JEM-CWI-TPP-0001-REV1 Frequency Authorization

TEST PLAN AND PROCEDURES

MIL-STD-188-125-1A Continuous Wave Immersion Shielding Effectiveness Test

Frequency Authorization

Jaxon Engineering & Maintenance

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TEST PLAN AND PROCEDURES

MIL-STD-188-125-1A CWI Testing

DOCUMENT NUMBER	This is the test plan and procedures document for the MIL-STD-188-125-1A CWI testing by Jaxon Engineering and Maintenance.

CONTRACT	PROJECT	CUSTOMER

FUNCTION	NAME	TITLE	SIGNATURE	DATE
Originator		Engineer Team Lead		
Engineering		Engineer		
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REVISION HISTORY

REV	DATE	FILENAME	DESCRIPTION
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0	14APR2023	JEM-CWI-TPP-0001-REV0-Frequency Authorization.pdf	Original Release

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Acronyms and Terms

DAS	Data Acquisition and Storage
dB	Decibel
dBm	Power in dB referenced to one milliwatt
DC	Direct Current
DoD	Department of Defense
EMP	Electromagnetic Pulse
H-FET	HEMP Fabrication, Engineering and Testing Facility
FWHM	Full-Width at Half-Maximum
HEMP	High-Altitude Electromagnetic Pulse
IAW	In Accordance With
JEM	Jaxon Engineering and Maintenance
MCE	Mission Critical Equipment
MCS	Mission Critical Systems
MR	Measurement Range (of the SE Measurement System)
POE	Point of Entry
PPD	Point of Entry Protective Device
RF	Radio Frequency
SE	Shielding Effectiveness
TA	Test Article
TPP	Test Plan and Procedures (document)
WBC	Waveguide Below Cutoff
WTG	Wire to Ground

1.0 Introduction

This Test Plan and Procedures (TPP) document describes the MIL-STD-188-125-1A High Altitude Electromagnetic Pulse (HEMP) Continuous Wave Immersion (CWI) testing to be performed by Jaxon Engineering and Maintenance (JEM).

1.1 Test Definition and Objective

A successful HEMP-verification test serves to identify any areas of HEMP-hardening weakness (if they exist) and address any issues so that the site can be upgraded to conform to hardening requirements.

The objective of this low-risk approach is defined by MIL-STD-188-125-1A as follows:

> 1.4 Objectives. Survivable C^4I capabilities are essential to a credible military deterrent. This standard supports nuclear survivability objectives by providing a standardized, low-risk protection approach for fixed ground-based facilities in HEMP-hardened C^4I networks. These uniform requirements ensure balanced HEMP hardening for all critical facilities in the network.

Furthermore, the objective and timing of a MIL-STD-188-125-1A verification test is clearly defined in the standard, as follows:

> 4.4.3 Verification testing. Verification testing of the operational facility shall be based upon successful demonstrations of compliance with hardness and mission performance requirements of this standard. After completion of the HEMP protection subsystem's installation and operational checks, and acceptance testing of the low-risk electromagnetic barrier, HEMP hardness of the facility shall be verified through a program of tests and supporting analysis. The verification program shall provide a definitive statement on the HEMP hardness of critical time-urgent mission functions at the facility under test. Verification test procedures and results shall be documented and retained for use as baseline configuration and performance data. The verification testing plan for the HEMP protection subsystem tests shall be documented IAW DI-NUSU-82341, "Verification Test Plan." The verification testing report for the HEMP protection subsystem tests shall be documented IAW DI-NUSU-82342, "Verification Test Report."

The purpose of a CWI verification test is as follows:

- Measure attenuation of electromagnetic fields in the HEMP portion of the spectrum by linear elements of the as-built electromagnetic barrier.
- Identify HEMP shield and aperture (POE) protective device (PPD) defects, faulty installation practices, and inadvertent POEs, so that repairs can be made.
- Characterize residual internal field and conducted electromagnetic stresses, within limitations of the linearity and planarity assumptions, through post-test analysis.

- Observe operation of the fixed building for interference or upset (interference which occurs as the result of the low-level continuous wave (CW) excitation that may indicate a circuit is particularly vulnerable to HEMP effects).
- Provide data for HEMP hardness assessment of the facility.

1.2 Test Scope/Summary

The MIL-STD-188-125-1A verification test set of the fixed facility, consists of a complete continuous wave immersion (CWI) test series of the main EM barrier. The CWI test approaches, which were performed in accordance with Appendix C of MIL-STD-188-125-1A, completely characterized the mission critical system response to the radiated components resulting from a HEMP event.

1.3 Test Schedule

The actual test will be scheduled following review and approval of this plan.

1.4 References

The following specifications, standards, documents, and handbooks were used in the preparation of this test plan and are relevant to this MIL-STD-188-125-1 acceptance shielding effectiveness test effort.

- MIL-STD-188-125-1A - High-Altitude Electromagnetic pulse (HEMP) Protection for Ground-Based C4I Facilities Performing Critical, Time-Urgent Missions, Part 1 - Fixed Facilities (document is available to the public)
- MIL-STD-2169C - High-Altitude Electromagnetic Pulse (HEMP) Environment (U) (document is classified Secret)
- MIL-HDBK-423 High-Altitude Electromagnetic Pulse (HEMP) Protection for Fixed and Transportable Ground-Based Facilities, Volume I: Fixed Facilities (document subject to Restricted Distribution)
- MIL-HDBK-419 – Grounding, Bonding, and Shielding for Electronic Equipment and Facilities (document is available to the public)

2.0 Test Article Description

2.1 Test Article Descriptions

2.1.1 Overview

A plan view drawing of the facility is shown in Figure 1. The building contains multiple offices, reception, and break rooms.

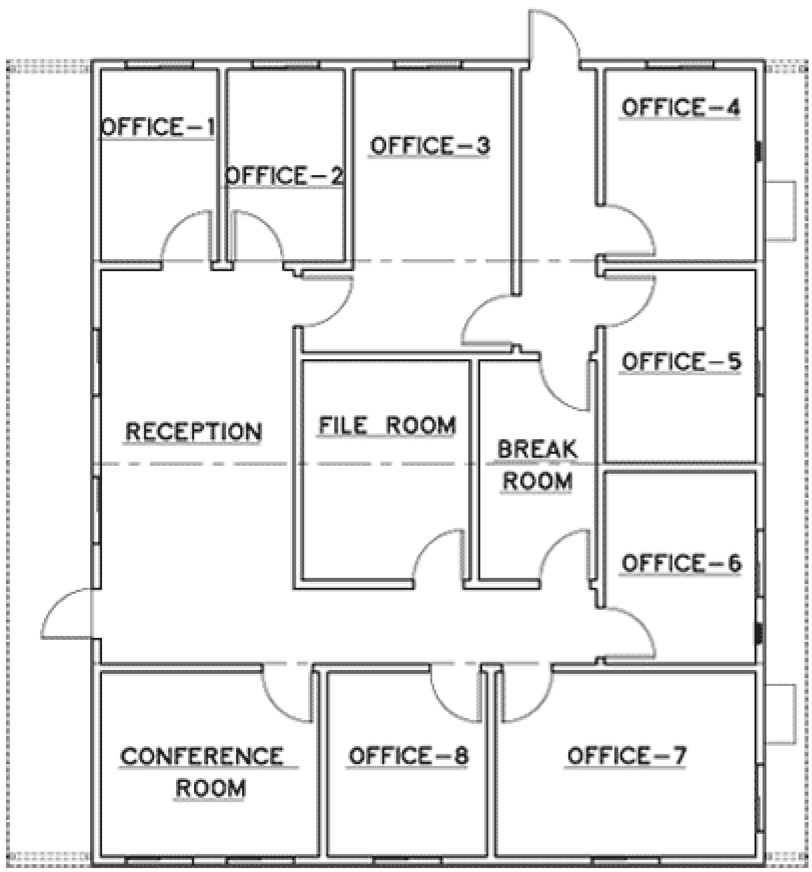


Figure 1. Fixed Facility Layout

3.0 Verification Test Requirements

3.1 MIL-STD-188-125-1A Verification Test Background

A MIL-STD-188-125-1A verification test sequence is designed to assess the HEMP effects on an operational system to ensure that, as stated in the standard, “no mission-aborting damage or upset occurs because of the simulated HEMP excitations.”

The HEMP environment is defined in MIL-STD-2169C to be a reasonable worst case HEMP threat. Protection from this HEMP environment is addressed in both the protection and test requirements of MIL-STD-188-125-1A, as illustrated in Figure 2.

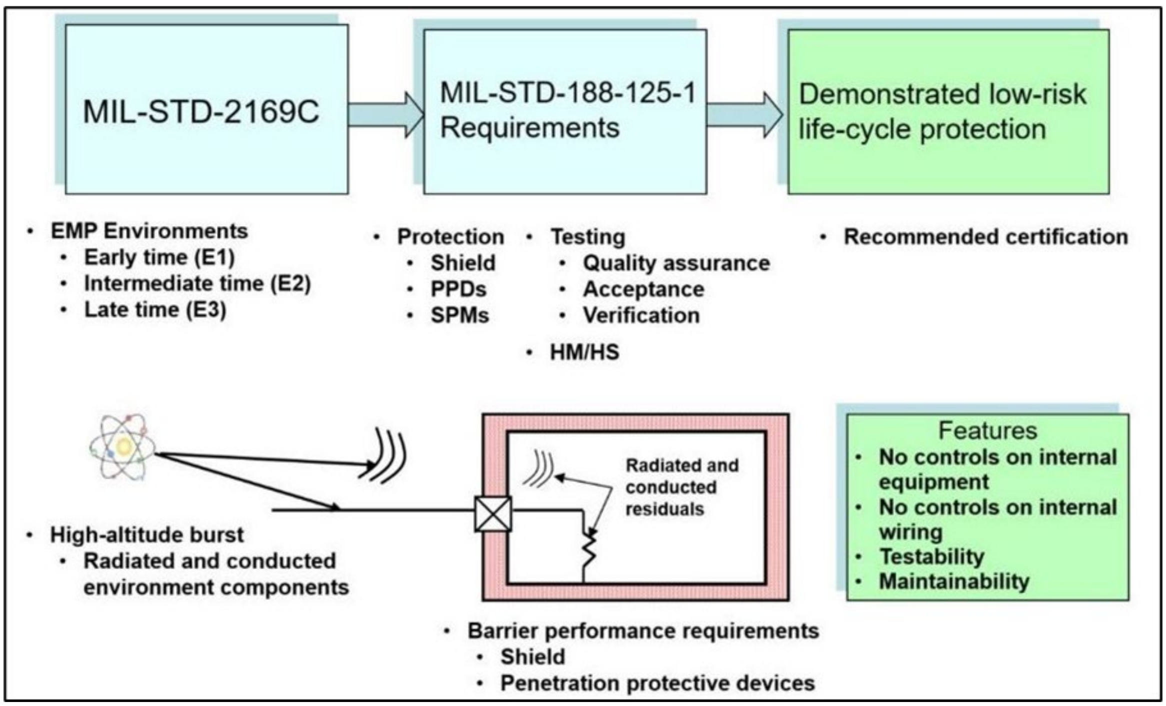


Figure 2. The Flow-Down of the HEMP Environments to Protection Requirements

HEMP-verification test sequences defined in MIL-STD-188-125-1A are designed to address both the radiated and conducted HEMP components that a hardened facility would be subjected to in a HEMP event.

The CWI verification testing was designed and performed to demonstrate that the fixed facility is protected against the conducted and radiated HEMP environmental components, and to identify any EM barrier protection weaknesses.

3.2 Verification CWI Testing Overview

The verification continuous wave immersion testing methodology is defined in Appendix C of MIL-STD-188-125-1A and is illustrated generically in Figure 3 which is taken from Appendix C of the standard. The radiated portion of a MIL-STD-188-125-1A verification test program consists of three distinct types of measurements, all of which are made using the same system to provide a low-level continuous wave immersion illumination of the system or facility under test.

Using the CW illumination system, shielding effectiveness measurements are made in a manner like that used for Appendix A SE measurements. The free (to the extent possible) fields produced by the CWI transmit antenna system are characterized at a range (or ranges) and angle (or angles) of incidence representative of that which will be used to illuminate the system or facility. This field mapping is performed for both horizontal and vertical polarities of the illuminating field. The system or facility is then illuminated by the CWI antenna system and internal field and surface current measurements are made at selection locations within the interior of the facility. These measurements are again made with both horizontal and vertical polarities of the illuminating field. The internal free field and surface current measurements are compared to the appropriate field mapping results to provide an estimate of the attenuation provided by the linear elements of the facility EM barrier, as a function of the illuminating field characteristics (polarity, range, orientation with respect to the facility, measurement frequency, etc.) at each interior measurement location within the facility. These measured shielding effectiveness results are then compared to the MIL-STD-188-125-1A CWI SE performance requirement which is provided in the following section of this TPP document.

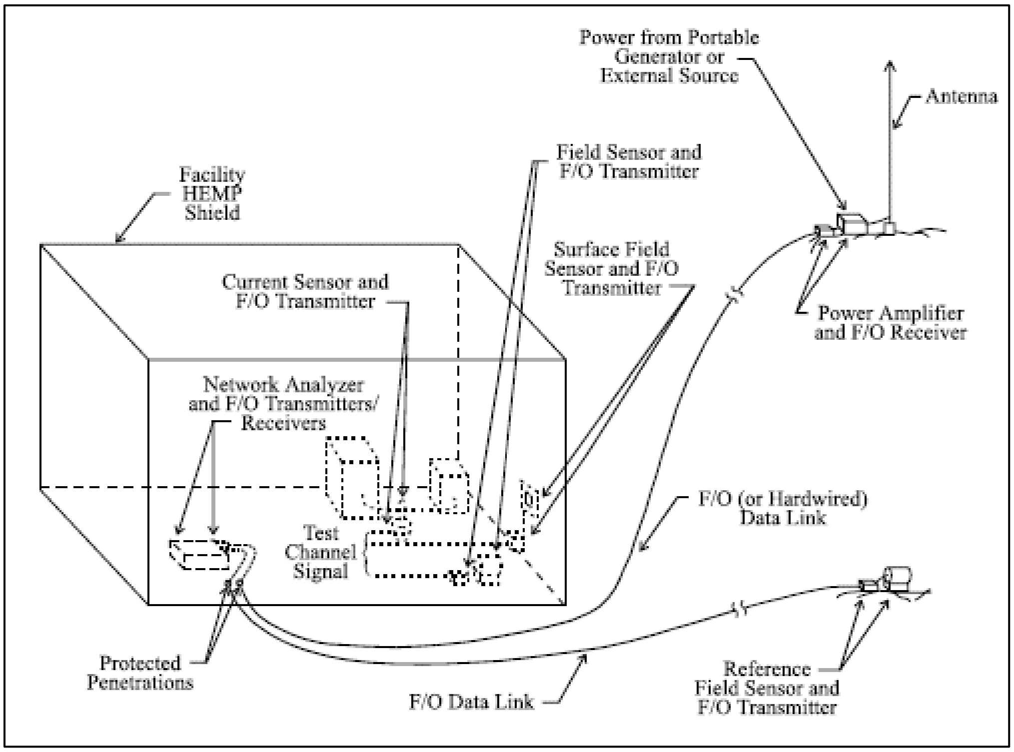


Figure 3. CWI Conceptual Diagram

Using the same CWI radiator (antenna system), measurements of the RF currents induced onto internal (within the main EM barrier) cables and conductors resulting from the leakage of the illuminating EM field into the protected volume are also made. These results are then processed to obtain transfer functions which—for each test point, CWI transmit antenna position and polarization—express as a function of frequency the ratio of the coupled current to the illuminating EM field as characterized during field mapping of the CWI radiating antenna. The transfer functions are then extrapolated (a multiplicative process in the frequency domain) by a representative threat-level free-field radiated HEMP transient to predict the currents that would be induced onto the test point (cable or wire) by an actual HEMP event. The time domain peak and peak derivative norms of these "threat level, extrapolated coupled current" (TLECC) predictions are then compared to the limits given in MIL-STD-188-125-1A (0.1 A and 1E7 A/sec, respectively).

3.3 MIL-STD-188-125-1A CWI Test Requirements

A MIL-STD-188-125-1A main barrier verification continuous wave immersion (CWI) test characterizes the shielding effectiveness of the linear elements of a protected volume including that of the shield itself and of all associated point of entry treatments (i.e., PoE PPDs). The CWI test also characterizes the coupling of RF energy into the protected volume in terms of currents coupled onto interior cables and wires. These coupled current measurements are then processed by extrapolating the measured transfer functions to threat level in order to predict the HEMP-induced responses (also called the "threat-level extrapolated coupled currents," or TLECC) on these same cables and wires. An overview of the CWI testing is provided in Section 5.14.1 of MIL-STD-188-125-1A which is reproduced below:

> 5.14.1 <u>CW immersion testing</u>. CW immersion testing shall be performed IAW procedures of Appendix C. At frequencies where the measurement dynamic range exceeds the attenuation required by figure 1 [of MIL-STD-188-125-1A], ratios of illuminating field strength to the internal field measurements shall be equal to or greater than the minimum shielding effectiveness requirement. Internal field measurements shall be below the instrumentation noise or operating signal level in frequency bands where measurement dynamic range is less than attenuation requirements of figure 1. Internal current measurements, when extrapolated to threat using equations defined in Appendix C, shall be ≤ 0.1 A, and the peak derivatives of the threat-extrapolated currents shall be ≤ 1 x 10^7 A/s. No interference with mission-critical communications-electronics or support equipment shall occur.
>
> When approved by the sponsoring agency for the verification test, a thorough program of shielding effectiveness measurements using procedures of Appendix A and a thorough SELDS survey IAW MIL-HDBK-423 guidance may be performed in lieu

The verification shielding effectiveness and coupled current measurement methodology to be utilized during this MIL-STD-188-125-1A verification testing program will be that which is given in Appendix C of the standard. The CWI shielding effectiveness and coupled current measurements will be made at selected locations through the interior of the facility to assess the coupling of RF energy into this protected volume and then onto cables and conductors of mission critical and support equipment and systems. The results of these shielding effectiveness and TLECC measurements will then be used to demonstrate that the site's HEMP hardening subsystems meet the minimum performance requirements given the standard.

The verification shielding effectiveness requirement levied by MIL-STD-188-125-1A is shown in Figure 4. Note that the upper frequency of the verification CWI SE or TLECC measurements required by Appendix C of MIL-STD-188-125-1A is 1 GHz; the segment of the requirement above 1 GHz shown in Figure 4 is the theoretical SE of a 10 cm waveguide below cut-off (WBC) with a 5x cross-section to length ratio and is provided for informational purposes only. Note also that while the SE requirement curve shown in Figure 4 extends down to 1 kHz, Appendix C of MIL-STD-188-125-1A requires that verification CWI SE or TLECC measurements start at 100 kHz.

The performance requirement given in Figure 4, over the frequency range of 100 kHz to 1 GHz, applies to all MIL-STD-188-125-1A verification CWI free field and surface current shielding effectiveness measurements. Internal magnetic free field and surface current density measurements are preferred (versus internal electric free field and surface charge density measurements) by MIL-STD-188-125-1A.

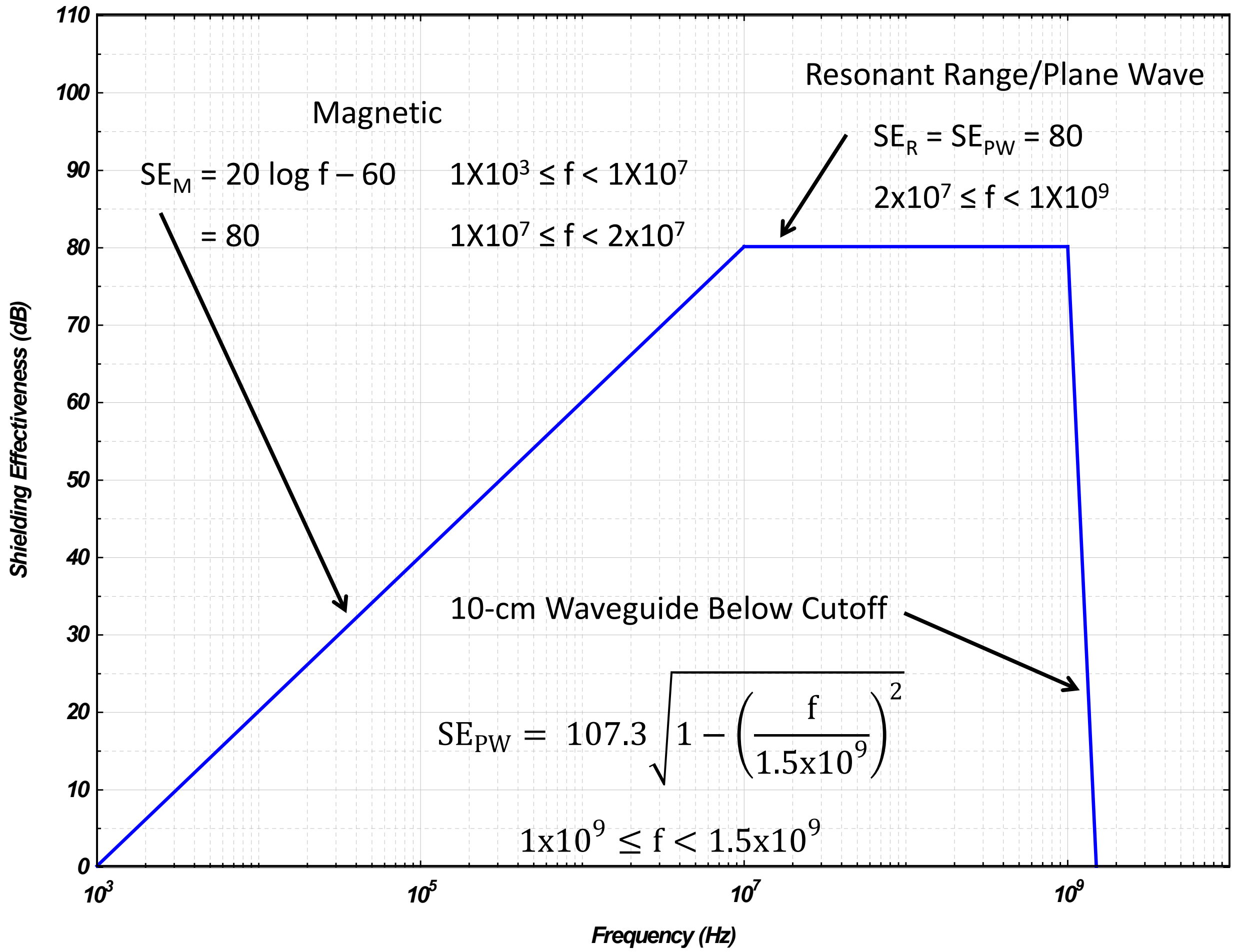


Figure 4. Nominal MIL-STD-188-125-1 CWI Verification performance requirement.

A MIL-STD-188-125-1 verification CWI test is intended to be a "low level" test – meaning that the transmitted CW signal is of a low power level, typically less than 10 – 25 W. Low radiated power levels are also typically required to obtain an authorization to transmit which is required to perform the testing. Furthermore, at the lower measurement frequencies, in the range of 100 kHz to a few MHz, the CWI transmit antenna is typically an inefficient radiator. (As a short dipole antenna, it is certainly an inefficient radiator of magnetic fields at these frequencies). For these reasons, the measurement range of a CWI measurement system is usually less than the required attenuation given in Figure 10. That is, below a few MHz a typical CWI measurement system is not capable of measuring the required shielding effectiveness values. This limitation is recognized in MIL-STD-188-125-1 which states that for those frequencies where the CWI system measurement range is less than the required attenuation, the performance requirement is that there is no observable test location measurement response above the system noise floor. The system noise floor is the signal level measured at the test location in the absence of RF illumination from the CWI transmit antenna.

Finally, the performance requirements provided in MIL-STD-188-125-1A for the threat-level, extrapolated coupled current (TLECC) measurements are given as maximum allowed numeric values of the peak and peak derivative norms of these results. When transformed into the time domain, the limit placed on the peak and peak derivatives norms, as defined in MIL-STD-188-125-1, of the TLECC result are as follows:

PEAK	0.1 A
PEAK DERIVATIVE	1E7 A/s

In addition to the barrier attenuation and TLECC norm limits performance requirements, no test article upset or damage during the CW illumination sequences is allowed. Given the low illuminating field strength levels produced by the CWI illumination antenna, system or facility upset and thus damage is extremely unlikely.

3.4 Verification CWI Measurement System Requirements

Appendix C of MIL-STD-188-125-1A provides details of the recommended or required verification CWI measurement system (for both free fields and surface and coupled currents), including transmit antenna locations, measurement (test point) locations, test frequencies, and so forth. These requirements are summarized in the following sections of this TPP document.

3.4.1 Transmit Antenna Locations

In general, during a MIL-STD-188-125-1A verification CWI test sufficient transmit antenna locations should be identified in order to illuminate all surfaces (walls and roof) of the facility EM barrier with the radiated field excitation. The actual transmit antenna locations selected for any particular MIL-STD-188-125-1A verification CWI test are dependent upon many factors including the size of the protected volume, ease of or restrictions in accessing desired transmit antenna locations, and many other factor. Typically, two to four transmit antenna locations are usually sufficient to meet verification CWI testing needs. At each location the CWI transmit antenna is positioned at a sufficient distance from the facility to ensure a fairly uniform exposure across the surfaces of the facility being illuminated in both horizontal and vertical polarities.

3.4.2 Measurement locations

For a nominal verification CWI test program, MIL-STD-188-125-1A defines the minimum total number of free fields, surface current, and coupled current measurements to be made with the CWI illumination antenna positioned at each defined transmit antenna location. For facilities with a protected floor area of 10,000 sq-ft or less, these totals are:

Free field	5 (x3 orthogonal components)
Surface current	3 (x2 orthogonal components)
Coupled current	20

Furthermore, measurement points for each transmit antenna location should be concentrated in the 40 to 50 percent of the protected volume physically closest to the shield surfaces which are directly illuminated.

Internal free field measurement locations should be chosen to provide a representative mapping of responses throughout the protected volume in areas relative free of equipment, if possible. Magnetic free field measurements are preferred. Likewise, surface current measurements (versus surface charge density) measurements are preferred; surface current measurement locations should primarily be chosen near penetration areas such as RF doors and penetration panels. Coupled current measurement locations should be chosen to provide a representative sampling of the internal cable plant including selected penetrating cables near their PPDs, selected cables with long interior runs or efficient coupling configurations, and on cables connected to mission critical and support systems and equipment.

For each CWI transmit antenna location the specific interior free field and surface current measurement locations (test points) will be chosen in order to ensure a thorough characterization of the portion of the local EM barrier being illuminated. Likewise, the PAR coupled current test points will be selected to assess the coupling of the leakage fields onto a variety of conductor types associated with mission critical and support systems and equipment located within the protected volume.

3.4.3 Test Frequencies

MIL-STD-188-125-1A does not provide guidance as to frequency selection for verification CWI shielding effectiveness or coupled current testing, other than to state that “Test data are desired at frequencies from 100 kHz to 1 GHz.”

Because the MIL-STD-188-125-1A acceptance and verification CWI shielding effectiveness measurement methodologies are essentially the same, the same set of frequencies can be used for both (with the exception of a starting frequency of 10 kHz for acceptance SE and 100 kHz for verification CWI SE; the ending frequency for both is 1 GHz). Actually, other than the “Test data are desired…” statement, MIL-STD-188-125-1A does not explicitly define the frequency range over which CWI measurements are to be made. This range is implicitly defined by the free field and surface current requirement given in Appendix C which is given as "1E3/f dB for 1E5 <= F <= 1E7," and "1E-4 dB for 1E7 < f <= 1E9."

As is obvious, there is a distinct lack of guidance provided in MIL-STD-188-125-1A regarding test frequency selection criteria for verification CWI TLECC measurements. In fact, it can be argued that MIL-STD-188-125-1A does not define the frequency range over which verification CWI TLECC measurements are to be made. The only formal guidance provided in the standard is the TLECC performance requirements, namely 0.1 A and 1E7 A/s for the peak and peak derivative of the time domain extrapolated response, respectively. The frequency domain measurements made in support of the TLECC process (field mapping and coupled currents) must thus be of sufficient number and density to support the extrapolation process. However, the actual frequency range or density is not defined. Therefore, there is some basis to perform TLECC measurements over the frequency range where EM energy in the free-field HEMP threat is primarily contained, and over the range where this energy can couple to interior cables and wires. For example, a range of 1 MHz to 500 MHz might be reasonable (and, in fact, the start and stop frequencies shown in Figure C.2 "CW immersion test record" of MIL-STD-188-125-1A are 1 MHz and 100 MHz, respectively).

Note that MIL-HDBK-423 does provide some guidance in Section 16.3.3.3.1 "Principles of cw immersion testing." As is stated in this section:

> Ideally, the number and spacing of test frequencies should be sufficient to resolve any resonances in the response of the system being tested. Fortunately, ground-based facilities are generally not highly resonant structures. Thus, facility responses can be expected to vary relatively slowly with frequency. For a system with a quality factor of 10, the response transfer function will vary only moderately over a 10 MHz interval at 100 MHz. Since quality factors as high as 30 are very rare, several tens of test points per decade of frequency will ordinarily be sufficient to resolve facility response transfer functions.

In addition, the extrapolation process involves both forward and inverse fast-Fourier transforms (FFTs). FFT algorithms require inputs and produce results with time and frequency points which are linearly spaced. Thus, linearly spaced frequency points may be desirable for TLECC measurements although this can result in a large overall number of points. Obviously additional and innovative investigation into the selection of frequencies to be used for MIL-STD-188-125-1 verification CWI TLECC measurements is needed. Given that such investigation is yet to be performed, a conservative set (in terms of the total number) of measurement frequencies for the MIL-STD-188-125-1A CWI TLECC measurements is recommended.

Such a set is given in Table 1 which is based on a frequency spacing corresponding to a Q of approximately 86, which is quite conservative. This results in a constant ratio of approximately 1.011579 between subsequent frequency points (i.e., f_{n+1} / f_n = 1.0111579), for a sub-total of approximately 200 frequency points per decade, or a total of approximately 800 frequency points across the entire 100 kHz to 1 GHz band. The frequency list given in Table 1 will suffice for all measurements (for both CWI SE and coupled currents) to be performed during this effort.

The list in Table 1 is provided as a starting point for the frequency authorization process. Frequencies can be moved, deleted, or added to accommodate local restrictions and keep-outs as required. Frequencies within the FAA, AFTCC, and DOD specific bands are pre-notched in the testing software suite but left in the overall list if the testing location is not located within the active use of those bands. Additionally, due to the nature and scheduling of this testing, these bands are notched out due to the time required to coordinate with the FAA, AFTCC, and DOD. The objective, however, is to maintain—to the extent possible—the minimum number of approximately equally spaced (in the log frequency domain) measurement frequencies over each decade.

For frequencies that require special protections, the testing location is in an industrial area with rural areas surrounding the industrial area, which has 40 to 50-foot trees located within 100-meters to the east and southwest. Two, three-story warehouse type buildings directly west and northwest, and one three-story office building 150-meters to the southeast. As well as farmland for 500-meters to the north and 700-meters to south. The transmitting antenna will primarily located outdoors, however, the transmitter will be pointed into 12-inch reinforced concrete walls lined 3/4-in plate steel, from a distance of 40-meters when transmitting and when not in operation. When transmitting, the frequencies are tested at 30 milliseconds intervals which would also further limit any impact to public safety operations. The Stop Buzzer contact for this testing is Tyler Wallner and his cell # is (719) 494-6923.

Table 1. Generic MIL-STD-188-125-1 verification measurement frequency list.

1	1.000000E+05	81	2.511886E+05	161	6.309573E+05	241	1.584893E+06	321	3.981072E+06	401	1.000000E+07	481	2.511886E+07	561	6.309573E+07	641	1.584893E+08	721	3.981072E+08
2	1.011579E+05	82	2.540973E+05	162	6.382635E+05	242	1.603245E+06	322	4.027170E+06	402	1.011579E+07	482	2.540973E+07	562	6.382635E+07	642	1.603245E+08	722	4.027170E+08
3	1.023293E+05	83	2.570396E+05	163	6.456542E+05	243	1.621810E+06	323	4.073803E+06	403	1.023293E+07	483	2.570396E+07	563	6.456542E+07	643	1.621810E+08	723	4.073803E+08
4	1.035142E+05	84	2.600160E+05	164	6.531306E+05	244	1.640590E+06	324	4.120975E+06	404	1.035142E+07	484	2.600160E+07	564	6.531306E+07	644	1.640590E+08	724	4.120975E+08
5	1.047129E+05	85	2.630268E+05	165	6.606934E+05	245	1.659587E+06	325	4.168694E+06	405	1.047129E+07	485	2.630268E+07	565	6.606934E+07	645	1.659587E+08	725	4.168694E+08
6	1.059254E+05	86	2.660725E+05	166	6.683439E+05	246	1.678804E+06	326	4.216965E+06	406	1.059254E+07	486	2.660725E+07	566	6.683439E+07	646	1.678804E+08	726	4.216965E+08
7	1.071519E+05	87	2.691535E+05	167	6.760830E+05	247	1.698244E+06	327	4.265795E+06	407	1.071519E+07	487	2.691535E+07	567	6.760830E+07	647	1.698244E+08	727	4.265795E+08
8	1.083927E+05	88	2.722701E+05	168	6.839116E+05	248	1.717908E+06	328	4.315191E+06	408	1.083927E+07	488	2.722701E+07	568	6.839116E+07	648	1.717908E+08	728	4.315191E+08
9	1.096478E+05	89	2.754229E+05	169	6.918310E+05	249	1.737801E+06	329	4.365158E+06	409	1.096478E+07	489	2.754229E+07	569	6.918310E+07	649	1.737801E+08	729	4.365158E+08
10	1.109175E+05	90	2.786121E+05	170	6.998420E+05	250	1.757924E+06	330	4.415704E+06	410	1.109175E+07	490	2.786121E+07	570	6.998420E+07	650	1.757924E+08	730	4.415704E+08
11	1.122018E+05	91	2.818383E+05	171	7.079458E+05	251	1.778279E+06	331	4.466836E+06	411	1.122018E+07	491	2.818383E+07	571	7.079458E+07	651	1.778279E+08	731	4.466836E+08
12	1.135011E+05	92	2.851018E+05	172	7.161434E+05	252	1.798871E+06	332	4.518559E+06	412	1.135011E+07	492	2.851018E+07	572	7.161434E+07	652	1.798871E+08	732	4.518559E+08
13	1.148154E+05	93	2.884032E+05	173	7.244360E+05	253	1.819701E+06	333	4.570882E+06	413	1.148154E+07	493	2.884032E+07	573	7.244360E+07	653	1.819701E+08	733	4.570882E+08
14	1.161449E+05	94	2.917427E+05	174	7.328245E+05	254	1.840772E+06	334	4.623810E+06	414	1.161449E+07	494	2.917427E+07	574	7.328245E+07	654	1.840772E+08	734	4.623810E+08
15	1.174898E+05	95	2.951209E+05	175	7.413102E+05	255	1.862087E+06	335	4.677351E+06	415	1.174898E+07	495	2.951209E+07	575	7.413102E+07	655	1.862087E+08	735	4.677351E+08
16	1.188502E+05	96	2.985383E+05	176	7.498942E+05	256	1.883649E+06	336	4.731513E+06	416	1.188502E+07	496	2.985383E+07	576	7.498942E+07	656	1.883649E+08	736	4.731513E+08
17	1.202264E+05	97	3.019952E+05	177	7.585776E+05	257	1.905461E+06	337	4.786301E+06	417	1.202264E+07	497	3.019952E+07	577	7.585776E+07	657	1.905461E+08	737	4.786301E+08
18	1.216186E+05	98	3.054921E+05	178	7.673615E+05	258	1.927525E+06	338	4.841724E+06	418	1.216186E+07	498	3.054921E+07	578	7.673615E+07	658	1.927525E+08	738	4.841724E+08
19	1.230269E+05	99	3.090295E+05	179	7.762471E+05	259	1.949845E+06	339	4.897788E+06	419	1.230269E+07	499	3.090295E+07	579	7.762471E+07	659	1.949845E+08	739	4.897788E+08
20	1.244515E+05	100	3.126079E+05	180	7.852356E+05	260	1.972423E+06	340	4.954502E+06	420	1.244515E+07	500	3.126079E+07	580	7.852356E+07	660	1.972423E+08	740	4.954502E+08
21	1.258925E+05	101	3.162278E+05	181	7.943282E+05	261	1.995262E+06	341	5.011872E+06	421	1.258925E+07	501	3.162278E+07	581	7.943282E+07	661	1.995262E+08	741	5.011872E+08
22	1.273503E+05	102	3.198895E+05	182	8.035261E+05	262	2.018366E+06	342	5.069907E+06	422	1.273503E+07	502	3.198895E+07	582	8.035261E+07	662	2.018366E+08	742	5.069907E+08
23	1.288250E+05	103	3.235937E+05	183	8.128305E+05	263	2.041738E+06	343	5.128614E+06	423	1.288250E+07	503	3.235937E+07	583	8.128305E+07	663	2.041738E+08	743	5.128614E+08
24	1.303167E+05	104	3.273407E+05	184	8.222426E+05	264	2.065380E+06	344	5.188000E+06	424	1.303167E+07	504	3.273407E+07	584	8.222426E+07	664	2.065380E+08	744	5.188000E+08
25	1.318257E+05	105	3.311311E+05	185	8.317638E+05	265	2.089296E+06	345	5.248075E+06	425	1.318257E+07	505	3.311311E+07	585	8.317638E+07	665	2.089296E+08	745	5.248075E+08
26	1.333521E+05	106	3.349654E+05	186	8.413951E+05	266	2.113489E+06	346	5.308844E+06	426	1.333521E+07	506	3.349654E+07	586	8.413951E+07	666	2.113489E+08	746	5.308844E+08
27	1.348963E+05	107	3.388442E+05	187	8.511380E+05	267	2.137962E+06	347	5.370318E+06	427	1.348963E+07	507	3.388442E+07	587	8.511380E+07	667	2.137962E+08	747	5.370318E+08
28	1.364583E+05	108	3.427678E+05	188	8.609938E+05	268	2.162719E+06	348	5.432503E+06	428	1.364583E+07	508	3.427678E+07	588	8.609938E+07	668	2.162719E+08	748	5.432503E+08
29	1.380384E+05	109	3.467369E+05	189	8.709636E+05	269	2.187762E+06	349	5.495409E+06	429	1.380384E+07	509	3.467369E+07	589	8.709636E+07	669	2.187762E+08	749	5.495409E+08
30	1.396368E+05	110	3.507519E+05	190	8.810489E+05	270	2.213095E+06	350	5.559043E+06	430	1.396368E+07	510	3.507519E+07	590	8.810489E+07	670	2.213095E+08	750	5.559043E+08
31	1.412538E+05	111	3.548134E+05	191	8.912509E+05	271	2.238721E+06	351	5.623413E+06	431	1.412538E+07	511	3.548134E+07	591	8.912509E+07	671	2.238721E+08	751	5.623413E+08
32	1.428894E+05	112	3.589219E+05	192	9.015711E+05	272	2.264644E+06	352	5.688529E+06	432	1.428894E+07	512	3.589219E+07	592	9.015711E+07	672	2.264644E+08	752	5.688529E+08
33	1.445440E+05	113	3.630781E+05	193	9.120108E+05	273	2.290868E+06	353	5.754399E+06	433	1.445440E+07	513	3.630781E+07	593	9.120108E+07	673	2.290868E+08	753	5.754399E+08
34	1.462177E+05	114	3.672823E+05	194	9.225714E+05	274	2.317395E+06	354	5.821032E+06	434	1.462177E+07	514	3.672823E+07	594	9.225714E+07	674	2.317395E+08	754	5.821032E+08
35	1.479108E+05	115	3.715352E+05	195	9.332543E+05	275	2.344229E+06	355	5.888437E+06	435	1.479108E+07	515	3.715352E+07	595	9.332543E+07	675	2.344229E+08	755	5.888437E+08
36	1.496236E+05	116	3.758374E+05	196	9.440609E+05	276	2.371374E+06	356	5.956621E+06	436	1.496236E+07	516	3.758374E+07	596	9.440609E+07	676	2.371374E+08	756	5.956621E+08
37	1.513561E+05	117	3.801894E+05	197	9.549926E+05	277	2.398833E+06	357	6.025596E+06	437	1.513561E+07	517	3.801894E+07	597	9.549926E+07	677	2.398833E+08	757	6.025596E+08
38	1.531087E+05	118	3.845918E+05	198	9.660509E+05	278	2.426610E+06	358	6.095369E+06	438	1.531087E+07	518	3.845918E+07	598	9.660509E+07	678	2.426610E+08	758	6.095369E+08
39	1.548817E+05	119	3.890451E+05	199	9.772372E+05	279	2.454709E+06	359	6.165950E+06	439	1.548817E+07	519	3.890451E+07	599	9.772372E+07	679	2.454709E+08	759	6.165950E+08
40	1.566751E+05	120	3.935501E+05	200	9.885531E+05	280	2.483133E+06	360	6.237348E+06	440	1.566751E+07	520	3.935501E+07	600	9.885531E+07	680	2.483133E+08	760	6.237348E+08
41	1.584893E+05	121	3.981072E+05	201	1.000000E+06	281	2.511886E+06	361	6.309573E+06	441	1.584893E+07	521	3.981072E+07	601	1.000000E+08	681	2.511886E+08	761	6.309573E+08
42	1.603245E+05	122	4.027170E+05	202	1.011579E+06	282	2.540973E+06	362	6.382635E+06	442	1.603245E+07	522	4.027170E+07	602	1.011579E+08	682	2.540973E+08	762	6.382635E+08
43	1.621810E+05	123	4.073803E+05	203	1.023293E+06	283	2.570396E+06	363	6.456542E+06	443	1.621810E+07	523	4.073803E+07	603	1.023293E+08	683	2.570396E+08	763	6.456542E+08
44	1.640590E+05	124	4.120975E+05	204	1.035142E+06	284	2.600160E+06	364	6.531306E+06	444	1.640590E+07	524	4.120975E+07	604	1.035142E+08	684	2.600160E+08	764	6.531306E+08
45	1.659587E+05	125	4.168694E+05	205	1.047129E+06	285	2.630268E+06	365	6.606934E+06	445	1.659587E+07	525	4.168694E+07	605	1.047129E+08	685	2.630268E+08	765	6.606934E+08
46	1.678804E+05	126	4.216965E+05	206	1.059254E+06	286	2.660725E+06	366	6.683439E+06	446	1.678804E+07	526	4.216965E+07	606	1.059254E+08	686	2.660725E+08	766	6.683439E+08
47	1.698244E+05	127	4.265795E+05	207	1.071519E+06	287	2.691535E+06	367	6.760830E+06	447	1.698244E+07	527	4.265795E+07	607	1.071519E+08	687	2.691535E+08	767	6.760830E+08
48	1.717908E+05	128	4.315191E+05	208	1.083927E+06	288	2.722701E+06	368	6.839116E+06	448	1.717908E+07	528	4.315191E+07	608	1.083927E+08	688	2.722701E+08	768	6.839116E+08
49	1.737801E+05	129	4.365158E+05	209	1.096478E+06	289	2.754229E+06	369	6.918310E+06	449	1.737801E+07	529	4.365158E+07	609	1.096478E+08	689	2.754229E+08	769	6.918310E+08
50	1.757924E+05	130	4.415704E+05	210	1.109175E+06	290	2.786121E+06	370	6.998420E+06	450	1.757924E+07	530	4.415704E+07	610	1.109175E+08	690	2.786121E+08	770	6.998420E+08
51	1.778279E+05	131	4.466836E+05	211	1.122018E+06	291	2.818383E+06	371	7.079458E+06	451	1.778279E+07	531	4.466836E+07	611	1.122018E+08	691	2.818383E+08	771	7.079458E+08
52	1.798871E+05	132	4.518559E+05	212	1.135011E+06	292	2.851018E+06	372	7.161434E+06	452	1.798871E+07	532	4.518559E+07	612	1.135011E+08	692	2.851018E+08	772	7.161434E+08
53	1.819701E+05	133	4.570882E+05	213	1.148154E+06	293	2.884032E+06	373	7.244360E+06	453	1.819701E+07	533	4.570882E+07	613	1.148154E+08	693	2.884032E+08	773	7.244360E+08
54	1.840772E+05	134	4.623810E+05	214	1.161449E+06	294	2.917427E+06	374	7.328245E+06	454	1.840772E+07	534	4.623810E+07	614	1.161449E+08	694	2.917427E+08	774	7.328245E+08
55	1.862087E+05	135	4.677351E+05	215	1.174898E+06	295	2.951209E+06	375	7.413102E+06	455	1.862087E+07	535	4.677351E+07	615	1.174898E+08	695	2.951209E+08	775	7.413102E+08
56	1.883649E+05	136	4.731513E+05	216	1.188502E+06	296	2.985383E+06	376	7.498942E+06	456	1.883649E+07	536	4.731513E+07	616	1.188502E+08	696	2.985383E+08	776	7.498942E+08
57	1.905461E+05	137	4.786301E+05	217	1.202264E+06	297	3.019952E+06	377	7.585776E+06	457	1.905461E+07	537	4.786301E+07	617	1.202264E+08	697	3.019952E+08	777	7.585776E+08
58	1.927525E+05	138	4.841724E+05	218	1.216186E+06	298	3.054921E+06	378	7.673615E+06	458	1.927525E+07	538	4.841724E+07	618	1.216186E+08	698	3.054921E+08	778	7.673615E+08
59	1.949845E+05	139	4.897788E+05	219	1.230269E+06	299	3.090295E+06	379	7.762471E+06	459	1.949845E+07	539	4.897788E+07	619	1.230269E+08	699	3.090295E+08	779	7.762471E+08
60	1.972423E+05	140	4.954502E+05	220	1.244515E+06	300	3.126079E+06	380	7.852356E+06	460	1.972423E+07	540	4.954502E+07	620	1.244515E+08	700	3.126079E+08	780	7.852356E+08
61	1.995262E+05	141	5.011872E+05	221	1.258925E+06	301	3.162278E+06	381	7.943282E+06	461	1.995262E+07	541	5.011872E+07	621	1.258925E+08	701	3.162278E+08	781	7.943282E+08
62	2.018366E+05	142	5.069907E+05	222	1.273503E+06	302	3.198895E+06	382	8.035261E+06	462	2.018366E+07	542	5.069907E+07	622	1.273503E+08	702	3.198895E+08	782	8.035261E+08
63	2.041738E+05	143	5.128614E+05	223	1.288250E+06	303	3.235937E+06	383	8.128305E+06	463	2.041738E+07	543	5.128614E+07	623	1.288250E+08	703	3.235937E+08	783	8.128305E+08
64	2.065380E+05	144	5.188000E+05	224	1.303167E+06	304	3.273407E+06	384	8.222426E+06	464	2.065380E+07	544	5.188000E+07	624	1.303167E+08	704	3.273407E+08	784	8.222426E+08
65	2.089296E+05	145	5.248075E+05	225	1.318257E+06	305	3.311311E+06	385	8.317638E+06	465	2.089296E+07	545	5.248075E+07	625	1.318257E+08	705	3.311311E+08	785	8.317638E+08
66	2.113489E+05	146	5.308844E+05	226	1.333521E+06	306	3.349654E+06	386	8.413951E+06	466	2.113489E+07	546	5.308844E+07	626	1.333521E+08	706	3.349654E+08	786	8.413951E+08
67	2.137962E+05	147	5.370318E+05	227	1.348963E+06	307	3.388442E+06	387	8.511380E+06	467	2.137962E+07	547	5.370318E+07	627	1.348963E+08	707	3.388442E+08	787	8.511380E+08
68	2.162719E+05	148	5.432503E+05	228	1.364583E+06	308	3.427678E+06	388	8.609938E+06	468	2.162719E+07	548	5.432503E+07	628	1.364583E+08	708	3.427678E+08	788	8.609938E+08
69	2.187762E+05	149	5.495409E+05	229	1.380384E+06	309	3.467369E+06	389	8.709636E+06	469	2.187762E+07	549	5.495409E+07	629	1.380384E+08	709	3.467369E+08	789	8.709636E+08
70	2.213095E+05	150	5.559043E+05	230	1.396368E+06	310	3.507519E+06	390	8.810489E+06	470	2.213095E+07	550	5.559043E+07	630	1.396368E+08	710	3.507519E+08	790	8.810489E+08
71	2.238721E+05	151	5.623413E+05	231	1.412538E+06	311	3.548134E+06	391	8.912509E+06	471	2.238721E+07	551	5.623413E+07	631	1.412538E+08	711	3.548134E+08	791	8.912509E+08
72	2.264644E+05	152	5.688529E+05	232	1.428894E+06	312	3.589219E+06	392	9.015711E+06	472	2.264644E+07	552	5.688529E+07	632	1.428894E+08	712	3.589219E+08	792	9.015711E+08
73	2.290868E+05	153	5.754399E+05	233	1.445440E+06	313	3.630781E+06	393	9.120108E+06	473	2.290868E+07	553	5.754399E+07	633	1.445440E+08	713	3.630781E+08	793	9.120108E+08
74	2.317395E+05	154	5.821032E+05	234	1.462177E+06	314	3.672823E+06	394	9.225714E+06	474	2.317395E+07	554	5.821032E+07	634	1.462177E+08	714	3.672823E+08	794	9.225714E+08
75	2.344229E+05	155	5.888437E+05	235	1.479108E+06	315	3.715352E+06	395	9.332543E+06	475	2.344229E+07	555	5.888437E+07	635	1.479108E+08	715	3.715352E+08	795	9.332543E+08
76	2.371374E+05	156	5.956621E+05	236	1.496236E+06	316	3.758374E+06	396	9.440609E+06	476	2.371374E+07	556	5.956621E+07	636	1.496236E+08	716	3.758374E+08	796	9.440609E+08
77	2.398833E+05	157	6.025596E+05	237	1.513561E+06	317	3.801894E+06	397	9.549926E+06	477	2.398833E+07	557	6.025596E+07	637	1.513561E+08	717	3.801894E+08	797	9.549926E+08
78	2.426610E+05	158	6.095369E+05	238	1.531087E+06	318	3.845918E+06	398	9.660509E+06	478	2.426610E+07	558	6.095369E+07	638	1.531087E+08	718	3.845918E+08	798	9.660509E+08
79	2.454709E+05	159	6.165950E+05	239	1.548817E+06	319	3.890451E+06	399	9.772372E+06	479	2.454709E+07	559	6.165950E+07	639	1.548817E+08	719	3.890451E+08	799	9.772372E+08
80	2.483133E+05	160	6.237348E+05	240	1.566751E+06	320	3.935501E+06	400	9.885531E+06	480	2.483133E+07	560	6.237348E+07	640	1.566751E+08	720	3.935501E+08	800	9.885531E+08

4.0 Testing Equipment and Procedures

The typical diagnostic equipment set-up and configuration for MIL-STD-188-125-1A verification CWI SE and TLECC measurements made using the Jaxon CWI measurement system is shown in Figure 5; a complete listing of the corresponding CWI equipment suite is provided in the following section.

As with acceptance SE testing, the heart of the Jaxon MIL-STD-188-125-1A verification CWI measurement system is an Agilent E5071C (or equivalent) network analyzer. At each frequency point in a measurement sweep the E5071C generates the RF signal to be transmitted. This signal is then sent by a zero-gain RF / fiber optic link to an RF power amplifier. Normally an Amplifier Research 10U1000 broad-band RF amplifier (rated at 10 W conducted output) is used for verification CWI measurements although other amplifiers (covering the 100 kHz to 1 GHz range) are possible. The amplified signal is then radiated by a hybrid transmit antenna positioned at a pre-determined "transmit antenna location" on the outside of and directed towards the surface of the EM barrier under test. Typically, the distance from the CWI transmit antenna zero point to a representative mid-point on the surface of the EM barrier under test closest to the TX antenna is approximately 40 m.

At select test points within the protected volume free field and surface current measurements are made using magnetic field probes (B-dot, large and small for low and high frequencies, respectively). In addition, the current coupled onto interior wires and cables by the leakage fields from the CWI transmit antenna are measured using broadband current probes. The measured signal (output of the magnetic field or current probe) is sent back is then sent back to the network analyzer using a high-performance RF / fiber optic link which can provide both attenuation (-50 dB) and gain (+50 dB) as required. The network analyzer then completes the measurement and reports the ratio (difference in dB power) of the outgoing (TX) and incoming (RX) signals.

A screen box (Faraday cage) is used to house the diagnostic equipment (RX side FO receiver, network analyzer) to provide maximum measurement flexibility as well as RF isolation from both the fields generated by transmit antenna and from any ambient RF signals that may be present. If necessary (such as at an active PAVE PAWS / BMEWS radar sites) a second screen box can be used to house the fiber optic receiver and RF amplifier on the transmit side of the measurement (located near the CWI TX antenna). Note that a 1 GHz low-pass filter is placed at the TX antenna input to ensure that there are no spurious emissions above 1 GHz.

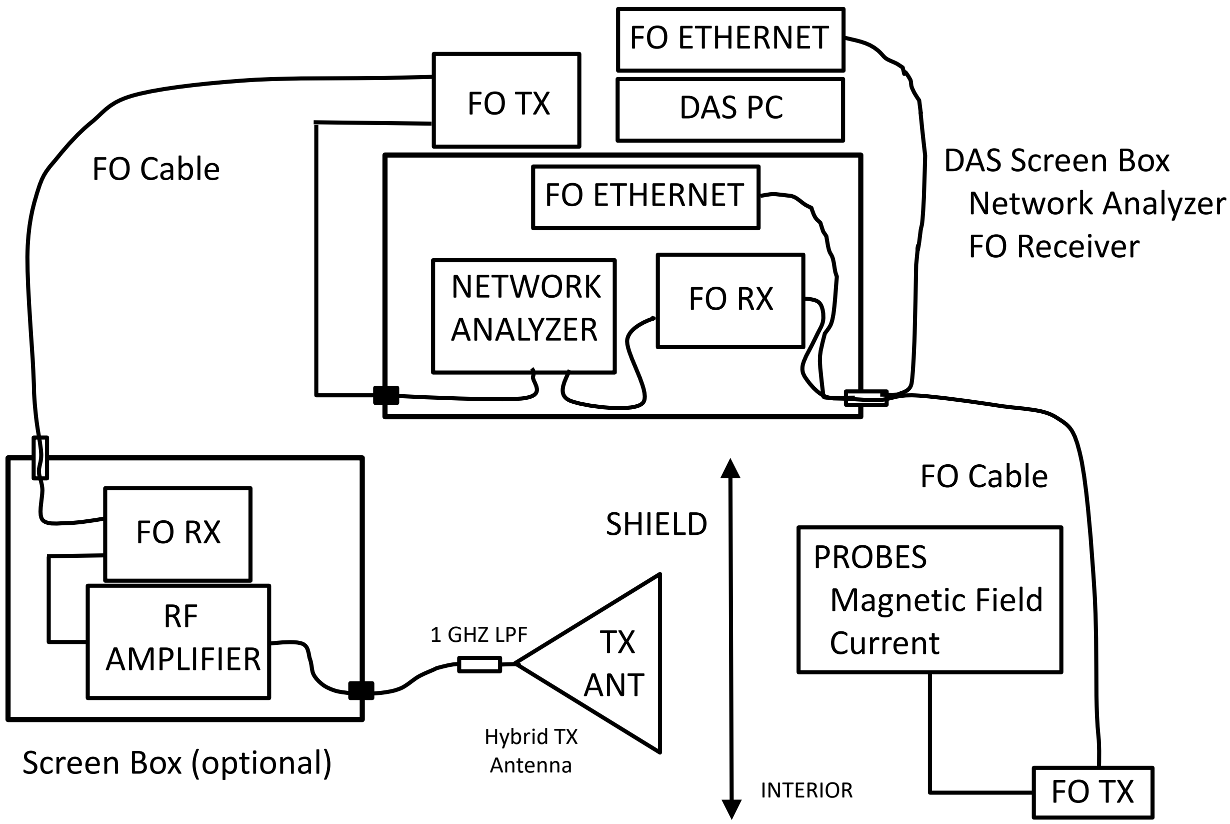


Figure 5. Jaxon MIL-STD-188-125-1A verification CWI test set-up.

The TX antenna used with the Jaxon CWI measurement system is a hybrid combination of a traditional broad-band log periodic (LP) with either a horizontal or vertical dipole added to the low-frequency end of the LP to provide some low frequency radiation. The LP is rated to operate over the 30 MHz – 1 GHz range. The horizontal or vertical dipole is resonant at a few MHz. All of these elements are mounted onto a platform which in turn is mounted to an extended reach forklift. The lift is capable of raising the hybrid antenna to at least 10 m and the platform can be tilted to obtain any desired angle of incidence. A view of the Jaxon hybrid CWI antenna system is shown in Figure 6; in this photo the antenna is in the horizontal polarization.

Figure 6. Jaxon verification CWI transmit antenna system.

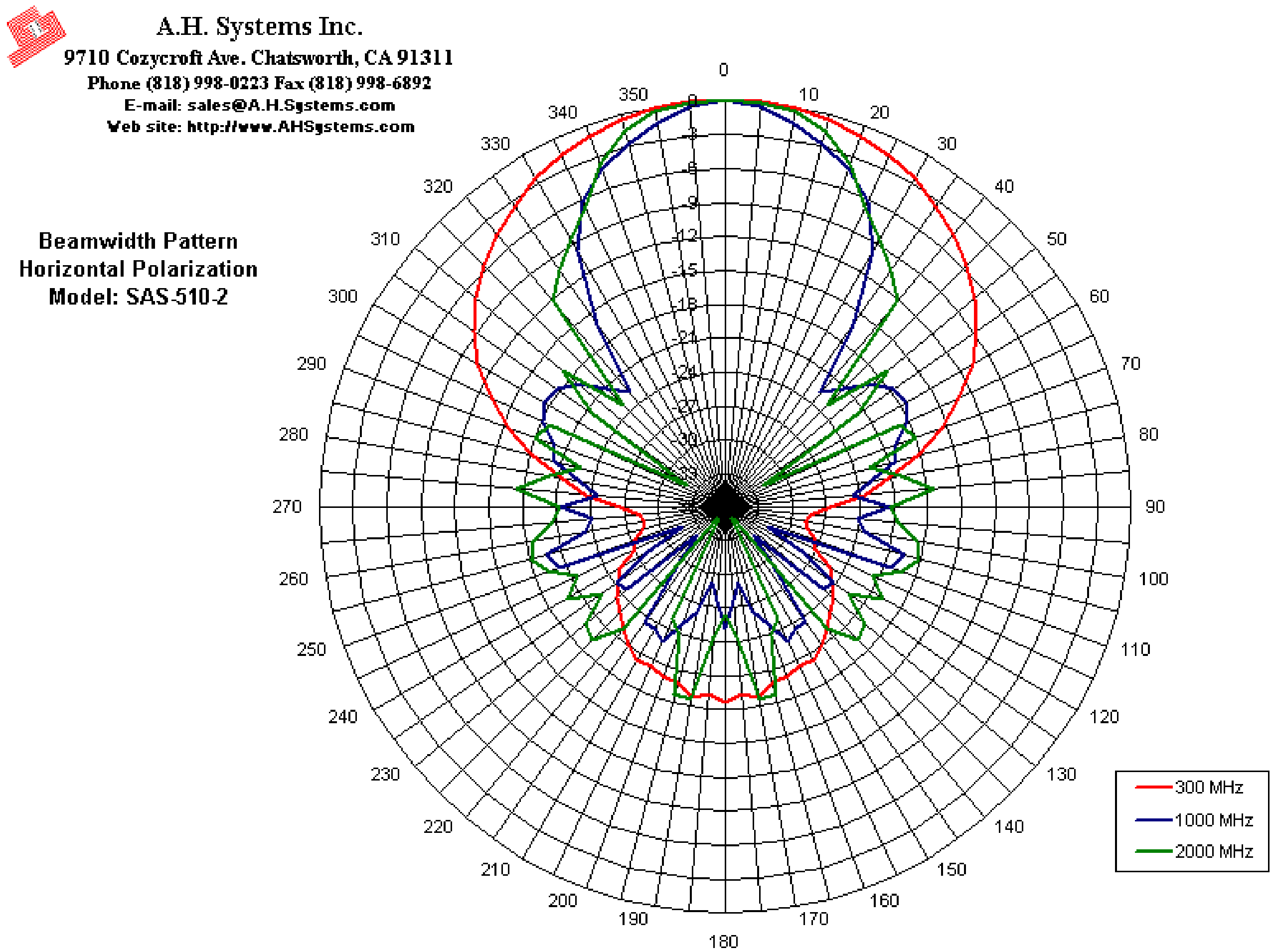
4.1 Jaxon MIL-STD-188-125-1A Verification Test Equipment

The typical list of equipment used in the Jaxon MIL-STD-188-125-1 verification CWI measurement system is provided in Table 2.

Table 2. JEM MIL-STD-188-125-1 verification CWI test equipment list.

Description	Function	Manufacturer and Model
Network Analyzer	RF source and measurement	Agilent E50171C (or EQ)
Broadband RF - Fiber link	non-conductive signal path; signal attenuation and gain	EG&G, JAXON EM
RF Broadband Power Amplifier	Increase amplitude of transmitted signal	Amplifier Research, JAXON EM
Hybrid CWI Antenna	Illuminate facility under test	Cobham + Custom Extensions
Field Probes	Measure electric and magnetic fields	Prodyn and JEM custom
Current Probes	Measure coupled currents	Prodyn I-125-1HF, I-262
Sniffers	Isolate RF leaks	JAXON EM
DAS Computer	Data Acquisition and Storage laptop PC	Dell (or eq)
GPIB IO	DAS GPIB interface to oscilloscopes	National Instruments
Data Acquisition SW	Acquire and save scope traces on DAS PC	JAXON EM
Data Reduction SW	Process raw test data and generate data plots	JAXON EM; EasyPlot
Coaxial cables and connectors	various	various
FO Communications	Communications from insde to outside of test article	Owl Hoots (OR EQ)
Screen Box	Shielded enclosure for network analyzer and EG&G FO RX	JAXON EM
Screen Box	Shielded enclosure for TX side FO RX and RF amplifer	JAXON EM

4.1.1 CWI Transmit Antenna Engineering Drawing and Specs:



ANTENNA EXPERTS

E-mail: info@antennaexperts.in Website: www.antennaexperts.in

Model LP-100-1000	100-1000MHz	9 dBi Gain

HIGH GAIN LOG PERIODIC ANTENNA

Design Features: The LP-100-1000 log periodic dipole antenna use 6063T6 ultra corrosion resistant architectural anodized aluminum alloy and designed to provide wideband directional transmission/reception of radio signals from 100-1000 MHz bands. The specially designed mounting arrangement results in fast installation. The extra spacers are used between the support booms to improve mechanical durability of antenna. This log periodic dipole antenna system is particular suitable for transmission, reception, monitoring, surveillance, scanning and jamming applications due to its broad band design feature. This high gain LPA provides strong performance over the entire frequency of 100-1000 MHz as the LPDA does not use loading technique to reduce the overall size of array. The high gain log periodic antenna can be assembled in less than 5 minutes by 2 technicians. Antenna is supplied with rear end mounting. The antenna can also be supplied with mounting at center of gravity on request.

Constructions: The LP-100-1000 assembled log periodic antennas outer-most dimensions are 1.8 meters (71 Inches) long and 1.5 meters (60 Inches) wide. The antenna has foldable elements, the longest of which is 0.75 meter. All the elements are supplied in two segments for easy of shipping and handling. The elements are attached via a stainless steel stud system which is fixed at each element end for attaching the same on the corresponding marked position on support boom. The log periodic antenna operates at D.C. ground with low resistance discharge path for protection against lightning and immunity to noise. The complete antenna is supplied with epoxy based powder coating finish to protect it further from severe environmental conditions All the screws, nuts and bolts of high gain log periodic dipole antenna are made of type 316 marine grade stainless steel. The LP Antenna is supplied with olive green military colour finish. The mounting arrangement of log periodic antenna permits to change the polarization from horizontal to vertical and vice-versa.

Electrical Specifications:	
Frequency Range	100-1000MHz
Gain	9 dBi
Bandwidth	100-1000MHz
Polarization	Vertical or Horizontal
Input Impedance	50 Ohms
Radiation Pattern	Directional
Horizontal Beamwidth -Half Power Points	90 +/-10 Degrees Typical
Vertical Beamwidth -Half Power Points	65 +/-10 Degrees Typical
Front to Back Ratio	18 +/-2 dB. Typical
VSWR - Equal To or Better Then	2.5:1
RF Power Handling Capacity	250 Watts CW
Input Termination	N-Female
Lightning Protection	Direct Ground

Mechanical Specifications:	
Antenna Materials	6063T6 Aluminum Alloy
Mounting Hardware -Materials	Marine Grade Stainless Steel
Wind Rating	200 Km/Hr.
Overall Length	1.8 Meters (71 Inches)
Shipping Length	1.9 Meters (75 Inches)
Support Boom - Material - O.D.	6063T6 Aluminum Alloy Square Tube
Elements - Materials - Cross Section - Outer Diameter	6063T6 Aluminum Alloy Round Tube
Mounting Clamps Position	At Rear End of Boom
Maximum Mount Pipe Diameter	52 mm (2 Inches)
Gross Weight	5 Kgs.

Environmental Specifications:	
Operating Temperature	(-) 30 to +70 Degrees Celsius
Storage Temperature	(-) 40 to +80 Degrees Celsius
Humidity	0 to 95% RH

Verification CWI Transmit Antenna Locations

For the MIL-STD-188-125-1A verification CWI testing of the site the CWI transmit antenna will be positioned within the facility compound at four locations around the periphery of the building; the distance from the CWI antenna "zero" point to central point on the nearest surface of the protected volume under test will be approximately 40 m. The exact CWI transmit antenna positions will be determined at the time of the test and will depend primarily on access and the ability to park the extended reach forklift where needed. As noted, because of site access limitations SE will be performed in lieu of CWI on the facility west wall. Potential CWI transmit antenna locations for the MIL-STD-188-125-1A verification CWI test are shown in Figure 7. In this figure, the distance between the TX antenna zero point and the mid-point of the nearest EM barrier wall is approximately 40 m.

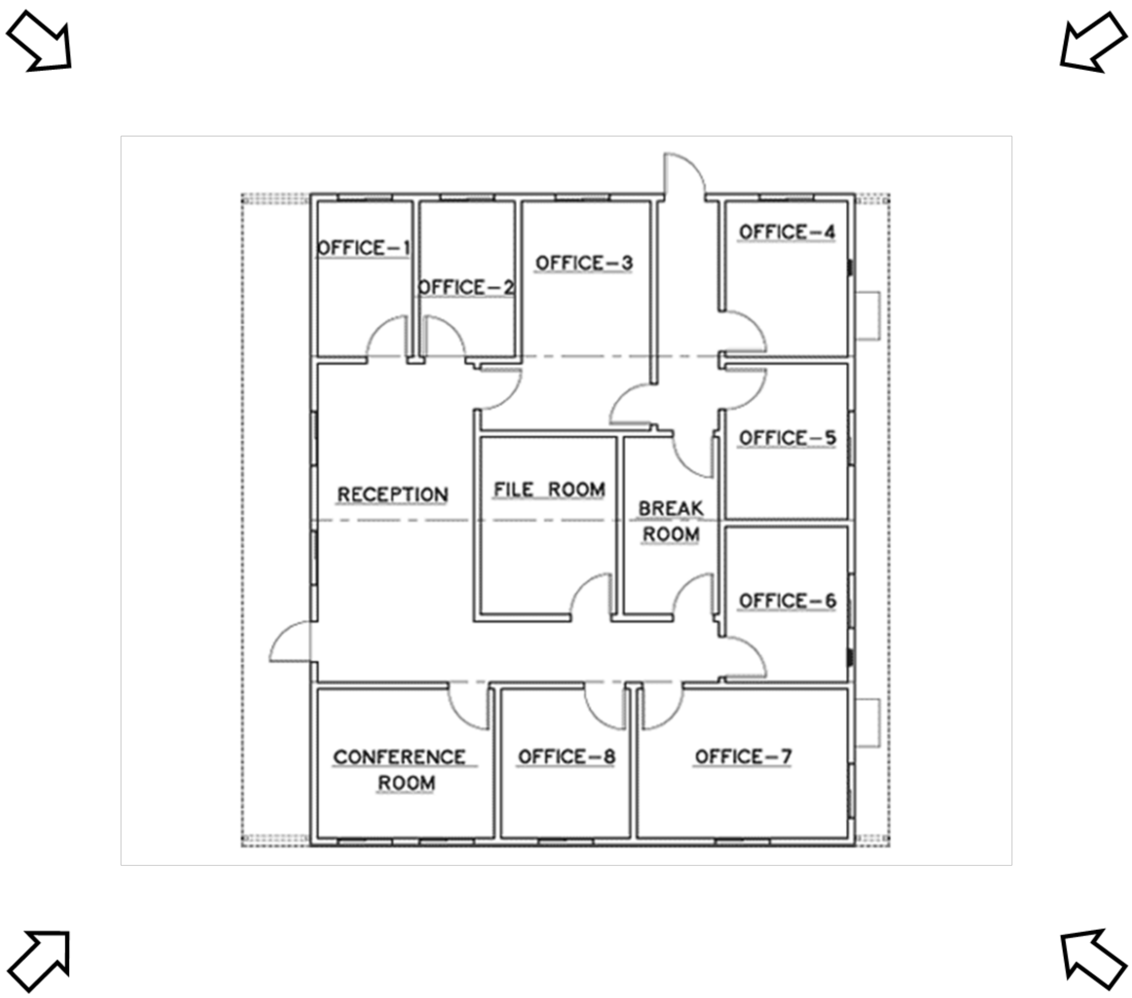


Figure 7. Potential CWI transmit antenna locations.

4.2 CWI Test System Calibration and Field Mapping

The EM fields produced by the Jaxon MIL-STD-188-125 verification CWI hybrid antenna will be mapped at the start of this MIL-STD-188-125-1A verification CWI test. This mapping will be performed in a clear area (to the extent possible around the site. The fields produced by the antenna in both horizontal and vertical orientations will be mapped at ranges of 40 m and other distances based on the achievable antenna-to-facility ranges determined during the test effort. The principal components of both the electric and magnetic illuminating fields will be mapped at a height of 1 m; these fields will be mapped at other heights if necessary.

Typical principal magnetic field mapping results for horizontal and vertical orientations of the JEM CWI hybrid transmit antenna are shown in Figure 8 and Figure 9 The results given in Figure 8 are the raw (but corrected for diagnostic system gain) measurements of the principal magnetic field component of the illuminating field. That is, for the case where the CWI transmit antenna is horizontally polarized, the vertical (Bz) component of the magnetic field is dominant and is measured. Conversely, when the CWI transmit antenna is vertically polarized, the horizontal (By) component of the magnetic field is dominant and is measured. For either case, the field map measurements will be made at a height of 1 m and at ranges to be determined at the time of the test, as well as 40 m, from the CWI antenna zero point. This geometry will be used during post-test analysis of the CWI coupled current measurements to generate a total illuminating threat waveform consisting of incident field incident and ground-reflected components.

MIL-STD-188-125-1A provides guidelines for the suggested (“should be” and “as a design objective”) field strengths of the principal component of the illuminating field (PDIF) produced by the CWI transmit antenna as measured during field mapping. These are:

“SHOULD”	“DESIGN OBJECTIVE”	Frequency Range
	0.1 V/m	100 kHz – 1 MHz
1 V/M		1 MHz – 50 MHz
0.1 V/m		50 MHz – 100 MHz
	0.01 V/m	100 MHz – 1 GHz

Note that these “should” and “design objective” field strengths of the PCIF are goals and not absolute requirements. The actual field strengths achieved by the JEM CWI measurement system during this present effort will be limited by the maximum conducted power permitted by the GFE frequency authorization provided for this test effort.

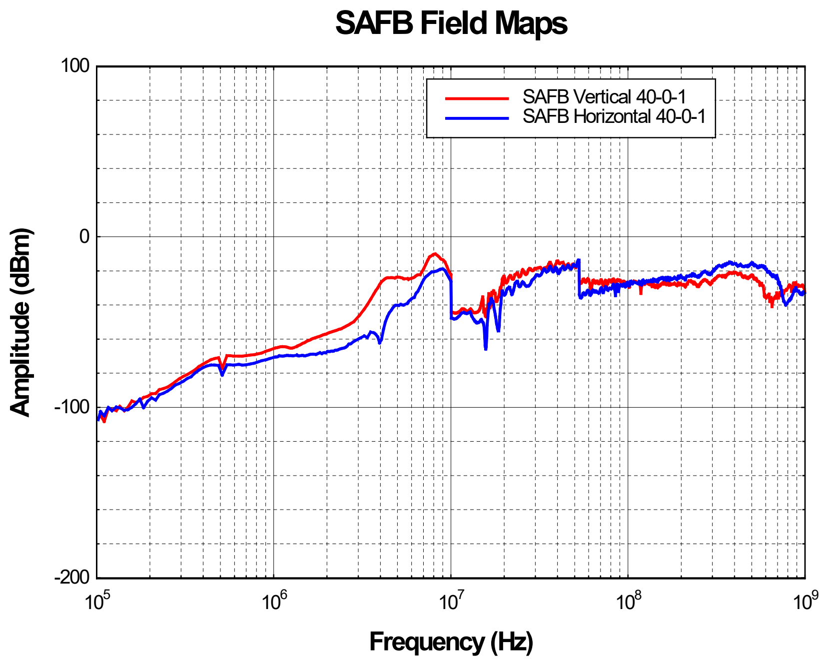


Figure 8. Raw field dominant components at (40, 0, 1).

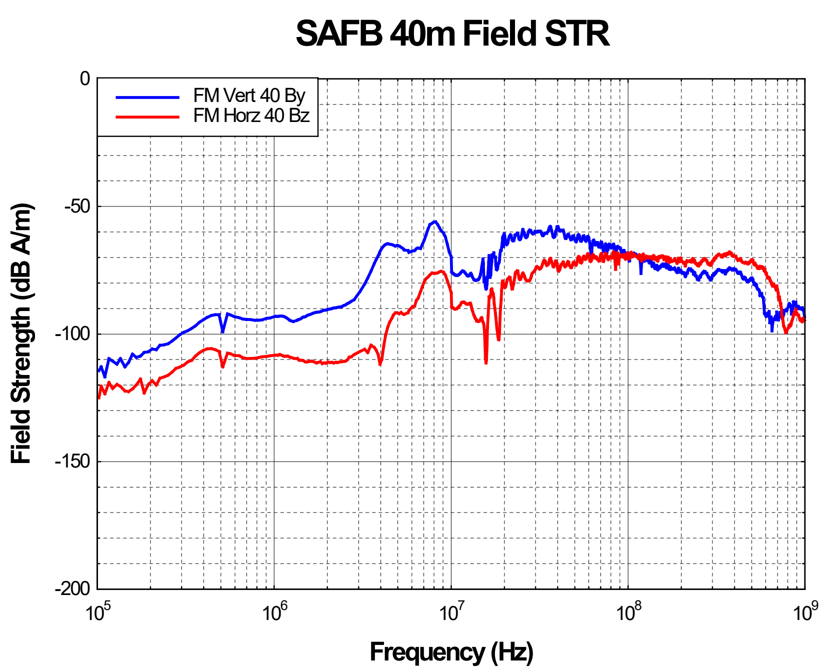


Figure 9. Field strengths of dominant field components at (40, 0, 1).

A raw calibration result for the horizontal CWI SE field mapping measurement is shown in Figure 10. To obtain a CWI SE result, the field (or surface) measurement at a test point is compared to (subtracted from) the calibration curve. The ambient noise measurement at the test point is similarly processed to obtain the measurement range, which represents the maximum SE that can be measured for the SE calibration and test point noise measurements. Measurements can also be taken to show the maximum SE the diagnostic system is capable of characterizing; this is done by removing all inputs to the diagnostic system (FO transmitter) and then processing the resultant “FTN” (fiber terminated noise) trace in the same manner.

Figure 11 demonstrates typical CWI SE measurement range results at a generic test point. The blue curve in Figure 11 represents the maximum SE that can be measured at the test point given the ambient RF noise conditions. The red curve represents the maximum SE that the diagnostic system is capable of measuring in the absence of ambient RF noise (but accounting for coupling of RF produced by the CWI transmit antenna to the measurement equipment if not appropriately shielded).

At lower frequencies, (below ~5 MHz), the hybrid CWI antenna is not particularly effective as the length of the antenna low-frequency monopole or dipole elements become much shorter than a wavelength. In addition, as a short dipole the antenna is a very inefficient radiator of magnetic fields. This makes the generation of an incident EM field of any significant field strength impractical. This dynamic range limitation coupled with the active system ambient noise results in an SE measurement that typically falls below the CWI SE performance requirements given in MIL-STD-188-125 (the purple curve in Figure 11) at the lower (magnetic field) measurement frequencies, generally below a few MHz. This is true even for the ideal conditions where there is no ambient noise (the “FTN” result).

The inability to measure the required levels of shielding effectiveness at the lower measurement frequencies is recognized by MIL-STD-188-125-1A. All MIL-STD-188-125-1A verification CWI measurement systems which operate at reasonable RF power levels (10 W or less conducted output power to the transmit antenna) and which are limited by reasonable transmit antenna dimensions will suffer this limitation. A high ambient RF noise level at the test point further exacerbates this limitation.

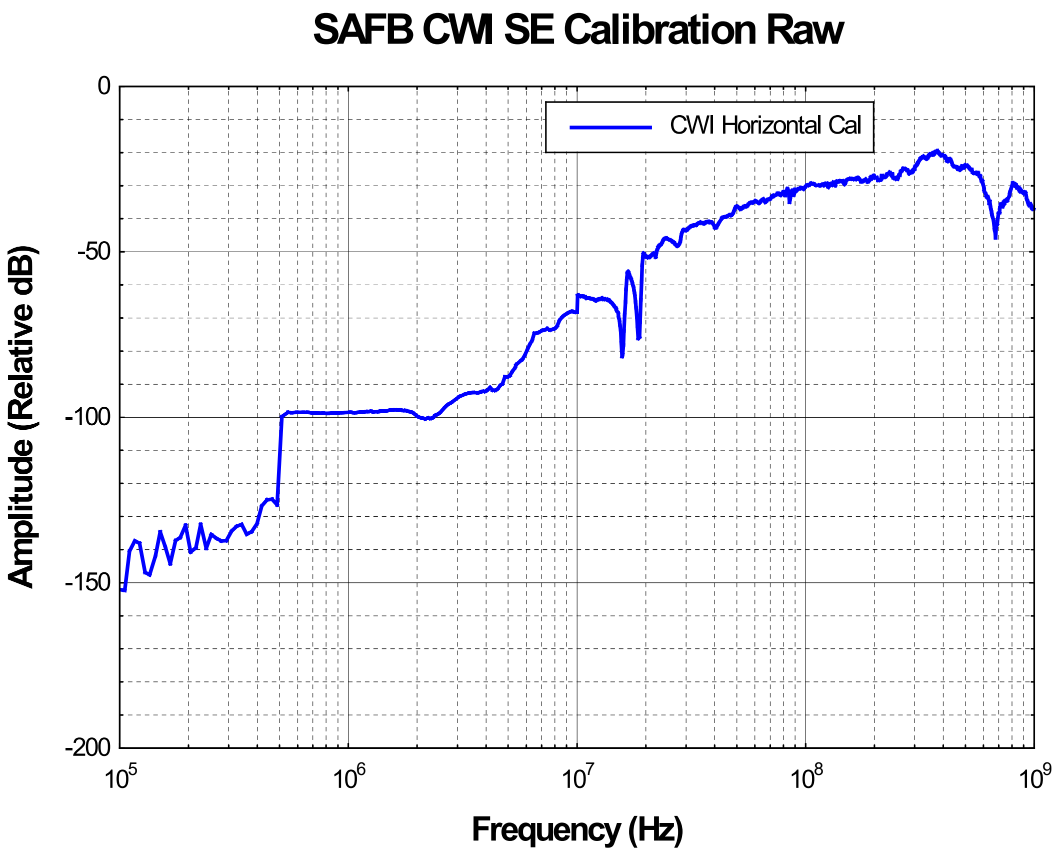


Figure 10. CWI SE raw horizontal calibration result.

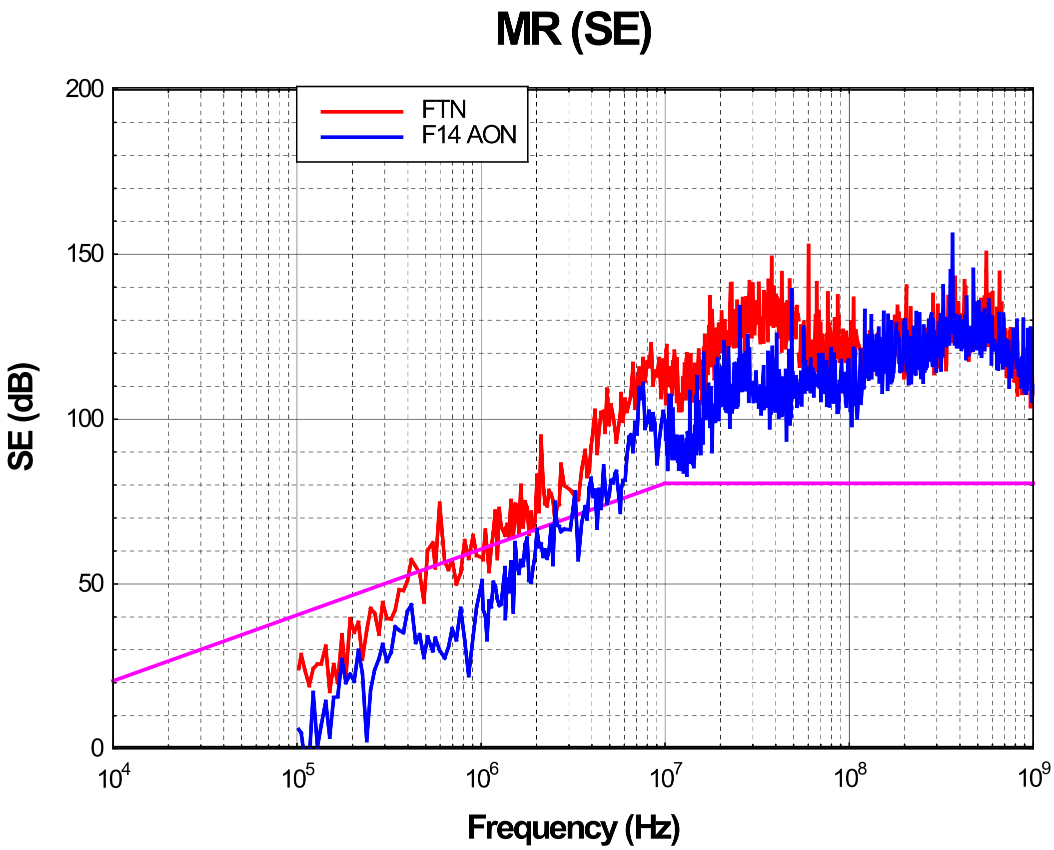


Figure 11. Typical horizontal CWI SE measurement ranges (AON and FTN).

4.3 CWI Measurement Procedure

The overall measurement procedure that will be followed during this MIL-STD-188-125-1A verification CWI-based EM barrier characterization test is as follows:

1) Conduct Safety briefing. Lead engineer or test director will conduct a safety briefing for personnel (site and test personnel) involved in the CWI measurement sequences.
2) Ensure CWI frequency lists used by JEM software is configured properly (for this specific test).
3) Define CWI transmit locations. Measure the distance to the facility under test for each CWI transmit antenna position. Antenna height will be 10 m for all CWI measurements.
4) CWI test system setup and free field calibration. Perform field mapping of CWI antenna in area relatively free of EM reflectors. Mapping will be performed at the antenna (zero

point) to field point distances determined in Step 3, with the field probes at a height of 1 m (nominally 40 m).

5) Collect field map data from each field probe at each test distance for both vertical and horizontal polarizations of CWI antenna. For each measurement position (range, height, offset) collect field map data using low and then high frequency magnetic and electric field probes. Collect data in all axes (x, y, z). Record all relevant information in test logbook.

6) Mark CWI test points inside EM barrier (coupled currents and free fields). Record in test logbook and, if possible, document with photographs.

7) Set up transmit CWI antennas at first transmit location (TL) in horizontal polarization.

8) Perform measurements at selected coupled currents, free field, and surface current test points. Two sweeps are typically required for each point (low and high frequencies); free field measurements are made with magnetic field probe in three orientations (x, y, z); surface current measurements are made with magnetic field probe in two orientations (typically x or y, z). Evaluate degree of leakage and isolate any significant barrier defects. Record and document in test logbook. If necessary, localize leakage (using sniffing techniques) and determine if repairs are required.

9) Repeat for vertical polarization.

10) Repeat steps 8 and 9 for remaining transmit antenna locations.

11) At the discretion of the test director, additional transmit antenna location and interior measurement points may be added to fully characterize the facility EM barrier and to aid leak localization.

4.4 Verification CWI Data Acquisition and Processing

For MIL-STD-188-125-1A verification CWI testing, raw frequency domain sweeps are transferred from the network analyzer to the Data Acquisition (DAS) PC using various JEM-developed SW packages. These packages covert the raw data into reduced units, either shielding effectiveness, coupled current or magnetic field strength, depending on the type of measurement. Post processing of the coupled current measurements is performed by a separate package to generate the threat-level extrapolated coupled current (TLECC) predictions, including both the time (or frequency) domain waveforms and the corresponding peak and peak derivative norms.

A typical MIL-STD-188-125-1A verification shielding effectiveness measurement result is provided in Figure 12; here the cyan trace represents the measurement range of the system at this test point. As has been previous described, the measurement range of the CWI SE measurement system generally cannot characterize SE values exceeding the MIL-STD-188-125-1A SE performance required for frequencies below a few MHz. In this frequency range the SE results are considered satisfactory if there is no measurable test point response above the noise and operating signal level.

The final comprehensive test report will contain a complete set of data for each CWI measurement test point for each CWI transmit antenna position and polarity. This includes shielding effectiveness curves for each free field and surface current test point, one curve for each probe orientation. For each coupled current test point the time-domain TLECC waveform along with the corresponding peak and peak derivative norms will be provided.

In many cases the CWI TLECC results are dominated by low-frequency ambient RF noise present on the test point (cable or wire). In these cases, the TLECC results can be filtered to emphasize the high-frequency portion of the response where RF leakage, if it exists, is measured above the ambient noise.

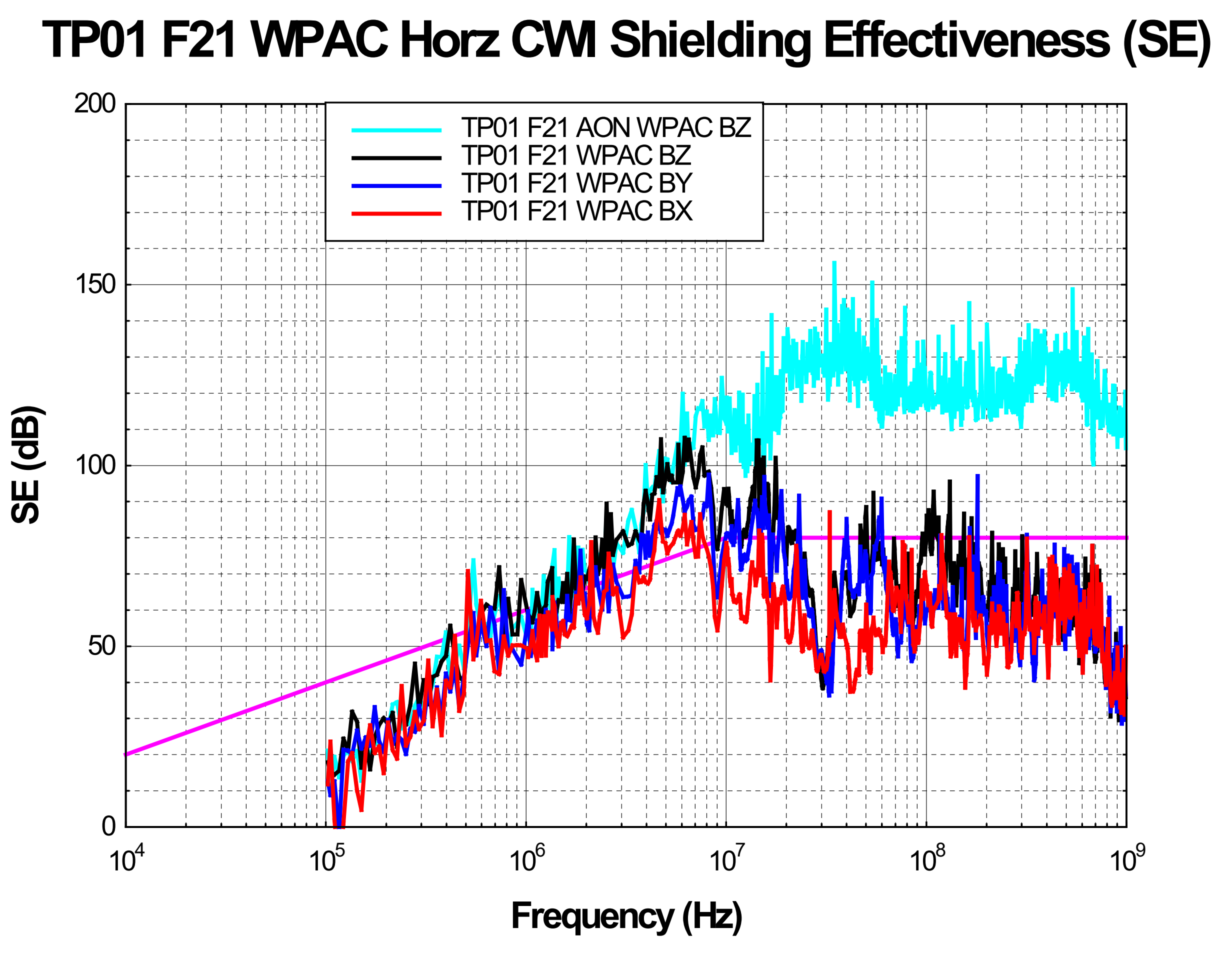


Figure 12. Typical verification CWI SE measurement results.

A raw (after removal of diagnostic system gain) coupled current measurement result from a prior MIL-STD-188-125-1A verification CWI test effort is shown in Figure 13. Included in the figure are the measured coupled currents for both the horizontal and vertical polarities of the CWI transmit antenna, as well as the ambient noise measurement (with the CWI transmit source, specifically the RF amplifier, disabled; "AON" stands for "Amp Off Noise"). As is evident there is no measurable RF coupling of the illuminating field to the test point in this example; that is, the actual coupled current measurements overlay perfectly with the ambient (Amp Off Noise) measurement.

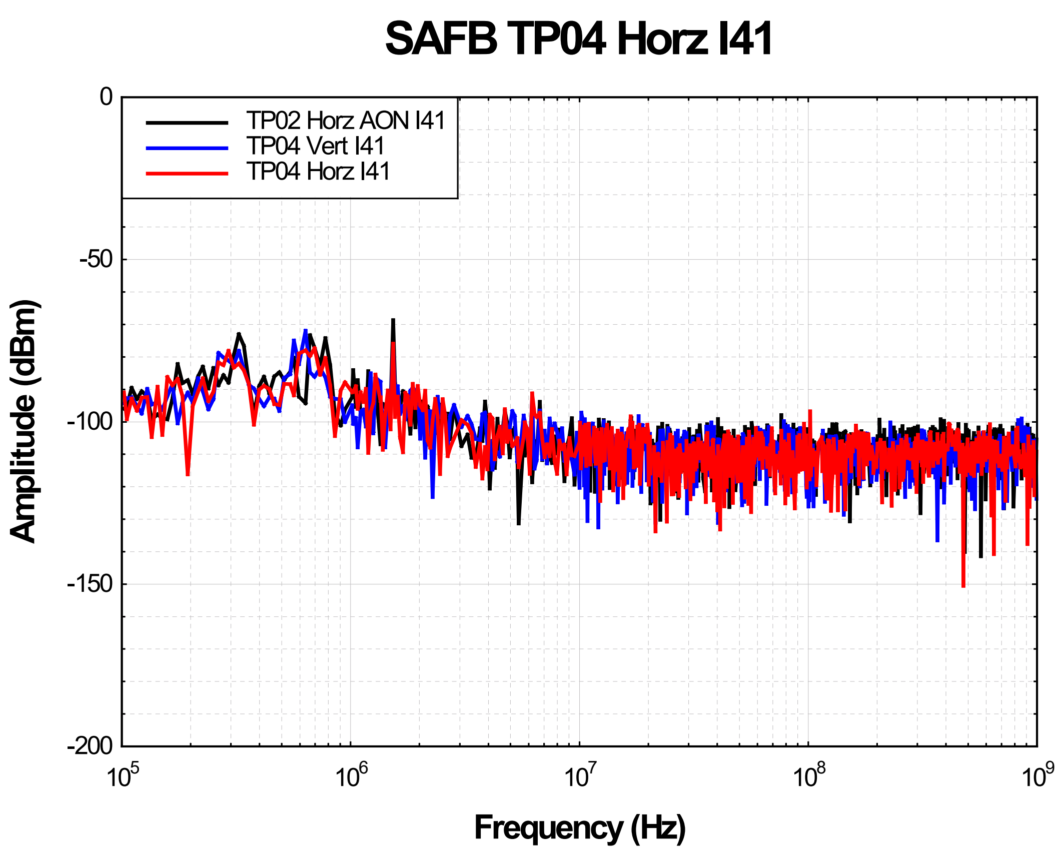


Figure 13. Raw CWI coupled current measurements (nominal and AON).

The time-domain TLECC (threat-level extrapolated coupled current) waveform obtained from the processing of the vertical (orientation of the CWI transmit antenna) coupled current measurement is shown in Figure 14. In many cases the time domain response is dominated by the contribution of the low-frequency portion of the raw coupled current measurement which often dominated by ambient RF noise (i.e., the RF signal measured in the absence of any CWI-induced leakage). In order to de-emphasize this effect to permit the extraction of a realistic TLECC result, a high-pass filter must be applied to the data. This allows the TLECC response of the test point to be determined without being overwhelmed by the low-frequency ambient noise present at this (and many other) test points. The corresponding TLECC result in the time domain after application of a minimal high-pass filter is shown in Figure 15.

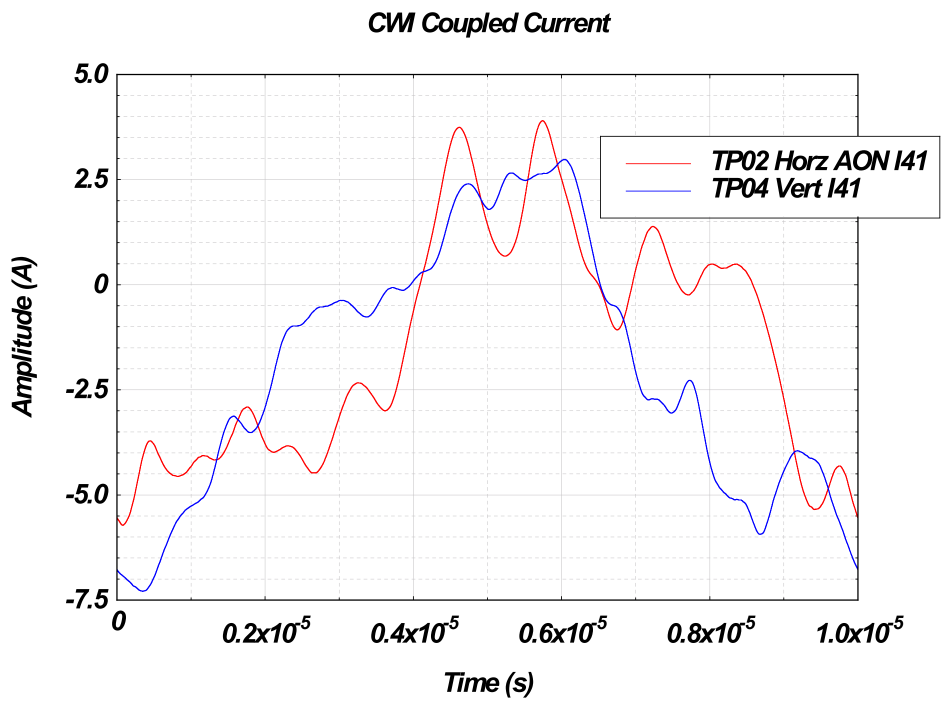


Figure 14. Typical CWI TLECC results (nominal and AON).

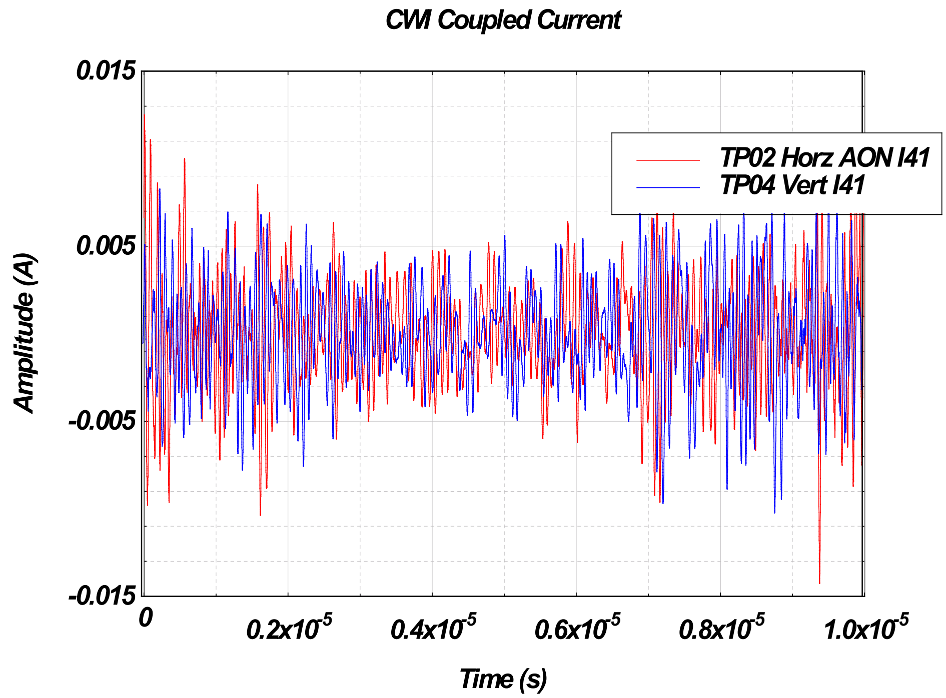


Figure 15. Typical CWI TLECC results (nominal and AON) with minimal HP filtering.

5.0 Data Handling, Anaylsis and Reporting

All raw CWI test data collected during the site MIL-STD-188-125-1A verification test will be treated as customer confidential.

5.1 Real Time Data Analysis

Real time data analysis will ensure the acquisition of high-quality data. The initial check will use the data and analyses plotting capabilities of the recording equipment and will be based on visual inspection of the raw data traces as they are obtained. The data quality review will include flat-line indications of data absence, clipping indications of incorrect instrumentation settings, and high noise indications of instrumentation problems. Data content review will involve evaluation of the reasonableness of the data versus expectations. When the data pass the initial QC review, they are recorded into the temporary test data file for a quick look evaluation.

In approximately real-time, and no less than once per test day, the data will undergo an analytical review. Data will be compared to that from previous measurements or with rough order analytical estimates to assure their basic credibility. Re-measurement candidates will be identified from data whose information content is determined to be contradictory or inadequate. Data which passes this screening is considered approved data and will immediately be put into the permanent test data file.

5.2 Post Test Data Analysis

Post-test analyses will focus on integration, evaluation, and interpretation of the full complement of CWI data for inclusion in the final test report, including calculation of residual current and TLECC norms, analysis of any anomalies, and an overall assessment of site hardness based on the results of all testing performed.

6.0 Logistical requirements

6.1 Safety

A daily safety briefing shall be conducted by the Jaxon test director / lead engineer to ensure that appropriate safety procedures are in place and followed at all times.

MIL-STD-188-125-1A verification CWI testing is performed using a hybrid antenna system driven at a relatively low (less than 10 W conducted) RF power level. There are no RF safety, exposure, or damage concerns to either site personnel or equipment due to the CWI transmissions.

6.2 Test Risks

Because of the low field strength levels produced by the hybrid CWI antenna there is essentially no risk of impact to the HEMP-protected equipment located inside the PAR of power plant. However, the CWI transmission could potentially affect external (to the PAR) equipment, such as sensitive radio receivers. All radiated CWI testing will be performed in accordance with the frequency authorization and approval provided for this effort. All site and base missions which could potentially be affected should be made aware that a MIL-STD-188-125-1A verification CWI test is being performed. Furthermore, a local (site) “stop buzzer” point-of-contact should be provided so that transmissions can be halted should any actual or perceived interference be observed. Should any interference be noted and reported to the site POC or Jaxon team all CWI testing activities will immediately be stopped until the source of the issue is identified, and corrective action implemented. Such action(s) include identification of the specific frequencies or frequency band(s) of concern which will then be removed from the list of CWI testing frequencies.

6.3 Support Requirements

Jaxon anticipates transporting all test equipment to the site via a commercial carrier. Access to the site is required. Shipper information will be provided to the appropriate site personnel as needed.

Jaxon requests that a camera (and operator, if required) be provided to photographically document test set-ups and execution. Alternatively, Jaxon can provide a camera for approval, in which case the site shall provide the guidelines to obtain a camera permit and facilitate approval.

The nature of the testing will require that various filter cabinets be powered down in order to configure the test setups. These activities will need to be coordinated with the site in advance. Site lock-out / tag-out procedures will be followed.

Local sources will be utilized to supply the insulating oil and compressed air necessary for PCI testing. One cylinder of dry compressed air and one barrel of insulating oil will be delivered to the site from a local vendor prior to the test. This delivery will be coordinated with the site as required.

An all-terrain extended reach forklift is required as a mount for the hybrid CWI antenna. The delivery will also come from a local vendor prior to the test and will also be coordinated with the site as required.

6.4 Frequency Approvals

Because it is a radiated test, the MIL-STD-188-125-1A verification CWI testing effort requires frequency approval. Jaxon will support the frequency approval process as required with additional information, details, or any other inputs needed to facilitate the process.