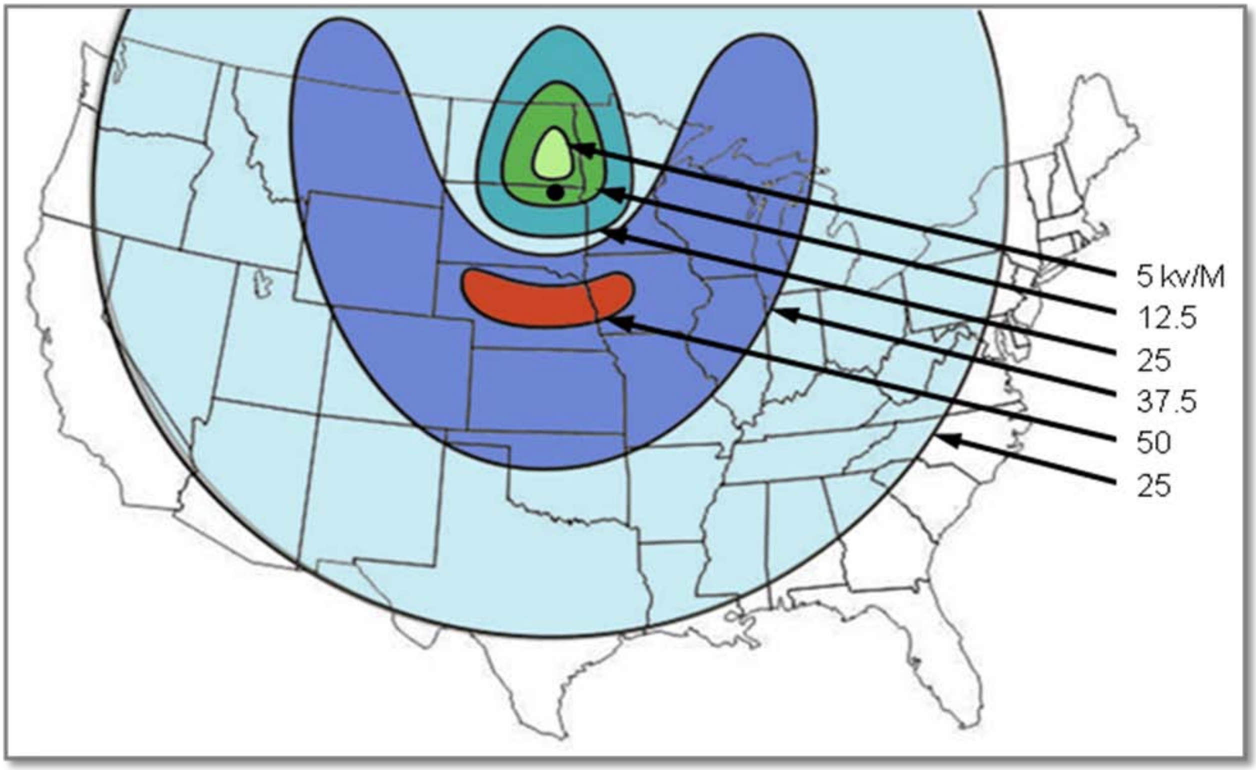


Figure A-7. Generated E-Field Contours at the Earth's Surface from a HEMP.

EMP testing requires the use of both experimental and analytical techniques to determine the response of systems and components to the EMP. Adequate testing of a system requires simulation of the EMP environment in terms of amplitude, time and geometrical effects of the entire system under study. Detonation altitude, angles of arrival and polarization of the field must be considered. Frequency domain calculations may be applied to determine critical resonant frequencies inherent to the test system. Current injection techniques must be utilized for distributed systems as an integral part of the EMP test. Current injection is greatly beneficial in the context of determining safety margins and enhancing and verifying HEMP simulator results. But, current injection should not be the primary means of obtaining accurate HEMP data.

Also, deliberate hardening devices like terminal protection devices must be analyzed and tested if necessary, to determine safety margins. Likewise, the attenuation afforded by enclosures must be analyzed so that its effects on the survivability of the enclosed electronics can be quantified.

APPENDIX B: DETAILED TEST PLAN SUBTEST EXAMPLE.

2.6 Vertical Electromagnetic Pulse (VEMP).

2.6.1 Objectives.

a. To assess the survivability of the GENERIC MISSILE when exposed to the VEMP environment specified in MIL-STD 2169B and using the MIL-STD 464A E-Field parameter.

b. To update the LCN&ES database and identify the baseline configuration of the GENERIC MISSILE for the Life-Cycle management and control as specified in AR 70-75, and MIL-STDs 2169B and 464A. This will be accomplished by entering into the Life-Cycle database pertinent data, results and information from this VEMP test.

2.6.2 Criteria AND Data Analysis Procedures.

2.6.2.1 Criteria.

2.6.2.1.1 VEMP Levels.

The GENERIC MISSILE shall perform all its mission essential operational performance functions following exposure to the VEMP environment specified in its system specification. The missile shall remain combat effective without component replacement. The missile will be subjected to Early-time (E1) peak electric field intensity from MIL-STD 464A using the two timing parameters of the E1 HEMP waveform defined in MIL-STD 2169B. The VEMP criteria levels for the GENERIC MISSILE are:

E-field	=	Omitted	[volts/meter]
H-field	=	Omitted	[amp-turns/meter]
Rise Time	=	Omitted	[seconds]

2.6.2.1.2 Omission.

The two E1 HEMP timing levels are extracted from the MIL-STD 2169B and system specification, which are classified SECRET. The E1 VEMP timing criterion levels are omitted from this document in order to maintain its UNCLASSIFIED status. The E1 VEMP peak E-Field of 50 kV/m is extracted from MIL-STD 464A. The E1 HEMP criteria of MIL-STD 2169B are available by contacting TEDT-WS-SV, WSMR, or by obtaining a copy from the U.S. Army Nuclear and Combating Weapons of Mass Destruction Agency (USANCA). The E1 HEMP criterion levels will be provided in the classified Detailed Test Report (DTR).

2.6.2.1.3 VEMP Description.

The GENERIC MISSILE will only be subjected to the Early-Time Waveform of the VEMP environment produced by an exo-atmospheric nuclear detonation. The VEMP environment has two additional waveform components, E2 for Intermediate-Time and E3 for Late-Time. These two waveforms will not be considered for the GENERIC MISSILE because they are applicable for systems connected by very long cables (E2) or to systems connected to the power grid or communications lines (E3). The E2 and E3 HEMP waveforms will contribute some energy coupling to the GENERIC MISSILE; but, the amount of energy coupled by these two waveforms to this discrete system will be insignificant relative to E1. Also, energy coupled by these two waveforms will not be additive since they will be out of time phase with each other as well as with E1.

2.6.2.1.4 LCN&ES.

IAW AR 70-75, MIL-STDs 2169B and 464A, a life-cycle program shall be established and implemented for mission critical systems such as the GENERIC MISSILE. In addition, the GENERIC MISSILE's operational performance requirements shall be met throughout its rated life cycle. The production, operation, maturity, maintenance, storage, upgrades, enhancements, ambient environment, and DMS solutions and technology insertions, shall not introduce any VEMP susceptibilities or unacceptable levels of degradation into the GENERIC MISSILE.

2.6.2.2 Data Analysis / Procedure.

2.6.2.2.1 Data.

The pre-test analysis will consist of evaluating results from the previous GENERIC MISSILE VEMP program and reviewing the test system's configuration. Pertinent data, results and information will be incorporated into the test planning of the SVAD VEMP program for the GENERIC MISSILE. The incorporation of all test data will be used to enhance and reduce the scope of testing. Pertinent data will be included in the SVAD failure diagnostics, post-test analysis/assessment, and documented in the detailed test report to support the test results.

2.6.2.2.2 Criteria Compliance.

The VEMP environmental data from the VEMP facility will be corrected to account for the percent error associated with the DAS:

a. A mean and standard deviation will be established from the error corrected VEMP E-Field parameters.

b. The H-Field parameter will be derived by dividing this mean error corrected VEMP E-Field parameter by 377 ohms.

c. A mean and standard deviation rise time will be established from the VEMP E-Field data.

d. The VEMP E-Field data, test point current data and test point FFTs will be examined using MATLAB to determine the primary coupling frequency or coupling frequency range, critical damping factor, and energy content.

e. The data in Paragraphs 2.6.5.2a through 2.6.5.2d will be compared and evaluated against the MIL-STD 2169B E1 VEMP criteria to determine criteria compliance.

2.6.2.2.3 System Configuration Compliance.

The test system configuration will be evaluated against the expected production configuration and all differences will be identified and documented. Differences that could impact the results will be discussed in the final report. The existing baseline configuration will be updated and documented.

2.6.2.2.4 Effects Analysis.

Effects will be scored at the test level of occurrence. Cause(s) and victim(s) will be identified, and impact(s) on the GENERIC MISSILE mission will be discussed. Failures or operational performance degradation occurring at levels above criteria will be classified as system shortcomings, unless verified by additional data and/or energy coupling analysis to be valid as a result of manufacturing variations or assembly. This information will be used primarily to provide the needed level of confidence in the survivability assessment of the GENERIC MISSILE to meet its defined VEMP criteria.

2.6.2.2.5 System Performance.

Comparison of pre- and post-illumination functional checkout data for the GENERIC MISSILE test system will be used to determine the effects of the VEMP test environment on the GENERIC MISSILE. Degradation resulting in system performance outside specifications, or total failure(s), will be addressed with regards to cause(s), victim(s), test level at which they occurred, allowable downtime, and mission impact.

2.6.2.2.6 Survivability Assessment.

A VEMP survivability assessment will be performed on the production or baseline configuration against the VEMP criteria using the results of Paragraphs 2.6.2.2.2 through 2.6.2.2.5. This assessment may produce results different than obtained during the testing due to corrections for manufacturing variations and/or test environment deficiencies.

2.6.2.2.7 LCN&ES.

Both, the configuration for the test system and proposed baseline production system will be archived into the GENERIC MISSILE Life-Cycle program database along with pertinent test data and results, extrapolated results, and information from this VEMP subtest. This database will enable implementation of the Life-Cycle program of Hardness and Sustainment Assurance, and Surveillance tests.

2.6.3 Test Procedures and Data Required.

2.6.3.1 Test Procedures.

2.6.3.1.1 General Procedures

The VEMP survivability program for the GENERIC MISSILE will include testing at SVAD HEMP simulator, the Vertical Electromagnetic Pulse (VEMP) facility. The survivability of the GENERIC MISSILE to its VEMP criteria level will be assessed by:

a. Performing a pre-test energy coupling analysis.

b. Establishing its complete performance baseline prior to VEMP testing, using baseline self test checks and diagnostic tests.

c. Performing detailed bulk current measurements on cables identified in the pre-test analysis (external cables, POE and internal cables).

d. Testing the SUT in different configurations. The GENERIC MISSILE will be tested in two hull orientations with respect to the electric field vector, i.e., longitudinal axis parallel to electric field vector, and perpendicular to the electric field vector. At each E-Field level for each test configurations, if no failures occur, the GENERIC MISSILE SUT will be illuminated, at a minimum, twice more or until all data acquisition has been completed.

e. Illuminating the GENERIC MISSILE SUT in four configurations to 75%, 100%, 120% 150% and 200% (6 dB margin IAW MIL-STD 464A) of its E-Field criterion level.

f. Illuminating the GENERIC MISSILE SUT in a fully operational mode.

g. Repeating the necessary pre-test baseline checks on the GENERIC MISSILE SUT after each illumination.

h. Illuminating the SUT multiple times. The number of test pulses performed will depend on how many tank harness shields are monitored for VEMP induced currents. It is planned to measure all accessible cables; no physical changes will be made to access data points. Unacceptable effects will be investigated to quantify, determine the cause, and identify fixes.

i. Diagnosing all effects. Most VEMP responses are manifested as system upsets. In the event of an upset, the system power will be cycled to determine if normal operation can be restored. If normal operation is restored, the illumination will be repeated to verify the effect. If system operation is not restored, further investigation will be performed to determine the affected LRU.

j. Documenting upsets, failures, downtime, and corrective actions; most problems induced will be transient upsets and will be correctable by cycling power OFF/ON.

k. Identifying and classifying all failures to the electronic piece-parts/component level.

2.6.3.1.2 Test Equipment.

The following test equipment is scheduled for this test.

a. Simulator: Free field VEMP simulator and antenna.

b. Data transmitter Links: Nanofast® OP300 fiber-optic.

c. Inductive current probes: EATON® 91550-2.

d. Environment reference probe: MGL-2 D-dot free field probe.

e. Environment monitoring probe: EG&G ADC-4 Free-Field probe.

f. Environment data recording device: Tektronix® TDS 7154B Digital Phosphor Oscilloscopes.

2.6.3.1.3 Test Facility.

The VEMP testing performed on the GENERIC MISSILE SUT will utilize the SVAD VEMP facility, which generates the E1-type HEMP waveform defined in MIL-STD 2169B. The VEMP facility provides a vertically polarized EM Environment (EME), which is ideal for a vertically coupling system like the GENERIC MISSILE.

2.6.3.1.4 Pre-test Analysis.

A pre-test analysis will be conducted to:

a. Evaluate and incorporate pertinent test data and results from previous tests.

b. Analyze drawings and circuits to identify potentially harmful energy paths.

c. Identify test system's internal configuration.

d. Identify and determine all energy coupling POEs.

e. Analyze grounding schemes and identify EM barrier features such as shielded cables to include connectors/backshells.

f. Evaluate deliberate hardening devices and techniques.

g. Define DAS requirements.

h. Identify cables for measurements.

i. Identify test levels, orientations, configurations, and operational modes based on the results of the hardening determination.

2.6.3.1.5 System Setup.

a. Prior to testing, the GENERIC MISSILE SUT will be functionally checked to ensure proper operation. Problems will be documented, reported, and corrected if detrimental to the VEMP survivability assessment program on the GENERIC MISSILE.

b. The GENERIC MISSILE SUT in a pre-test analysis selected configuration will be positioned in the VEMP facility near the center of the test volume for the desired test level (defined by the peak E-Field). The GENERIC MISSILE SUT will then be powered and a functional check performed.

c. A bulk current probe will be placed near (but not attached to) the longest cable length in the SUT and an EM noise measurement taken to establish the data collection base. This type of base-line measurement will be made for all of the current probes.

d. Bulk current measurements will be obtained on cables identified in the pre-test analysis as being potential paths for harmful levels of VEMP induced energy. Pin current measurements will only be collected if a failure is identified. The pin current data will be utilized in a failure analysis and/or to perform corrective actions.

2.6.3.1.6 System Test.

The GENERIC MISSILE SUT will be illuminated by a transverse electromagnetic wave whose E-Field magnitude is approximately 75% of the E1 VEMP criterion value. After illumination, the GENERIC MISSILE will again be checked to establish the functional status of the system. At the completion of each successful test series (all cables measured), the GENERIC MISSILE SUT will be changed to account for energy coupling into different cable layouts and functions in the system. Once the series of four orientation-positions and modes described in Para 2.6.3.1.d have been completed, then the E-Field magnitude will be increased to the next E-Field level and the test procedures repeated. These procedures will be repeated for the third E-Field test level.

2.6.3.1.7 Effects Procedure.

If an effect/anomaly occurs, it will be documented and diagnosed. Testing will not continue until the problem is understood, and its effect on the GENERIC MISSILE SUT has been assessed as well as potential impacts on the GENERIC MISSILE SUT results if testing is continued. If an upset occurs, the GENERIC MISSILE power will be cycled OFF/ON. If the SUT fully recovers, testing will be repeated at the same level and test orientation to determine whether the problem was EME induced or an anomaly. Borderline cases may require an additional test exposure or Current Injection (CI) testing to explicitly establish whether the effect was environmentally induced. If the SUT does not recover, then follow-up checks, measurement review, and review of the pre-test analysis will be used to identify the energy path and the affected electronic piece-part/component. If the effect is a failure, diagnostic checks will be performed to determine energy path and victim(s). If the operational status of the SUT can be restored, an engineering judgment will be made of potential risk to the SUT if testing is continued. Every effort will be made to complete testing.

2.6.3.1.8 Environment Measurements.

Measurements of each illumination will be made using an Electric Flux Density per unit time (D-dot) probes, so that the magnitude of the E-Field and pulse shape can be determined. This information will be digitized, reviewed, and stored for later environment compliance analysis. Injected current signals will be measured using a calibrated bulk current probe, reviewed and then stored for later stress level compliance analysis and upset / problem evaluations.

2.6.3.2 Data Required.

a. Detailed description of each VEMP environment to include photographs of the test facility setup showing test system position relative to the VEMP antenna array.

b. Complete set of pre-test mapping data of each VEMP illumination level with the Electric Field expressed in Volts/meter (V/m) (±5%), rise time and pulse width expressed in nanoseconds (nsec) (±5%), frequency expressed in Hertz (Hz) (±5%), and Magnetic Field (H-Field) amplitude expressed in Amp-turns/meter (±5%).

c. Detailed description of the GENERIC MISSILE functional checks used to baseline the GENERIC MISSILE SUT to determine its post-illumination capabilities.

d. Visual inspection, logs, test conductor notes, and photographs.

e. Detailed description, serial numbers, and the GENERIC MISSILE subsystems.

f. Detailed description and recording of all inspections, downtime and recovery time (sec) (±10%), and checkout data.

g. Log of baseline checks from the Operator manuals, i.e., self-test, and as needed diagnostic tests with descriptions of discrepancies.

h. GENERIC MISSILE physical and operating configuration during each subtest illumination.

i. Log sheets of test illumination to include induced upsets or failures.

j. Description and calibration of current/voltage measuring probes and the DAS. In addition, description of all probe locations is required.

k. Results of all facility environment measurements expressed in the same units as listed in Para 2.6.4.b above.

l. Results of all current and voltage measurements, and Fast Fourier Transforms data obtained from the DAS.

m. Results of previous VEMP, HEMP and CI tests performed by the contractor or another government agency on the GENERIC MISSILE.

n. Detailed description of all deliberate VEMP hardening devices and/or techniques employed on the GENERIC MISSILE.

o. Percent error incorporated into the DAS.

p. Calibration dates for all test equipments.

q. Test Incident Reports (TIRs), if applicable.

APPENDIX C: DATA DOCUMENTATION.

TESTING DOCUMENTATION EXAMPLE.

TEST CONDUCTOR: XXXXXXX DATE: 20 May 09
FACILITY: VEMP Facility PAGE_1__ OF _10_

Shot # and Item #	Utilized Equipment Serial #s	Test Level kV/m	Test Orientation	Test Mode	Pretest and Post-test Results	Test Points and Comments
1 # 5723	GENERIC MISSILE S/N# 26264 *Test Setup #1*	1^{st}	Tank Parallel to E-Field Distance = 15 Meters GCVP of Tank	Powered and Operational Hull = Turret - 0°	pre - OK post – OK	11 8-Input Multiple Links. – See Test Point Information
2 #5724	Same as 1 Above	1^{st}	Same as 1 Above	Same as 1 Above	pre - OK post – OK	Same as 1 Above
3 # 5725	Same as 1 Above	1^{st}	Same as 1 Above	Same as 1 Above	pre - OK post – OK	Same as 1 Above
4 # 5726	Same as 1 Above	1^{st}	Same as 1 Above	Same as 1 Above	pre - OK post – OK	Same as 1 Above
5 # 5727	Same as 1 Above	1^{st}	Same as 1 Above	Same as 1 Above	pre - OK post – OK	Same as 1 Above
6 # 5728	Same as 1 Above	1^{st}	Same as 1 Above	Same as 1 Above	pre - OK post – OK	Same as 1 Above
7 # 5729	Same as 1 Above	1^{st}	Same as 1 Above	Same as 1 Above	pre - OK post – OK	Same as 1 Above

General Comments: E-Field = Electric Field

Table C-1. (U) VEMP Test Point – Current Probe Information Example.

Link Name	LINK S/N	Input #	Test Point ID	Test Point Description
Alpha	312	0	DID1	DID J1
Alpha	312	1	DID2	DID J2
Alpha	312	2	DID3	DID J3
Alpha	312	3	HMP1	HMPU J1
Alpha	312	4	HMP7	HMPU J7
Alpha	312	5	HMP8	HMPU J8
Alpha	312	6	HMP9	HMPU J9
Alpha	312	7	HMPX	HMPU J10
Bravo	423	0	HPDE	HPDU J14
Bravo	423	1	HPDB	HPDU J11
Bravo	423	2	HPD1	HPDU J1
Bravo	423	3	HPD8	HPDU J8
Bravo	423	4	HPD7	HPDU J7
Bravo	423	5	HPDD	HPDU J13
Bravo	423	6	HPDC	HPDU J12
Bravo	423	7	HPDA	HPDU J10
Charlie	133	0	HPD9	HPDU J9
Charlie	133	1	HPD6	HPDU J6
Charlie	133	2	HPD5	HPDU J5
Charlie	133	3	HPD4	HPDU J4
Charlie	133	4	FEA2	FEA J2
Charlie	133	5	TCU1	TCU J1
Charlie	133	6	DEC3	DECU J3
Charlie	133	7	DEC5	DECU J5
Delta	101	0	AIM6	AIM J6
Delta	101	1	AIM7	AIM J7
Delta	101	2	AIM1	AIM J1
Delta	101	3	AIM2	AIM J2
Delta	101	4	AIM3	AIM J3
Delta	101	5	AIM5	AIM J5
Delta	101	6	RS21	RSM2 J1
Delta	101	7	RS22	RSM2 J2

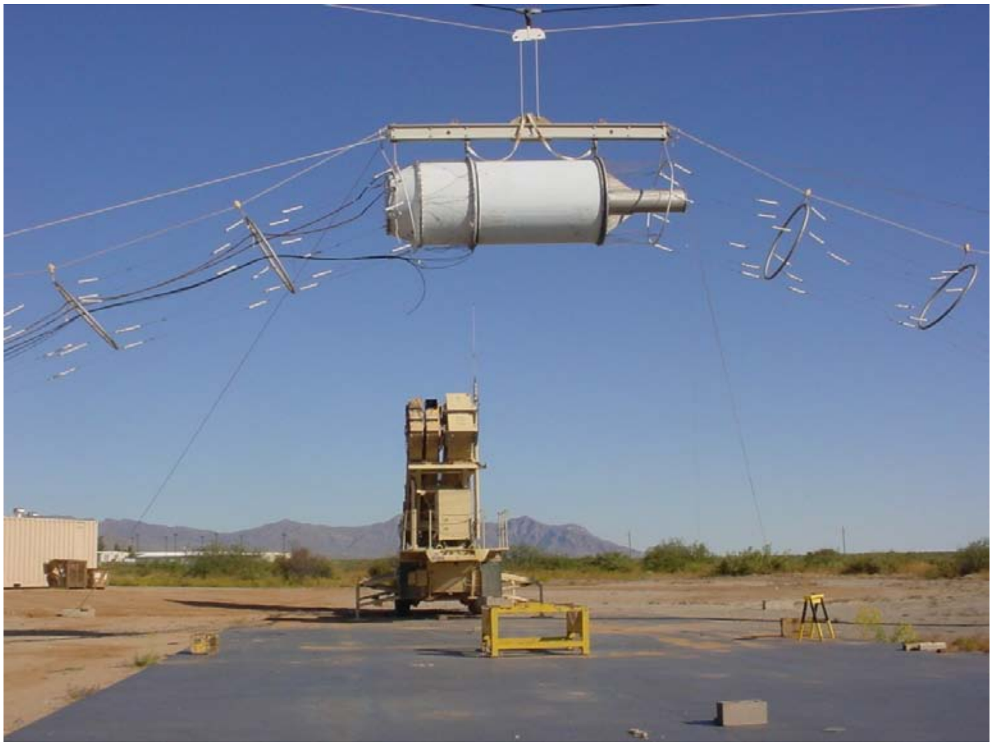


Figure C-1. (U) Generic Missile Launcher VEMP Test Setup.

Figure C-2. (U) Generic Long Antenna VEMP Test Setup.

Table C-2. (U) VEMP Current Test Point Reduced Data Example.

TestID	Orien	Shot#	Peak I	ResFreq	LowFreq	HighFreq	Bandwidth	Q
CEU1	parallel-1-turret-front	5723	-0.72343	2.37E+07	2.33E+07	2.59E+07	2.54E+06	9.3128
RSC1	parallel-1-turret-front	5723	-0.78004	2.37E+07	2.34E+07	2.58E+07	2.40E+06	9.86972
AIM6	parallel-1-turret-front	5724	0.254524	1.52E+07	1.40E+07	1.62E+07	2.20E+06	6.90684
CDU1	parallel-1-turret-front	5724	0.854443	2.54E+07	2.17E+07	2.60E+07	4.36E+06	5.84013
CIT1	parallel-1-turret-front	5724	-0.87288	2.32E+07	2.25E+07	2.38E+07	1.29E+06	17.9898
DID1	parallel-1-turret-front	5724	-0.21612	3.15E+07	3.02E+07	3.21E+07	1.93E+06	16.3001
GCD4	parallel-1-turret-front	5724	0.879601	2.30E+07	2.18E+07	2.34E+07	1.58E+06	14.5688
HPD9	parallel-1-turret-front	5724	-0.26658	4.33E+07	4.26E+07	4.51E+07	2.51E+06	17.2656
HPDE	parallel-1-turret-front	5724	0.221622	3.17E+07	3.06E+07	3.22E+07	1.58E+06	20.1163
AIM7	parallel-1-turret-front	5725	-0.22246	1.19E+07	1.14E+07	1.22E+07	863666	13.7974
DID2	parallel-1-turret-front	5725	-0.15849	4.51E+07	4.43E+07	4.62E+07	1.93E+06	23.4194
HPD6	parallel-1-turret-front	5725	-0.43752	5.16E+07	5.02E+07	5.23E+07	2.12E+06	24.2788
HPDB	parallel-1-turret-front	5725	-0.18246	2.27E+07	2.19E+07	2.37E+07	1.84E+06	12.3403
MMU1	parallel-1-turret-front	5725	0.046358	2.37E+07	2.28E+07	2.59E+07	3.11E+06	7.63901
RSC4	parallel-1-turret-front	5725	0.72278	3.38E+07	3.29E+07	3.43E+07	1.42E+06	23.7429
AIM1	parallel-1-turret-front	5726	0.216101	4.89E+07	4.76E+07	4.97E+07	2.10E+06	23.3346
CDU2	parallel-1-turret-front	5726	1.65474	2.38E+07	2.29E+07	2.48E+07	1.96E+06	12.1048
CEU3	parallel-1-turret-front	5726	-7.05391	2.59E+07	2.53E+07	2.69E+07	1.68E+06	15.3943
DID3	parallel-1-turret-front	5726	0.235663	4.56E+07	4.44E+07	4.66E+07	2.25E+06	20.2586
FCE4	parallel-1-turret-front	5726	2.53957	2.39E+07	2.27E+07	2.48E+07	2.15E+06	11.1238

APPENDIX D: VEMP Ordnance Test Information

Provided are some example procedures for VEMP testing of materials and equipments which contain ordnance.

1. Most facilities will not allow the presence of full up ordinance during any type of electromagnetic testing and this includes VEMP. The types of systems which contain ordinance and require VEMP testing are those which are electrically controlled and actuated and not mechanically actuated. These systems utilize Electrically Initiated Devices (EIDs) to perform explosive train functions, such as initiating the battery, arming the device etc. In order to perform a VEMP assessment on a system that uses these EID, the main charge requires replacement with inert material and the testing needs to be performed on two system configurations;

a. The first and foremost configuration (i.e. **TYPE 1**) is the EIDs are replaced with an equivalent resistor and a current probe. The equivalent resistor provides the same impedance to the system under test and the current probe is routed such that the measurement of the induced current can be recorded by and external DAS system. In all ordinance systems the safety margin of the explosives with respect to the environment are of upmost importance. The VEMP EID induced current measurement is used in performing safety margin calculations based on the EID specifications.

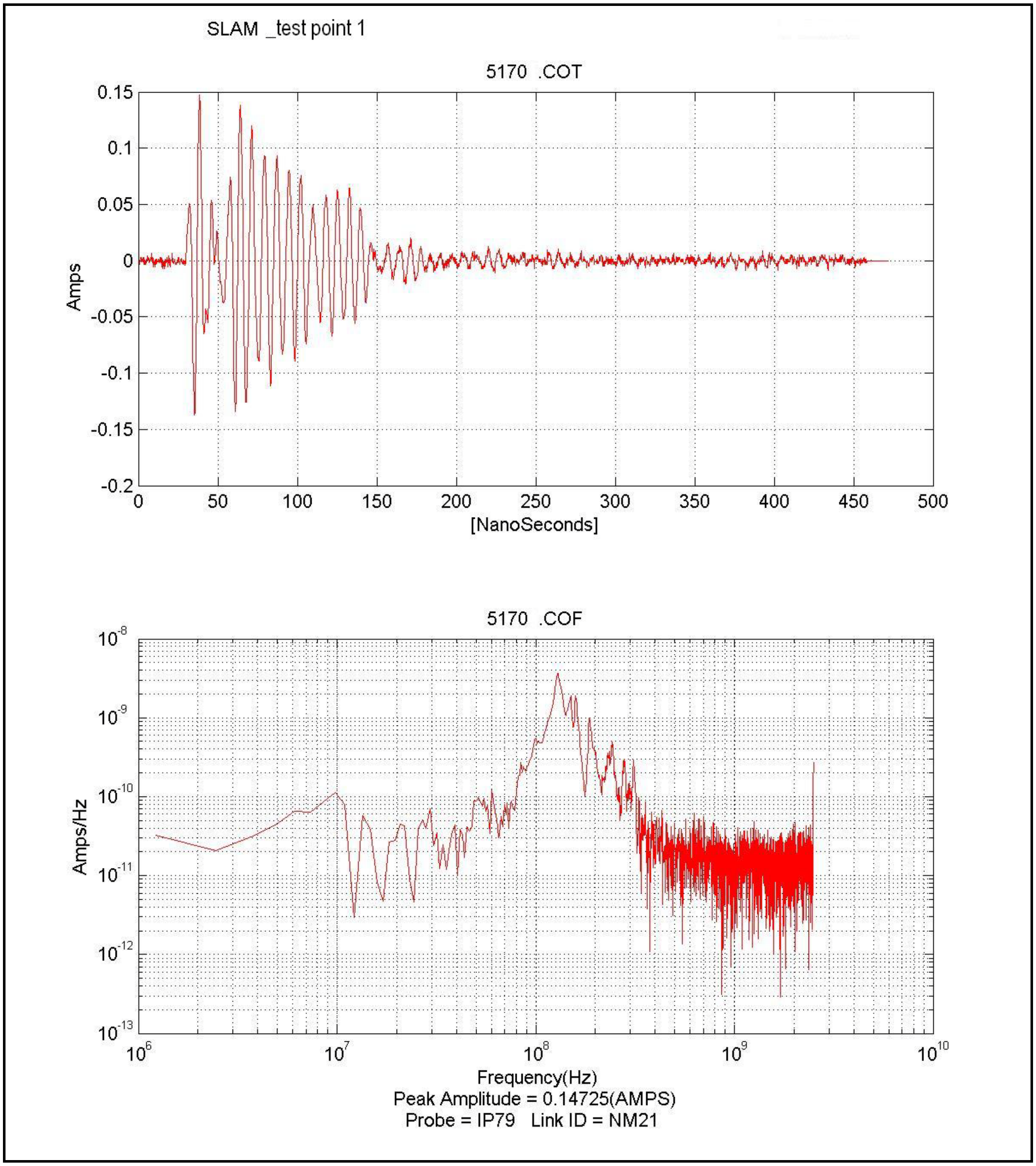
b. The second configuration (i.e. **TYPE 2**) is with the main charge removed and the EIDs installed. Safety procedures must be developed and strictly followed to insure that projectiles are not created should the EID function which could injure personnel or damage the facility or equipment. Potential for damage with only the EIDs installed usually is provided in the System Safety Assessment Report (SSAR). In some case the statement will be directly made that the functioning of the EID cannot deform the surface or create projectiles, in other cases the indication could be that the item requires enclosure in a plastic or plywood (i.e. non-conductive container for VEMP) of a specific thickness to insure that possible projectiles are contained. There must also be a method of determining if the EID has functioned. The test configuration is the basic GO-NO-GO configuration and provides an indication as to whether the calculations and measurements from the first configuration were correct.

2. EID specifications contain valuable pieces of data. The first is the device maximum no-fire current (i.e. the EID will not function with the continuous application of 20mA). The second is the device all fire current (i.e. the EID will function with the application of 1A). And the third is the timing for the EID to function (i.e. some will indicate a square pulse with an amplitude and a time and others may indicate all EIDs will fire within 10 milli-seconds when a 103.4 μ-Farad capacitor charged to 1.6 Volts is discharged through the EED.) From these specifications two important VEMP parameters are determined. The first is that for the best case the VEMP induced current regardless of time is less than the no-fire current. And the second is that the VEMP induced energy should provide for a minimum safety factor of 16.5 dB.

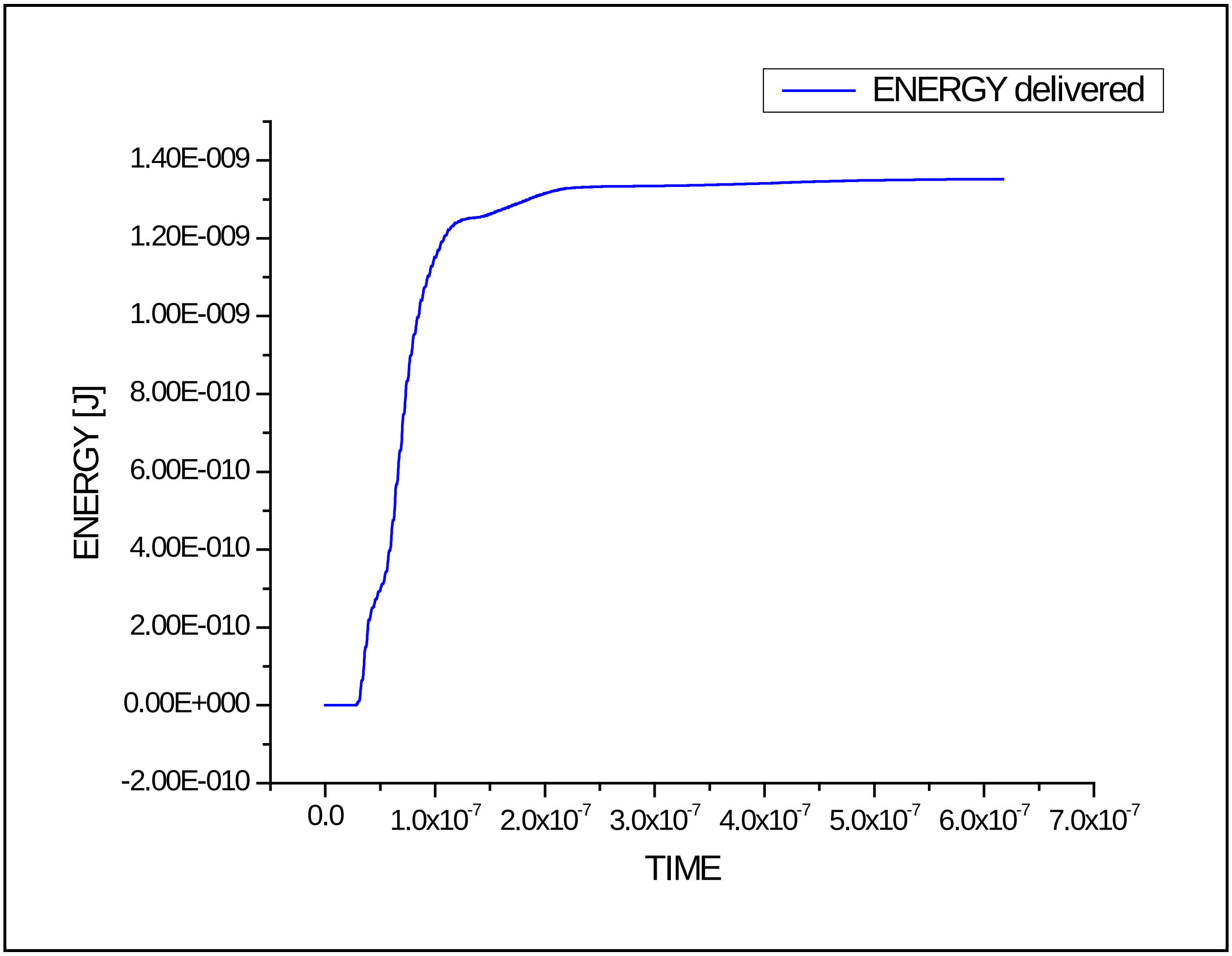
3. Provided are some possible measurements and calculations. Table D-1 provides example reduced VEMP test data for a system with three EIDs. Graph D-1on the following page provides a frequency and time corrected induced current. Graph D-2 provides the energy delivered to the EID by the VEMP pulse. The energy is acquired by rectifying the induced current, then calculating instantaneous power at each data point utilizing the EID impedance and finally integrating over time to convert to energy.

Table D-1. EED Induced Currents

Test point ID	Orient	Shot#	Peak I (Amp)	Peak Derivative	Peak Impulse	Rectified Impulse	Root Action Integral	Total Energy 1 Ohm	Total Energy 3 Ohms
1	1-front	5166	0.0858	8.56E+07	1.66E-10	4.04E-09	1.18E-05	1.38E-10	4.15E-10
2	1-front	5167	0.1030	1.29E+08	4.80E-10	7.44E-09	1.80E-05	3.26E-10	9.77E-10
3	1-front	5169	0.1551	1.63E+08	2.37E-10	5.21E-09	1.69E-05	2.85E-10	8.55E-10
1	2-front	5170	0.1473	1.74E+08	1.79E-10	6.73E-09	2.01E-05	4.03E-10	1.21E-09
2	2-front	5171	-0.1471	1.72E+08	1.03E-09	8.22E-09	2.12E-05	4.51E-10	1.35E-09
3	2-front	5173	0.1012	9.85E+07	1.19E-10	3.64E-09	1.07E-05	1.14E-10	3.42E-10
1	2-back	5175	0.0125	1.98E+07	2.04E-11	6.42E-10	1.72E-06	2.94E-12	8.83E-12
2	2-back	5176	0.0142	2.12E+07	1.92E-11	7.52E-10	1.94E-06	3.78E-12	1.13E-11
3	2-back	5177	-0.0168	2.25E+07	4.15E-11	6.63E-10	2.00E-06	4.00E-12	1.20E-11
1	2-side	5180	-0.0343	5.30E+07	8.81E-11	1.13E-09	3.43E-06	1.18E-11	3.54E-11
2	2-side	5181	0.0459	7.25E+07	1.44E-10	2.47E-09	6.59E-06	4.34E-11	1.30E-10
1	2-side	5182	-0.0324	5.06E+07	9.51E-11	1.12E-09	3.40E-06	1.16E-11	3.47E-11
3	2-side	5183	-0.0506	6.09E+07	7.10E-11	1.75E-09	5.46E-06	2.99E-11	8.96E-11
1	2-front	5184	-0.0553	8.63E+07	1.81E-10	1.67E-09	5.20E-06	2.71E-11	8.12E-11



Graph D-1. EID Current Example.



Graph D-2. EID VEMP Induced Energy.

4. Example EID Technical Analysis. The following is based on an EID with the following specifications provided:

a. The EID will not function with the application of 20mA for 1 minute

b. The EID will fire within 10 milli-seconds when a 103.4 μ-Farad capacitor charged to 1.6 Volts is discharged through the EID.

c. The EID impedance is 3 Ohms

4.1 At no point during testing did any of the ten **TYPE 2** units enable or fire as a result of the VEMP exposures. The test results initial indication is that insufficient energy was delivered to the EID for it to function.

4.2 The **TYPE 1** EID EMP induced current measurements indicate that a maximum of 1.35E-9 Joules are available to the EID at the specified impedance (three Ohms). Using the total length of recorded current waveform (600 nano-seconds) as time, the EID EMP induced energy deposition rate is calculated to be 2.25E-3 J/Sec. The specification indicates that all EIDs will fire within 10 milli-seconds when a 103.4 μ-Farad capacitor charged to 1.6 Volts is discharged through the EID. This correlates to an energy level of 1.32E-4 Joules as calculated by $\frac{1}{2}CV^2$ and a deposition rate of 1.32E-2 J/sec (based on the 10 milli-seconds time period). The specifications also indicates that no EID shall fire when subjected to a current of 20 milli-Amperes for a period of one minute, which corresponds to an energy of 7.2E-2 Joules at a deposition rate of 1.2E-3 J/sec. Therefore, based on energy deposition rates during firing, the EID has a conservative safety factor of five (5) as calculated by dividing the all fire energy deposition rate (1.32E-2 J/sec) by the EMP induced deposition rate (2.25E-3 J/sec). Based on total energy delivered for no-fire the EID has a large safety factor as calculated by dividing the No-fire energy delivered (7.2E-2 J) by the EMP energy delivered (1.35E-9 J). This agrees with the “TYPE 2” results in that no EIDs were discharged as a result of the HEMP environment.

APPENDIX E: Overview of VEMP test instrumentation and mathematics

Provided is an overview of the data processing that occurs in VEMP testing to form a basic knowledge foundation. It should be noted that this is not an in-depth presentation and that the procedures used and data accuracy provided by the instrumentation are in general the responsibility of the test facility.

1. DATA MEASUREMENTS: For testing at pulse/high frequency facilities most sensors and data links are self calibrated by the instrumentation specialist. The traceability back to a laboratory calibration is through the use of a network analyzer which has calibration performed at the factory or a standard calibration laboratory. The instrumentation is basically divided into three sections which will be discussed separately below:

SENSORS: In general the facility calibration of sensors is limited to the ones which measure voltage or current. Sensors for measuring fields (electric or magnetic) or for measuring surface currents are factory calibrated. The current probes are available with different current measuring capabilities and different through hole sizes; inmost cases (except for very small very specific probes) clamp on devices are used. A special adapter is required for each size probe for the facility calibration to be performed. The probe adapter (see Figure E-1) allows for the placement of a probe around the center conductor and inside the external conductor. The probe is then connected to a network analyzer. The network analyzer output feeds both the forcing function and the reference measurement and measures the voltage output of the current probe. This forcing function is driven across the frequency spectrum for which the current probe is being calibrated. The current probe voltage output is divided by the current through the fixture; the current through the fixture is based on the measured reference voltage and the fixed load impedance. The result is the transfer function of the current probe versus frequency which is called the probe transfer impedance since the units are volts/ampere. The voltage probes are calibrated in the same manner with the exception that the transfer function units are volts/volt. Experience has indicated that 400 measurements across the frequency spectrum tend to be adequate for calibration. This frequency calibration is used as follows: The data produced by the current or voltage probe is recorded on fast oscilloscopes as voltages in the time domain. The recorded data then requires correction for the probe transfer function (frequency response) and conversion to the correct units of measure. This is accomplished using convolution in the time domain, the process however takes place in the frequency domain since in the frequency domain convolution reduces to simple point by point division. The process for a current probe is that the recorded time domain waveform is converted to the frequency domain using Fast Fourier Transforms (FFT). The resulting frequency data is then divided on a per frequency basis by the probe transfer function at that frequency, interpolation between probe calibration frequency points is used to match the exact frequency resulting from the FFT. Once the convolution has taken place the FFT is now corrected for probe response and the inverse FFT results in the corrected time response with the appropriate units

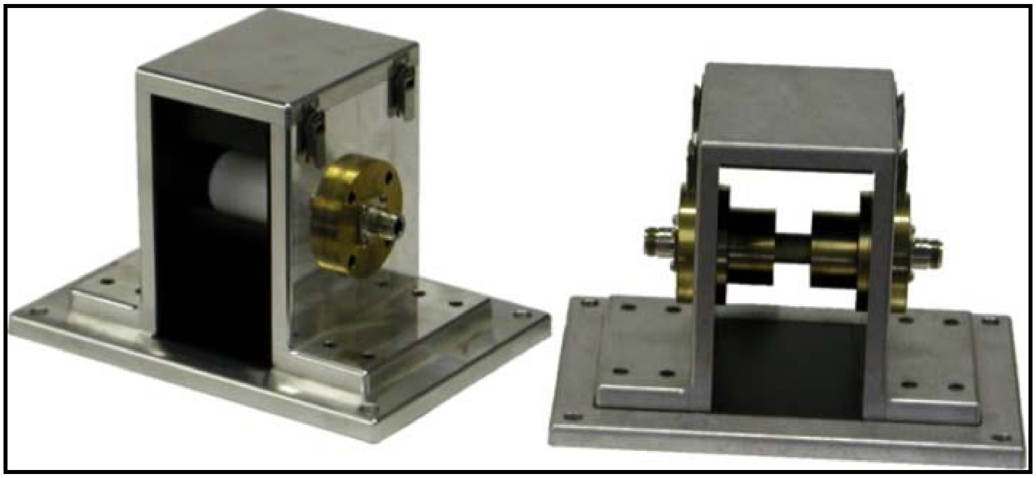
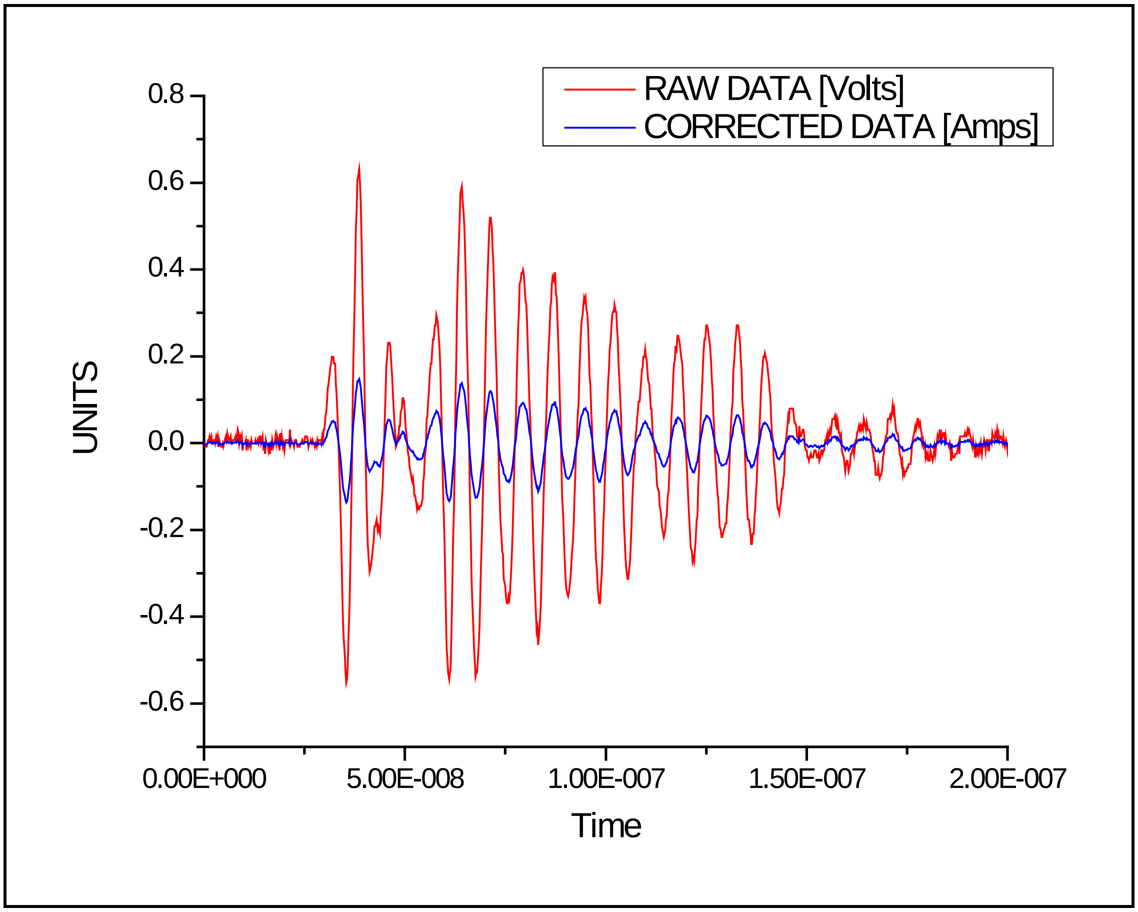


Figure E-1. Probe Adapter.

2. FIBER OPTIC DATA LINKS: In general the facility calibration of data links is performed as matching pairs (i.e. the optical transmitter and the optical receiver are matched into a data link). These matched pairs are always to be used together during data acquisition. The DATA links are available from several manufactures one of the most common is NANO-FAST. The link is connected to a network analyzer. The network analyzer output feeds both the forcing function and the reference measurement and measures the voltage output of the link. This forcing function is driven across the frequency spectrum for which the link is being calibrated. The link voltage output is divided by the measured reference voltage across the frequency range being calibrated. The result is the transfer function of the link versus frequency for which the units are volts/volt. Experience has indicated that 400 measurements across the frequency spectrum tend to be adequate for calibration. This frequency calibration is used as follows: The data produced by the sensor is input to the fiber transmitter and received by the fiber receiver and the receiver output voltage is recorded on fast oscilloscopes as voltages in the time domain. The recorded data then requires correction for the link transfer function (frequency response). This is accomplished using convolution in the time domain. The process however takes place in the frequency domain since in the frequency domain convolution reduces to simple point by point division. The process for a link is that the recorded time domain waveform is converted to the frequency domain using Fast Fourier transforms (FFT). The resulting frequency data is then divided on a per frequency basis by the link transfer function at that frequency, interpolation between probe calibration frequency points is used to match the exact frequency resulting from the FFT. Once the convolution has taken place the FFT is now corrected for the link response and the inverse FFT results in the corrected time response.

3. FIBER: The fiber is not calibrated versus frequency sine it possesses no elements which would result in a change in frequency spectrum transmission. Most fiber link provide for a standard signal being transmitter over the fiber to verify its acceptability. This measurement being unacceptable indicates two potential faults; the first is that the ends of the fiber are dirty and the second is that the fiber is broken.

4. DEMONSTRATION OF MEASUREMENT CONVERSION: As indicated in section X1, the data starts as a raw voltage measurement recorded on a digitizing oscilloscope. This raw data is processed through frequency domain convolution using the instrumentations factors indicated in section x1 into the final corrected measurement. Graph X-1 shows graphically the dramatic changes that occur in the data as the units are converted and the frequency response of the instrumentation is accounted for.

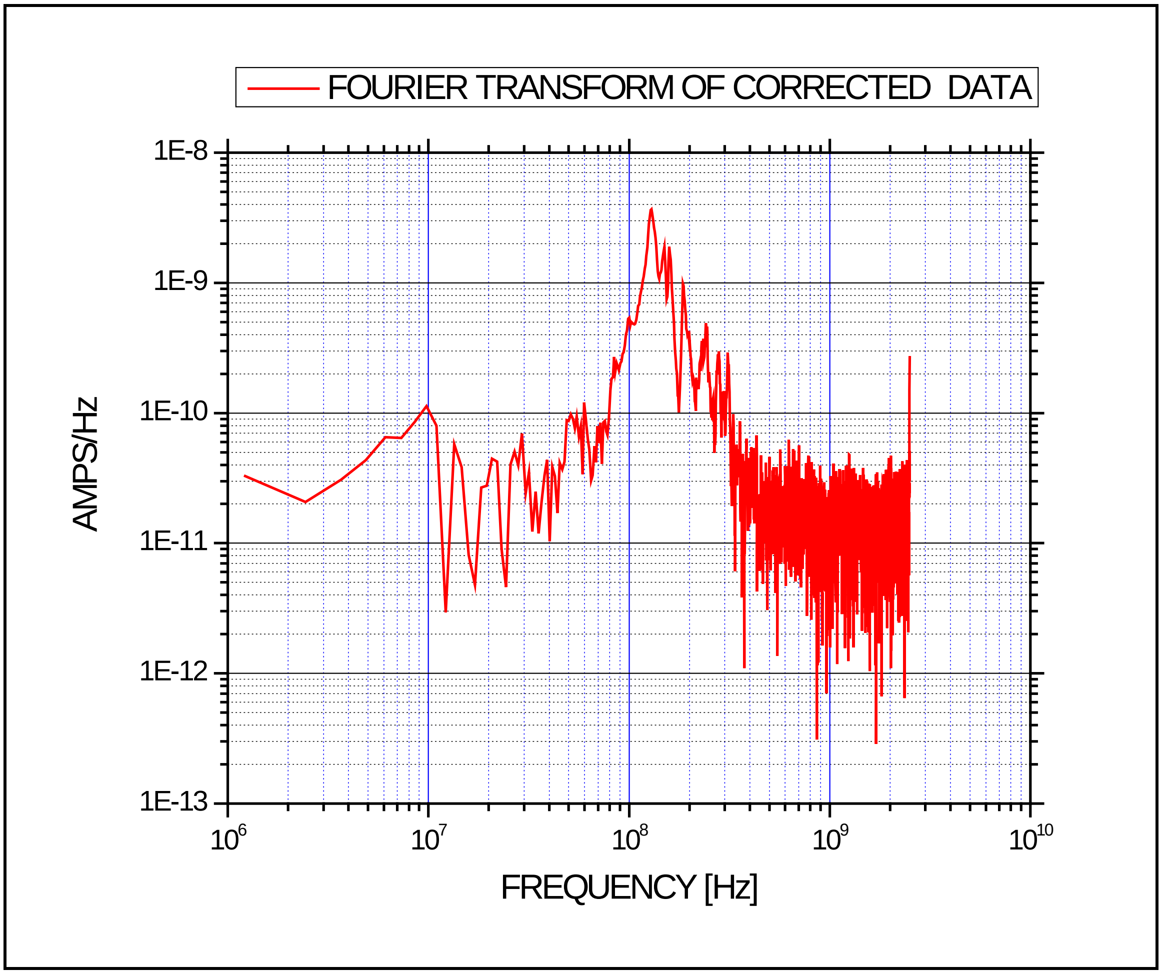


Graph E-1. Raw Data Correction.

5. DATA CALCULATIONS: The data manipulation and calculations at pulsed/high frequency facilities are usually performed by the facility data specialist. Provided is a basic overview of the methods and results. The purpose of the calculations is to develop a set of scalars or NORMS which can be used to describe the characteristics of the induced signals and provide engineering data for use in the correction of deficiencies if required. Provided in Table E-1 are examples of the SCALAR quantities for damped sinusoids and Graph E-2 is the FOURIER transform from which they were generated.

Table E-1. Example of Calculated Damped Sinusoid Scalar Values.

Test point ID	Orient	Shot#	Peak I (Amp)	Resonant Frequency	Lower Frequency	Higher Frequency	Bandwidth	Alpha	Q
1	2-front	5170	0.1478	1.29E+08	1.26E+08	1.33E+08	8.18E+06	2.38E+07	14.15
2	2-front	5170	0.1030	1.25E+08	1.20E+08	1.30E+08	9.80E+06	3.26E+07	15.67
3	2-front	5170	0.1551	1.63E+08	1.50E+08	1.70E+08	2.00E+07	2.85E+07	15.84



Graph E-2. Induced Current Fourier Transform.

The values are calculated in the time domain representation of the waveform as follows:

a. The resonant frequency (Fo) is the first pole in the frequency domain after the DC level and is displayed on the graph at about 1.3E8.

b. The low (Fl) and high (Fh) frequencies are measured at the 3 dB down points from the peak, with the low frequency being to the left and the high frequency being to the right. If necessary the slope is used to calculate the 3 dB point on signals containing more noise.

c. The bandwidth is the difference between the high and low frequency

d. Alpha (the exponential attenuation rate) is calculated by: $\alpha = \pi(Fh - Fl)$

e. Q (quality factor) is calculated by: $Q = \dfrac{\pi(Fo)}{\pi(Fh - Fl)}$

f. Df (Damping factor) is calculated by: $Df = \dfrac{1}{2\,Q}$

6. EXAMPLE TECHNICAL ANALYSIS. From the scalars presented in table E-1, which were generated from the measured EMP induced current the following is known; a) the induced current is at a frequency of 129 MHz, b) the bandwidth is approximately 10 MHz, c) the Q is large and the damping factor is small indicating the signal is over damped and will decay quickly, and d) the amplitude of the induced current was 0.15 Amps. Therefore, if the component connected to this cable was experiencing EMP induced problems, it could most likely be eliminated by designing a simple low pass filter (or a more complicated filter based on the circuit signal requirements) with an upper cutoff frequency of 119 MHz and which is capable of carrying the normal signal currents plus approximately 0.2 Amperes.

APPENDIX F: ABBREVIATIONS.

ADSS	- Army Decision Support System
Amp	- Ampere
AR	- Army Regulation
ARES	- Advanced Research Electromagnetic Simulator
ASAP	- As Soon As Possible
ATEC	- Army Test and Evaluation Command
BOBs	- Breakout Boxes
CDD	- Capabilities Development Document
CI	- Current Injection
cm	- centimeter
DAS	- Data Acquisition System
Df	- Damping Factor
DM	- Design Margin
DOD	- Department of Defense
DODI	- Department of Defense Instruction
DOE	- Department of Energy
DT	- Development Test
DTC	- Developmental Test Command
ECP	- Engineering Change Proposal
EID	- Electrically Initiated Device
E-Field	- Electric Field
EM	- Electromagnetic
EMP	- Electromagnetic Pulse
FFT	- Fast Fourier Transform
Fo	- Resonant Frequency
FWHM	- Full Width Half Maximum
GHz	- Gigahertz
HEMP	- High Altitude Electromagnetic Pulse
HF	- High Frequency
H-Field	- Magnetic Field
HOB	- Height-Of-Burst
HQ	- Headquarters
Hz	- Hertz
IAP	- Independent Assessment Plan
IAW	- In Accordance With
IEP	- Independent Evaluation Plan

KAFB	- Kirtland Air Force Base
kHz	- Kilohertz
kV/m	- Kilovolts Per Meter
LCNS	- Life-Cycle Nuclear Survivability
LF	- Low Frequency
LRU	- Line Replaceable Unit
m	- Meter
m^2	- Square Meter
mA	- Milliampere
MEF	- Mission Essential Functions
MF	- Middle Frequency
MHz	- Megahertz
MIL-STD	- Military Standard
ms	- millisecond
MSDS	- Materiel Safety Data Sheets
NHC	- Nuclear Hardening Criteria
NLT	- Not Later Than
ns	- Nanosecond
ORD	- Operational Requirements Document
PM	- Program Manager
Qf	- Quality Factor
QMR	- Qualitative Materiel Requirement
QSTAG	- Quadripartite Standardization Agreement
RF	- Radio Frequency
Ref	- Reference
s, sec	- second
SCTs	- Shielded Cable Tests
SN	- Serial Number
SREMP	- Source Region Electromagnetic Pulse
STA	- System Test and Assessment
Subj	- Subject
SUT	- System Under Test
TEM	- Transverse Electromagnetic wave
TEMP	- Test and Evaluation Master Plan
TIR	- Test Incident Report

TO	- Test Officer
TOP	- Test Operations Procedure
TPD	- Terminal Protection Device
UHF	- Ultra High Frequency
USA	- United States Army
USANCA	- United States Army Nuclear and Combating Weapons of Mass Destruction
μsec	- microsecond
VDL	- Vision Digital Library
VEMP	- Vertical Electromagnetic Pulse
VHF	- Very High Frequency
VLF	- Very Low Frequency
V/m	- Volts per Meter
VV&A	- Validation, Verification and Accreditation
WSMR	- White Sands Missile Range

APPENDIX G: GLOSSARY.

1. Electromagnetic Pulse - A burst of electromagnetic radiation from a nuclear explosion or a suddenly fluctuating magnetic field. The resulting electric and magnetic fields may couple with electrical/electronic systems to produce damaging current and voltage surges.

2. Source Region Electro-magnetic Pulse [SREMP] - is produced by low-altitude nuclear bursts. An effective net vertical electron current is formed by the asymmetric deposition of electrons in the atmosphere and the ground, and the formation and decay of this current emits a pulse of electromagnetic radiation in directions perpendicular to the current. The asymmetry from a low-altitude explosion occurs because some electrons emitted downward are trapped in the upper millimeter of the Earth's surface while others, moving upward and outward, can travel long distances in the atmosphere, producing ionization and charge separation. A weaker asymmetry can exist for higher altitude explosions due to the density gradient of the atmosphere.

3. Vertical Electromagnetic Pulse - This is the vertical component of a burst of electromagnetic radiation from a nuclear explosion or a suddenly fluctuating magnetic field. The resulting electric and magnetic fields may couple with electrical/electronic systems to produce damaging current and voltage surges.

APPENDIX H: REFERENCES.

REQUIRED REFERENCES:

1. Army Regulation (AR) 70-75, 2 June 2006, subject: Survivability of Army Personnel and Materiel.

2. Department of Defense Directive 5000.1, 12 May 2003, subject: The Defense Acquisition System.

3. Army Nuclear Hardening Criterion for System Under Test (SUT).

4. MIL-STD-2169B: High Altitude Electromagnetic Pulse (HEMP) Environment, December 1993.

5. DTC Pamphlet 73-1, 30 October 2006, subject: Developmental Test Guide.

6. AR 200-1: Environmental Protection and Enhancement, 31 December 2007.

7. AR 200-2: Environmental Effects of Army Actions, 15 January 2006.

8. Army Materiel Command Regulation (AMC-R) 385-100, Safety Manual, 26 September 1995

9. MIL-STD-461E, 20 August 1999, subject: Department of Defense Interface Standard, Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment.

10. MIL-STD-464A, 19 December 2002, subject: Department of Defense Interface Standard, Electromagnetic Environmental Effects Requirements for Systems.

11. QSTAG 244, Edition 4: Nuclear Survivability Criteria for Military Equipment, 19 January 1993.

12. QSTAG 620, Edition 2: Nuclear Survivability Criteria for Communications-Electronics Equipment, 29 January 1993.

13. TOP 1-2-612: Nuclear Environment Survivability, 15 May 2008.

Forward comments, recommended changes or any pertinent data which may be of use in improving this publication to the Test Business Management Division (TEDT-TMB), U.S. Developmental Test Command, 314 Longs Corner Road, Aberdeen Proving Ground, MD 21005-5055. Technical information can be obtained from the preparing activity, Commander, U.S. Army White Sands Missile Range, ATTN: TEDT-WSV, Survivability, Vulnerability and Assessment Directorate, WSMR NM 88002-5002. 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.