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02-2-595 Counter Remote Controlled Improvised Explosive Device (RCIED) Electronic Warfare (CREW) Compatibility In An Anechoic Chamber

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14. ABSTRACT
This TOP addresses the test methodology to verify compatibility with counter- Improvised Explosive Device systems that are within close proximity of the equipment under test.

15. SUBJECT TERMS
RCIED; CREW; VSWR; ERL

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U.S. ARMY TEST AND EVALUATION COMMAND
TEST OPERATIONS PROCEDURE

*Test Operations Procedure 02-2-595 7 December 2020
DTIC AD No.

COUNTER REMOTE CONTROLLED IMPROVISED EXPLOSIVE DEVICE (RCIED) ELECTRONIC WARFARE (CREW) COMPATIBILITY IN AN ANECHOIC CHAMBER

* Approved for public release; distribution unlimited.

1. SCOPE.

The procedures in this Test Operations Procedure (TOP) describe a method to determine the compatibility of Equipment Under Test (EUT) with a Counter Remote Controlled Improvised Explosive Device (RCIED) Electronic Warfare (CREW) system threat within close proximity to the EUT. Due to the potential high field strengths that can be encountered around a CREW device, compatibility needs to be determined in order to ensure interoperability and mission success.

2. FACILITIES AND INSTRUMENTATION.

2.1 Facilities.

Item	Requirement
Anechoic Chamber	Meet the chamber and anechoic requirements in Military Standard (MIL-STD)-461G**[1] and large enough to maintain at least 3 meters away from the CREW antenna to the EUT.
Copper table	If the EUT will be mounted on a metal surface such as a vehicle, a copper table will be used.
Non-Conductive Table	If the EUT will not be mounted on a metal surface, a non-conductive table will be used

2.2 Instrumentation.

System Name	Description
AN/VLQ-12 (or comparable)	Complete CREW system
AN/GLM-11(V)2 (or comparable)	Countermeasure Set (Universal Test Set (UTS)) to stimulate the CREW system to achieve maximum power output in all bands.
Spectrum analyzer	Used to monitor the CREW system. Will need proper rated attenuator at the RF input in order to not damage the instrument.
Vector signal generator	Used to simulate a threat to the CREW system.

** Superscript numbers correspond to Appendix C, References.

System Name	Description
Field probe	Used to monitor the field strength from the CREW antenna to verify personnel are within the Exposure Reference Level (ERL). The probe needs to be rated for the maximum possible field strength and frequency range.
High power attenuator	Rated for the maximum output power and the frequency range of the CREW system and used to simulate distance for analysis purposes.
Variable attenuator (1-70 decibel (dB))	Rated for the frequency range of the CREW system and used to fine tune the simulated distance.
Monitoring antennas	Rated for the maximum output power and the frequency range of the CREW system. These antennas are connected to the spectrum analyzer and used to monitor and verify that the CREW system is fully operational and operating at full threat.
Network analyzer	Used to measure Voltage Standing Wave Ratio (VSWR) and cable loss.

2.3 Measurement Tolerances.

Measurement	Tolerance
Frequency	2 percent
Amplitude	2 dB
Field strength	0.1 Volts per meter (V/m)

3. REQUIRED TEST CONDITIONS.

3.1 Preparations for Test.

3.1.1 EUT Inspection / Functionality Test.

a. Verify all equipment for the EUT is supplied and setup in a configuration that is reflective of normal operation.

b. Perform a functional test to verify that the equipment is ready for test.

3.1.2 CREW System Inspection.

a. Assemble the CREW system

(1) Obtain the wiring diagram for the CREW system in the technical manual or operators manual.

(2) Using the wiring diagram, verify the physical connections match the wiring diagram.

(3). An adequate power supply should be used to power the system.

(4) Verify the Radio Frequency (RF) cables and physical connections of the CREW system are properly connected at the interfaces.

b. Inspect the CREW system for proper operation.

(1) Turn the CREW system on, but not in “operation” mode.

(2) Load the load set.

(3) Verify that all the CREW system self-checkouts pass, such as the built-in-test check.

(4) In a closed loop system with proper attenuation, check that the CREW system is outputting the correct power level at each frequency as specified in the load set with a spectrum analyzer or the UTS.

c. Take a VSWR measurement of the CREW antennas to verify the antenna is not damaged and in good working order.

(1) Network analyzer method.

(a) Disconnect the RF cables of the antenna closest to the CREW transmitter.

(b) With a network analyzer, connect the RF cable of the antenna.

(c) Measure the VSWR.

(d) Compare the value with an expected value of the antenna from previous tests or from the manufacturer datasheet.

(2) Manual VSWR method.

(a) Figure 1 shows the test setup.

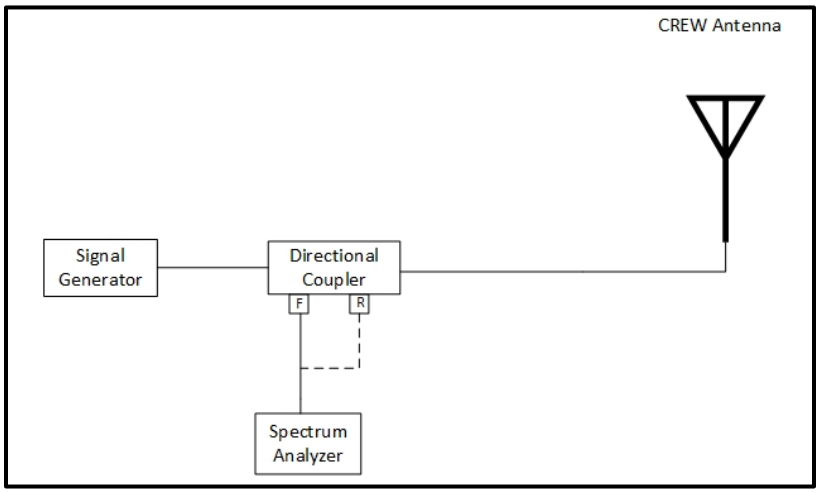

Figure 1. VSWR manual method setup.

(b) Output a frequency of interest using the signal generator, usually at 0 decibels with reference to one milliwatt (dBm).

(c) Measure the forward power from the spectrum analyzer and document the value with the unit dBm.

(d) Measure the reverse power from the spectrum analyzer and document the value with the unit dBm.

(e) Calculate the VSWR using Equation 1.

$$VSWR = \frac{1 + \sqrt{\frac{1}{10^{\left(\frac{FWR-RVS}{10}\right)}}}}{1 - \sqrt{\frac{1}{10^{\left(\frac{FWR-RVS}{10}\right)}}}} \qquad \textit{(Equation 1)}$$

where:

FWR = Forward power, typically in watts or dBm.
RVS = Reverse power, typically in watts or dBm.

NOTE: Both FWR and RVS need to be in a common unit.

3.2 Personnel Radio Frequency Exposure.

Since operating CREW systems can potentially exceed the Exposure Reference Level (ERL) outlined in the Department of Defense Instruction (DODI) 6055.11[2] and the Institute of Electrical and Electronics Engineers (IEEE) Standard C95.1-2019[3], precautions need to be taken for personnel to maintain a safe distance from the transmitting antenna.

3.2.1 Known Safe Separation.

Obtain the safe separation distance as determined from the CREW system literature.

3.2.2 Unknown Safe Separation.

If you are unable to determine the safe separation distance from literature, you will need to take some measurements to maintain a safe distance from the transmitting antenna. You will also need to activate the reactive bands in the CREW device by utilizing the CREW stimulation procedure in paragraph 4.1.2. During these measurements, all personnel besides the CREW system operator and the individual taking the measurements, should be removed from the chamber. The CREW operator should be far enough away from the beam width of the CREW antennas to not exceed the ERL and this location will be verified to be under the ERL before any other measurements are taken.

a. Measurements with an RF field meter must be taken and compared to DODI 6055.11.

(1) Determine the operating frequency bands of the CREW system and any power level information from the load set. Spectrum analyzer measurements will be taken in the proximity of each CREW antenna with the CREW system "operating" in both active and reactive modes. Record each frequency band with the highest peak amplitudes.

(2) When the operating frequency bands of the CREW system have been determined, reference DODI 6055.11 guidance to determine the corresponding maximum safe field levels for each frequency band.

(3) When calculating the standoff distance in relation to the maximum power density levels, use the frequency with the highest restriction for all calculations. This will ensure an increased safety margin for any operators who may be required to operate the EUT.

b. Measure power density levels at each antenna with a RF Field Meter and associated E-Field Probe.

(1) Starting at the furthest possible measurement point from the front of each antenna, slowly move towards the antenna face until the corresponding maximum safe power density measurement is displayed on the RF Field Meter. If the furthest possible measurement point is not far enough from the antenna to determine the corresponding maximum safe power density, a larger chamber would be required.

(2) When the maximum safe power density level is measured on the RF Field Meter, record the distance from the front face of the antenna to determine the safe standoff distance.

(3) Repeat this procedure for both active and reactive modes.

3.2.3 Marking the Exclusion Zone.

After you obtain the safe separation, you will need to properly mark the areas identified as exceeding the ERL to keep personnel out. Non-conductive signs that alert the personnel to the danger should be utilized along with non-conductive barriers (if applicable).

3.3 Chamber Conditions.

3.3.1 Shielding Effectiveness.

Chamber should be at least 100 dB of isolation to minimize interference caused by the CREW systems and to alleviate the need for frequency authorization.

3.3.2 Environmental Conditions.

a. RF ambience. Meets the 6 dB below the limit of MIL-STD-461G Radiated Emissions (RE) 102 Army Ground limit line (Figure 2).

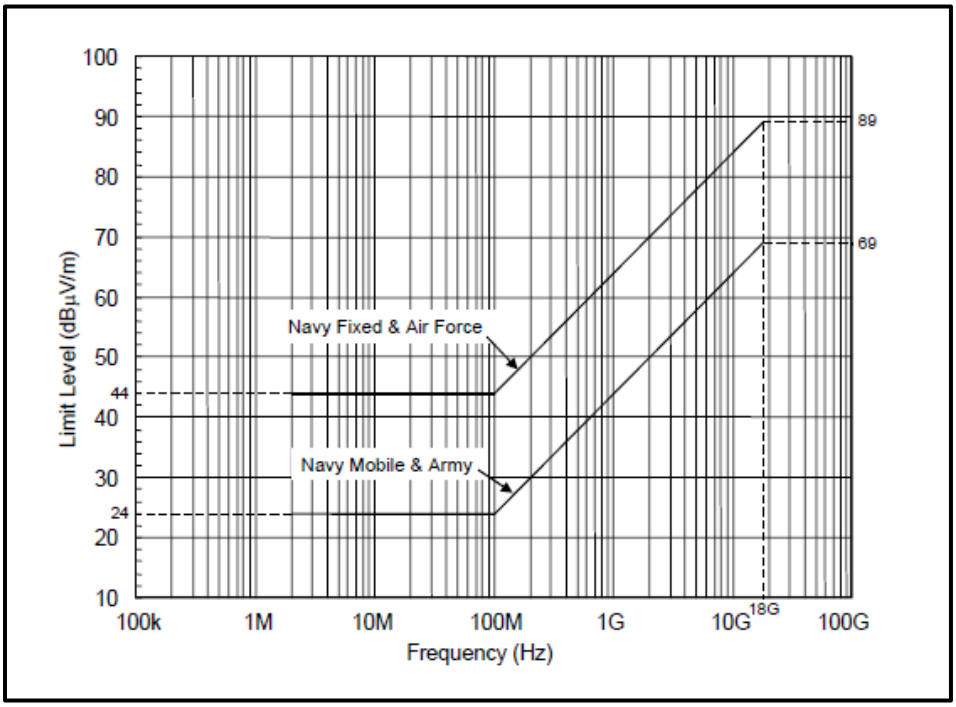

Figure 2. MIL-STD-461G RE102 Army ground limit line.

b. Ambient temperature: 20 to 30 °Celsius (68 to 86 °Fahrenheit).

c. Humidity: 30 to 70 percent.

4. TEST PROCEDURES.

4.1 Test Preparation.

4.1.1 CREW System Setup.

a. RF transmitter unit(s).

(1) Setup RF transmitter unit(s) on a table with wheels to allow it to be mobile (if needed).

(2) Position the units to the side of testing area, behind the transmit antennas.

(3) Verify the electrical power is adequate and can maintain any potential surge current without entering a fault condition.

(4) Properly ground the transmitters together (if applicable) and to the power supply.

b. Transmit antenna(s).

(1) The height of the antennas should mimic the worst realistic height of the CREW antenna to achieve the desired EUT location within the 3 dB beam width of the transmitting CREW antenna.

(2) The transmitter antennas should be setup on a tripod that can be moved and can have the height adjusted as needed.

(3) The antenna base and tripod should be grounded to the RF transmitter unit(s).

4.1.2 Crew Stimulating Setup.

In the event that the CREW system has reactive responses to threats, these threats will have to be simulated to stimulate the desired response from the CREW system. These responses are desired in order to achieve the maximum power of the system in each band and determine a potential RF vulnerability of the EUT to these responses. There are many ways to properly stimulate the CREW system. This is a general procedure.

a. Determine all the parameters that would cause a reaction from the CREW system.

b. Place the stimulating antenna near the CREW RF monitoring antenna.

c. Using the UTS or vector signal generator, generate the parameters that would cause a reaction from the CREW device.

d. With a spectrum analyzer connected to a monitoring antenna, verify that the reaction was achieved (use a proper attenuator to avoid damage to the spectrum analyzer). There should be an increase in both the bandwidth and the amplitude of the transmit signal.

4.2 Equipment Under Test Configurations.

4.2.1 General Systems.

The EUT should be setup utilizing MIL-STD-461G, Figure 2-5, as a guide. It should take into account the intended mounting surface and select the most applicable figure based on this.

4.2.2 Soldier Worn Systems.

Soldier worn systems are typically battery powered and do not exactly fit the general systems in paragraph 4.2.1. For these systems, the following setup should be used.

a. For testing locations that exceed the ERL or do not require an operator in the RF field:

(1) Should be setup on a non-conductive mannequin that can properly orientate the system.

(2) Placement of all interconnecting cables should be routed as they would be on a Soldier.

b. For testing locations that are within the ERL and require an operator:

(1) An operator should wear the equipment in the proper configuration.

(2) Placement of all interconnection cables should be routed as they would be on a Soldier.

4.2.3 Automotive Vehicles.

For a vehicle under test with a CREW system installed onboard, intra-system electromagnetic compatibility can be performed using MIL-STD-464C[4] in conjunction with TOP 01-2-511A[5]. The scenario in this section will address another vehicle or CREW device coming in close proximity with the vehicle under test.

a. Vehicle should be setup in the center of the chamber.

b. The chamber exhaust evacuation system should be hooked up to the vehicle’s tail pipe or other vehicle exhaust system component.

(1) Use non-metallic hose that is rated for the exhaust temperature.

(2) Ensure there is enough suction to evacuate the exhaust.

4.3 CREW Compatibility Testing.

4.3.1 Testing Locations.

a. Use MIL-STD-461G, Figure RE102-7, as a guide for determining the General Systems and Soldier worn systems locations. An engineering analysis of likely RF entry locations into the system should be made and included in the test location matrix.

b. For automotive vehicles, use the following guidance for the most prevalent locations:

(1) Components external to the vehicle.

(2) Apertures into the cab of the vehicle.

(3) External cables.

4.3.2 Testing Grid Setup.

a. For each testing location determined in paragraph 4.3.1, mark and number on the floor with successive one meter marks extending from the EUT locations as shown in Figure 3.

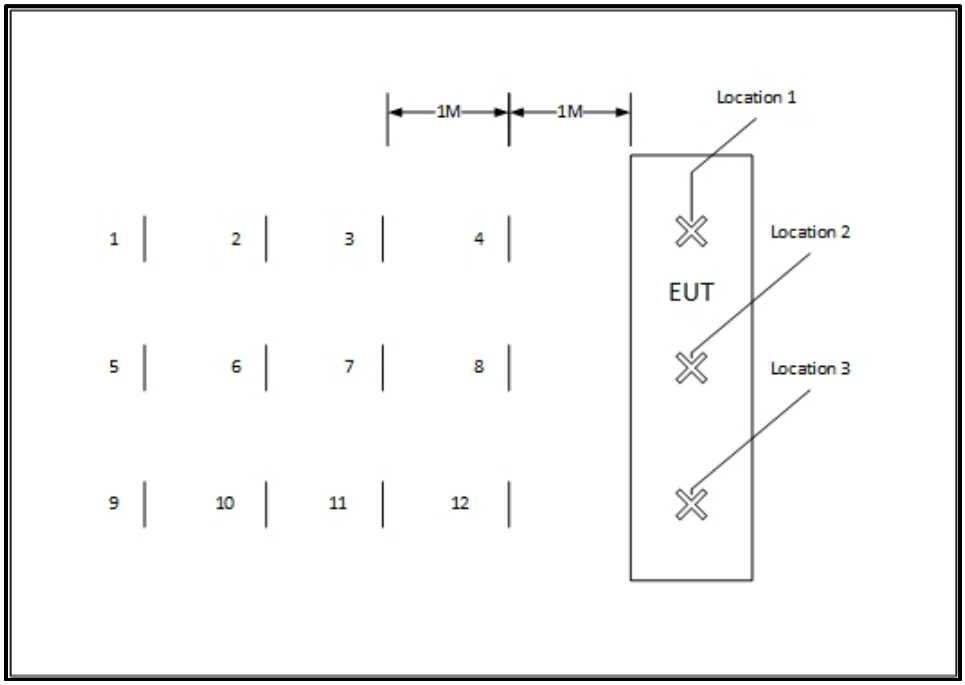

Figure 3. Grid setup.

b. The furthest distance out is dictated by the chamber size, but a typical distance used is four meters.

c. On a spreadsheet, document the testing number that corresponds with the location and distance for use during test execution.

4.3.3 Test Execution.

a. Select a test location and place the CREW antenna at the furthest distance mark for that location that has not been tested.

b. Adjust the height of the CREW antenna to put the EUT location within 3 dB of the beam width, but not raised or lowered to a height that is not representative of the operation of the CREW system. Multiple heights can be used to encompass a large item vertically.

c. Turn on the EUT and allow a sufficient time for stabilization.

d. Verify no personnel are within the areas that exceed the ERL.

e. Turn on the CREW system to operate. If the CREW system needs to be stimulated for reactive regions, turn on the CREW stimulator in accordance with paragraph 4.1.2.c.

f. Monitor the EUT for any degradation to performance.

g. Dwell no less than the EUT response time and the duration it takes to stimulate the reactive regions (this information may be classified and you need to reference the security classification guide for the CREW system).

h. If a vulnerability is encountered, perform the following:

(1) Document the test number.

(2) Document the height of the antenna.

(3) Document the vulnerability that was encountered.

(4) Move the antenna closer to the EUT at this location if the potential damage to the EUT can be minimized. This is not required if the potential for damage of the EUT is too severe, but is recommended depending on the severity of the vulnerability.

i. If multiple heights are required, adjust the height and repeat the steps in paragraphs 4.3.3.b through 4.3.3.g.

j. Repeat the steps in paragraphs 4.3.3.a through 4.3.3.g for each test number.

NOTE: Depending on the operation capabilities of the EUT, multiple modes of operations may be needed to properly assess the equipment (i.e. capable of operating on multiple frequencies).

4.3.4 Excessive Standoff Distance Measurement Procedure.

In the event that a vulnerability occurs at a distance larger than the chamber that you are testing in, the following procedure will be used:

a. Place the antenna at a vulnerable testing location at least two meters away (the antenna in the far field is desired).

b. Place a high powered attenuator in line of the RF output cable(s) on the CREW transmitter closest to the CREW transmitter. The high powered attenuator value will be based on reducing the transmitter output power to be below the threshold of the maximum power handling of the variable attenuator.

c. Place a variable attenuator at its lowest attenuation after the high power attenuator before the antenna (see Figure 4).

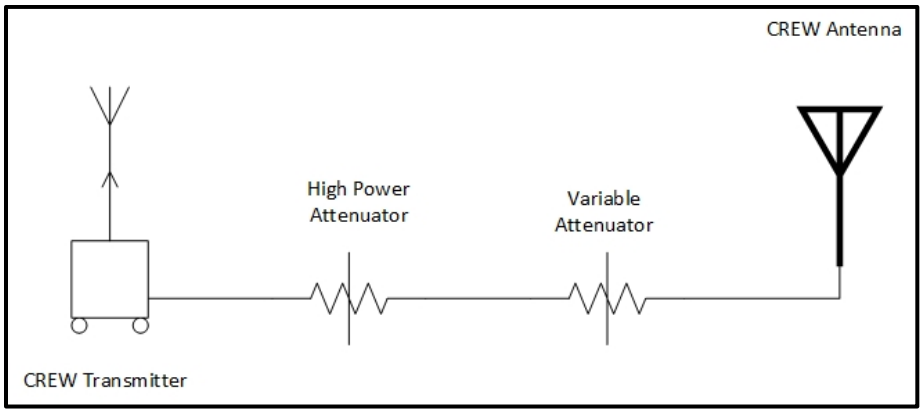

Figure 4. Attenuator placement.

d. Turn the CREW system on and verify the vulnerability is still encountered.

e. Increase the attenuation until the vulnerability disappears.

f. Let the EUT recover for no less than the EUT response time.

g. Gradually decrease the attenuation until the vulnerability is encountered again.

h. Document the total attenuation value as the threshold of susceptibility and also the testing number.

i. At the conclusion of testing, calculate the estimated distance using the free space calculation in Equation 2 in (paragraph 7.a).

5. DATA REQUIRED.

Based on the probability of the data being classified, reference the applicable security classification guide for both the CREW system and the EUT before collecting the following data.

a. EUT description, components, manufacturer, part, and serial number, etc.

b. EUT electrical schematics and interconnect diagrams (if applicable).

c. Test equipment list.

d. CREW system model, serial number, and load set information.

e. Test setup photos.

f. EUT testing locations.

g. Dwell time.

h. Any vulnerability data.

i. Excess standoff attenuation for any locations needed.

j. VSWR graphs of antennas.

6. PRESENTATION OF DATA.

Examples of how data can be presented are shown in Figures 5 through 7.

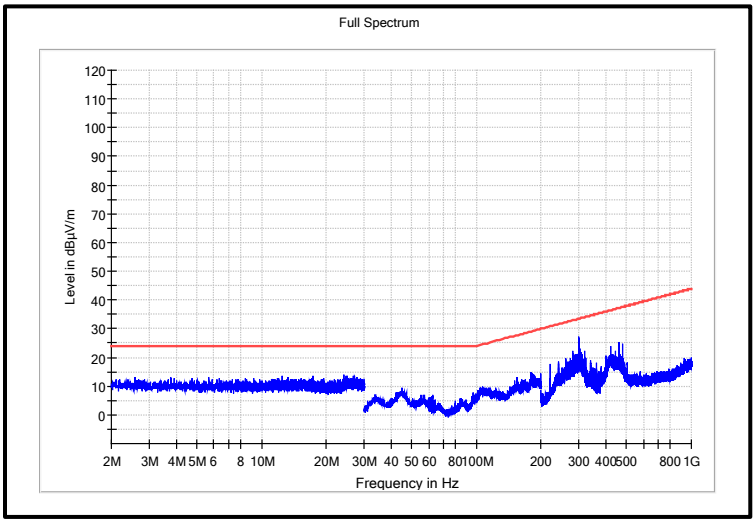

Figure 5. Chamber ambience example.

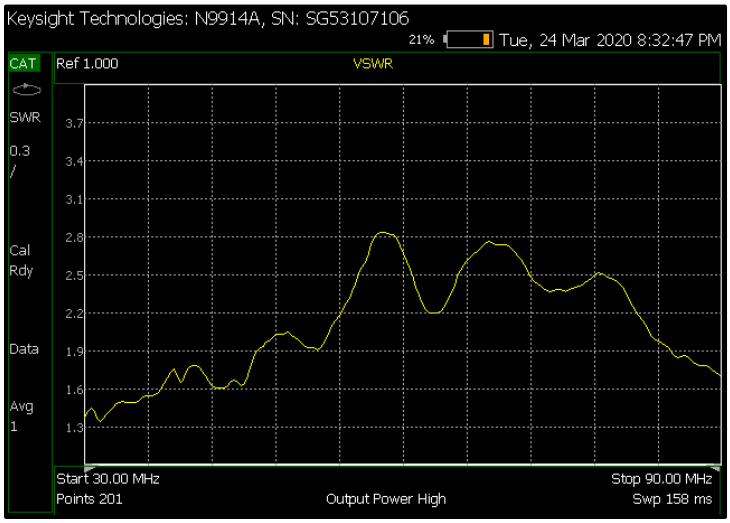

Figure 6. VSWR graph example.

CREW COMPATIBILITY

EUT Name: _____
Report Number: _____
Date: _____

Test Location #	Height (m)	Test Results
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		

Figure 7. CREW Compatibility Worksheet example.

7. DATA ANALYSIS.

a. The free space path loss calculation is shown in Equation 2

$$Distance = 10^{\frac{(dBLoss + 27.5 - 20\log_{10} Freq)}{20}} \qquad \textit{(Equation 2)}$$

where:

Distance = the distance in meters (CREW antenna distance in meters from the EUT should be added after this is calculated distance to accurately determine the standoff distance).
Freq = Frequency in Megahertz.
dBLoss = the total attenuation in dB.

b. The VSWR calculation was discussed in paragraph 3.1.2.c(e) and shown in Equation 1.

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APPENDIX A. GLOSSARY.

Term	Definition
Anechoic	Free from echo.
Attenuator	A device consisting of an arrangement of resistors which reduces the strength of a radio or audio signal.
Directional coupler	A device that samples a small amount of radio frequency power for measurement purposes.

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APPENDIX B. ABBREVIATIONS.

CREW	Counter Remote Controlled Improvised Explosive Device (RCIED) Electronic Warfare
dB	decibel
dBm	decibels with reference to one milliwatt
DODI	Department of Defense Instruction
ERL	Exposure Reference Level
EUT	Equipment Under Test
IEEE	Institute of Electrical and Electronics Engineers
MIL-STD	Military Standard
RCIED	Counter Remote Controlled Improvised Explosive Device
RE	Radiated Emissions
RF	Radio Frequency
TOP	Test Operations Procedure
UTS	Universal Test Set
V/m	Volts per meter
VSWR	Voltage Standing Wave Ratio

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APPENDIX C. REFERENCES.

1. MIL-STD-461G, Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment, 11 December 2015.

2. (DODI) 6055.11, Protecting Personnel from Electromagnetic Fields, Incorporating Change 2, 31 August 2018.

3. IEEE C95.1-2019, Standard for Military Workplaces - Force Health Protection Regarding Personnel Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 Hertz to 300 Gigahertz, 2019.

4. MIL-STD-464C, Electromagnetic Environmental Effects Requirements for Systems, 1 December 2010.

5. TOP 01-2-511A, Electromagnetic Environmental Effects System Testing, 20 November 2013.

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APPENDIX D. APPROVAL AUTHORITY.

CSTE-CI 7 December 2020

MEMORANDUM FOR

Commander, U.S. Army Operational Test Command
Director, U.S. Army Evaluation Center
Commanders, ATEC Test Centers
Technical Directors, ATEC Test Centers

SUBJECT: Test Operations Procedure 02-2-595, Counter Remote Controlled Improvised Explosive Device (RCIED) Electronic Warfare (CREW) Compatibility In An Anechoic Chamber, Approved for Publication

1. Test Operations Procedure (TOP) 02-2-595, Counter Remote Controlled Improvised Explosive Device (RCIED) Electronic Warfare (CREW) Compatibility In An Anechoic Chamber, has been reviewed by the U.S. Army Test and Evaluation Command (ATEC) Test Centers, the U.S. Army Operational Test Command, and the U.S. Army Evaluation Center. All comments received during the formal coordination period have been adjudicated by the preparing agency.

2. Scope of the document. The procedures in this TOP describe a method to determine the compatibility of Equipment Under Test (EUT) with a CREW system threat within close proximity to the EUT. Due to the potential high field strengths that can be encountered around a CREW device, compatibility needs to be determined in order to ensure interoperability and mission success.

3. This document is approved for publication and has been posted to the Reference Library of the ATEC Vision Digital Library System (VDLS). The VDLS website can be accessed at https://vdls.atc.army.mil/.

4. Comments, suggestions, or questions on this document should be addressed to U.S. Army Test and Evaluation Command (CSTE-CI), 6617 Aberdeen Boulevard-Third Floor, Aberdeen Proving Ground, MD 21005-5001; or e-mailed to usarmy.apg.atec.mbx.atec-standards@mail.mil.

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Forward comments, recommended changes, or any pertinent data, which may be of use in improving this publication to the following address: Policy and Standardization Division (CSTE-CI-P), U.S. Army Test and Evaluation Command, 6617 Aberdeen Boulevard, Aberdeen Proving Ground, Maryland 21005-5001. Technical information may be obtained from the preparing activity: Automotive Directorate (TEDT-AT-AD), U.S. Army Aberdeen Test Center, 6943 Colleran Road, Aberdeen Proving Ground, MD 21005. Additional copies can be requested through the following website: http://www.atec.army.mil/publications/topsindex.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.