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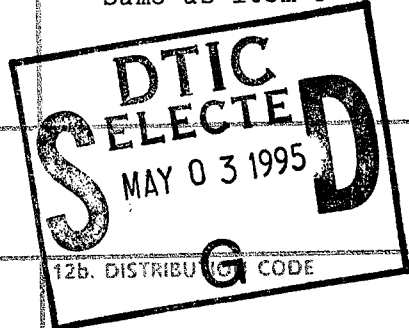
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U.S. ARMY TEST AND EVALUATION COMMAND
TEST OPERATION PROCEDURES

*Test Operation Procedures (TOP) 1-2-512
AD No.

15 May 1995

ELECTROMAGNETIC COMPATIBILITY TESTS

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1. SCOPE.

a. This TOP provides guidance for the planning, execution, and reporting of grounding and bonding and Electromagnetic Compatibility (EMC) tests of electrical, electronic, and electromechanical equipment, subsystems, and systems.

b. The purpose of grounding and bonding tests is to ensure that the subsystems of the equipment under test (EUT) meet the MIL-B-5087 (ref 1, App C) requirement of not more than 2.5 micro-ohms ($\mu\Omega$) direct current (dc) resistance between the subsystem and the EUT ground.

c. The purpose of EMC tests is to ensure that the EUT is able to operate in its intended electromagnetic environment without its performance being degraded and without degrading the performance of other system(s) in close proximity.

d. The grounding and bonding procedures described in this TOP are designed to assure compliance with MIL-B-5087. The EMC procedures described in this TOP are designed to meet the requirements of MIL-E-6051D (ref 2, App C).

e. This TOP is applicable to EMC testing for all systems and in all test categories.

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2. FACILITIES AND INSTRUMENTATION.

2.1 Facilities.

a. Grounding and bonding. The grounding and bonding test requires no special facilities and can be performed at any convenient location.

b. EMC. The EMC test should be performed outside in an electromagnetically-quiet location. The site should have frequency authorization to transmit on any frequencies required for test. The minimum requirement stated in MIL-E-6051D is to use 20 channels or frequencies per transmitter. The optimum frequency clearance would be to use a blanket clearance that covers the entire frequency spectrum.

2.2 Instrumentation.

a. Grounding and bonding. This test requires the use of a high accuracy, low resistance milliohmmeter. The milliohmmeter should have a resolution of at least $1 \mu\Omega$.

b. EMC. Instrumentation may be required to stimulate or monitor some, or all, of the EUT's subsystems. An analog distortion analyzer capable of measuring the signal plus noise and distortion (SINAD) ratio [in decibels (dB)] at the audio output of a receiver is required for any communications receiver in the EUT. The distortion analyzer should have a minimum resolution of 0.01 dB for ratios greater than 25 dB. For ratios less than 25 dB, the display can be rounded to the nearest 0.5 dB to reduce digit flickering with noisy signals.

$$\text{SINAD ratio} = \frac{\text{signal} + \text{noise} + \text{distortion}}{\text{noise} + \text{distortion}}$$

3. REQUIRED TEST CONDITIONS.

a. Grounding and bonding.

(1) The configuration of the EUT must be identical with the configuration that will be fielded.

(2) Prepare a data sheet (see example in Appendix B) that lists all the subsystem(s) of the EUT and provides space to record the grounding and bonding measurements.

b. EMC.

(1) The Electromagnetic Interference (EMI) test shall be completed prior to the EMC test. The data from the EMI test can be used to determine areas of the spectrum which may need special attention during the EMC test. EMI susceptibility tests can show areas of the frequency spectrum where the

equipment may be susceptible to radiated and conducted electromagnetic energy. EMI emissions test will show areas of the frequency spectrum where the equipment may have radiated or conducted electromagnetic energy.

(2) Prepare a matrix which lists each subsystem as a source of interference versus a list of the other subsystems as victims of interference (an example is in Appendix B).

(3) Determine appropriate operational mode(s) and how each subsystem will be monitored.

(4) Determine operational criteria, i.e., what indications signal anomalous operation, for each subsystem.

4. TEST PROCEDURES.

a. Grounding and bonding. In general, the procedure for grounding and bonding testing is to measure the dc resistance between every subsystem of the EUT to a common reference point, usually the system ground. On a vehicle, the reference point shall be a single point, if possible, on the frame or body of the vehicle. Specific procedures shall:

(1) Verify that the calibration on the ohmmeter is current. Verify the ohmmeter is operating correctly by checking the readings for calibrated samples that shall be provided with the ohmmeter.

(2) Scrape the paint from a small area at the reference point in order to get good contact between the ohmmeter probe and the EUT. This area shall be no larger than is required for the probe.

(3) Place one probe on the reference point and the other on the selected subsystem.

(4) Produce a reading on the ohmmeter which is fairly steady. Readings which constantly change may occur if the probes do not have good contact. A reading of 0 or ∞ indicates the range on the ohmmeter is set incorrectly and requires adjustment.

(5) If a good reading cannot be obtained, scrape the paint from a small area of the selected subsystem.

(6) Record the reading on the matrix.

(7) Repeat steps a. (2)-(6) until all the subsystems have been tested.

b. EMC. The general procedure for the EMC test is to operate each subsystem and to observe its effect, if any, on the other subsystems of the EUT. Specific procedures vary depending on the type of systems as follows:

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(1) Transmitter. The transmitter is the source of interfering electromagnetic energy.

(a) All equipment in the EUT should be turned off, except the selected transmitter.

(b) Turn on the selected victim subsystem and allow it to stabilize. The victim should be in a normal mode of operation. If the victim has more than one mode of operation, it must be tested in all modes.

(c) Set the transmitter at its lowest frequency.

(d) Key the transmitter for a sufficient amount of time to allow the victim to react to the presence of the electromagnetic energy.

(e) Note any anomalous operation on a data sheet. Any information that might help accurately describe the incompatibility must be recorded.

(f) Tune the transmitter to the next test frequency.

(g) Repeat steps b. (1) (d), (e), and (f) until all transmit frequencies have been tested.

(h) Turn off the victim subsystem.

(i) Repeat steps b. (1) (b) - (h) until the matrix for the transmitter has been completed.

(j) Repeat this procedure until all transmitters for the EUT have been tested.

(2) Communications receiver. The communications receiver is the victim of interfering electromagnetic energy.

(a) Turn off all the subsystems of the EUT with the exception of the selected receiver. The victim shall have the squelch turned off and the volume set to a comfortable level for listening to the background noise.

(b) Turn on the subsystem designated as the source for this test.

(c) Tune the receiver through every test channel while listening to the background noise. Note any channel that has a change in the intensity (increase or decrease) or quality (change in pitch, addition of a regular beat, etc.) of the noise.

(d) For every channel that was noted in step b. (2) (c), the SINAD tests, as identified in the following paragraph (3), will be performed.

(e) Repeat this test for every receiver in the test matrix.

(3) SINAD Test.

(a) Select a signal generator and antenna, in the appropriate frequency range. Set up the signal generator and antenna, as shown in Figure 1. Set the signal generator to the frequency of one of the channel(s) to be tested.

(b) Connect the distortion analyzer to the audio output of the receiver, via 50 Ω coaxial cable.

(c) Record the ambient level of the SINAD ratio.

(d) Increase the output level of the signal generator until the SINAD ratio level is increased 3 dB above the ambient level and record this output level.

(e) Turn on the selected victim subsystem (normal operating mode) and allow it to stabilize. If the victim subsystem has more than one mode, this test must be performed for each mode.

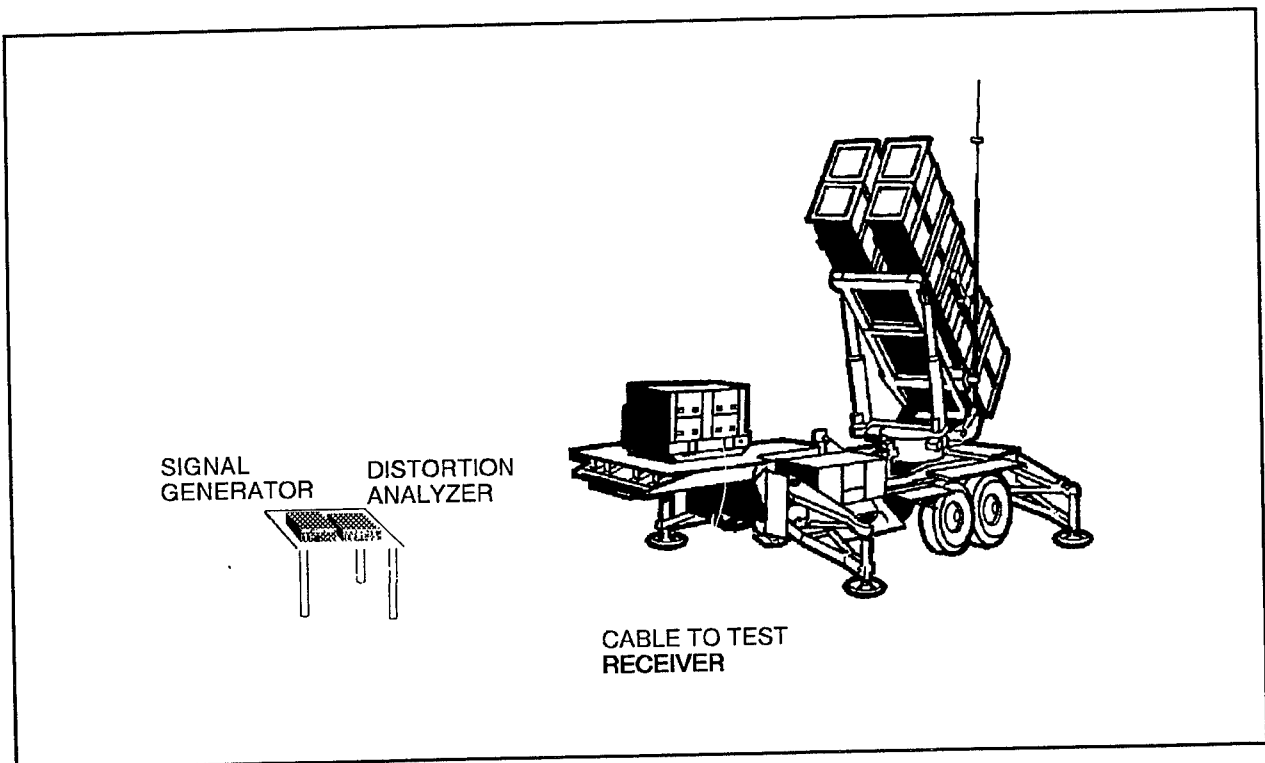


Figure 1. SINAD test setup.

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(f) Check for any change in the SINAD ratio level. If the SINAD ratio changed 1 dB or less, the source subsystem will not be noted as the cause of the interference that was experienced in step b. (3) (d) earlier. Record the result in the test matrix and return to step b.(3) (a) for the next frequency.

(g) If the change in SINAD ratio was more than 1 dB, note the level of the SINAD ratio.

(h) Increase the output level of the signal generator until the SINAD has returned to the same level that was noted in step b. (3) (d). Record the output of the signal generator.

(i) The desensitization of the receiver at the current frequency is determined by taking the signal generator output as in step b. (3) (h) minus the signal generator power output [step b. (3) (d)].

(j) Change the frequency of the signal generator to the next frequency to be tested and repeat steps b. (3) (c) - (i) for all the recorded channels to be tested on this receiver.

(4) Other equipment. All other electrical, electronic, or electromechanical equipment shall be tested as the victim of electromagnetic energy.

(a) Turn off all equipment in the EUT except the selected victim subsystem.

(b) Turn on the source subsystem.

(c) Monitor the victim subsystem for anomalous operation and record any that appear. Any information that may help accurately describe the anomalous operation shall be recorded.

(d) Turn off the source subsystem.

(e) Repeat steps b. (4) (b) - (d) until the matrix is complete.

5. DATA REQUIRED.

a. General.

(1) Nomenclature, model, and serial number of the test item.

(2) List of all other data acquisition instrumentation, antennas, and other ancillary equipment used to perform the tests. The location of all other equipment relative to the EUT.

(3) Records of operating conditions and modes, control settings,

loads and terminations, and monitoring equipment used.

(4) Tabulated listings of modes of operation, frequencies, signal levels, modulation characteristics, and thresholds of all susceptibilities.

b. Grounding and bonding. The measurements of dc resistance between each subsystem and the reference point. A sample data sheet is included in Appendix B.

c. EMC. Any anomalous conditions found during the test. All information that may relate to the condition, e.g., exactly what was the anomalous operation, sound of the noise, change in Bit Error Rate (BER), etc., should be included in the report. A sample data sheet is included in Appendix B.

6. PRESENTATION OF DATA.

a. Grounding and bonding. The data shall be presented in a form similar to the data sheet.

b. EMC.

(1) The data shall be presented in a form similar to the data sheet.

(2) Analysis of EMC data may be complicated. A number of factors must be considered. The following list is not intended to be comprehensive, but simply a starting point:

(a) What is the intended operational electromagnetic environment for the EUT?

(b) What other systems, if any, will be located in the same general area and approximately how far away?

(c) If other systems are in the general area, what are their frequency ranges, antenna type(s) and directivity, and power outputs?

(d) Can the problem be corrected with an operational fix as opposed to an equipment change, i.e., spectrum management?

(3) The following paragraphs are taken from MIL-E-6051D.

3.2.2 Subsystem/equipment criticality categories. All subsystems/equipments installed in or associated with the system shall be assigned to one of the EMC criticality categories. These assignments shall be based on the impact of an electromagnetic interference (EMI), susceptibility malfunction, or degradation of performance on the assigned mission.

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a. *Category I - EMC problems that could result in loss of life, loss of vehicle, mission abort, costly delays in launches, or unacceptable reduction in system effectiveness.*

b. *Category II - EMC problems that could result in injury, damage to vehicle or reduction in system effectiveness that would endanger success of mission.*

c. *Category III - EMC problems that result only in annoyance, minor discomfort, or loss of performance that does not reduce desired system effectiveness.*

APPENDIX A. BACKGROUND INFORMATION

1. BACKGROUND INFORMATION.

EMC testing is required by several documents, including Department of Defense Directive 3222.3, Electromagnetic Compatibility Program (EMCP) (ref 3, App C) and MIL-E-6051D. Unfortunately, neither document mandates any test methods. As a result, EMC tests are performed under different conditions and with different standards. The two areas that have the widest variation are as follows:

a. The number of frequencies to be tested. MIL-E-6051D, paragraph 4.4.10 reads, "Multichannel transmitters and receivers shall be tested at a representative number of frequencies, usually not less than 20." The channels tested should be spaced over the entire frequency range of the transmitter and/or receiver. Tests have been performed using as few as two channels. The usual reason given for the lack of sufficient channels being tested is that the FCC would not give clearance for additional frequencies. The risk of not discovering EMC problems is still fairly high when testing only 20 channels. The risk associated with testing fewer channels is unacceptable. If the testing agency can not obtain clearance for a sufficient number of frequencies, the test should be moved to another agency or test site where sufficient frequencies can be obtained.

b. The levels used in the SINAD test vary widely between test agencies. The reference level, i.e., the number of dB above the ambient level, has been set as high as 16 dB above the ambient. The degradation of the SINAD required to declare a problem has been as high as 10 dB. Using high values in the SINAD test will tend to mask many EMC problems. The reasoning behind using such levels is that the numbers represent the operational values of the transceiver. This logic is incorrect for many reasons. The following paragraphs provide some examples.

(1) An EMC test is not an operational test. The purpose of an EMC test is not to verify that a given transmitter or receiver is working properly, but to evaluate the effect of collocated equipment on the transmitter or receiver. The field strength necessary to generate signal strength 16 db above the ambient SINAD level will probably overcome all but the very worst interference.

(2) The operational characteristics of a receiver are immaterial to this test. The factor being measured is the ratio of signal strength to noise plus signal strength at the audio output of the receiver. Therefore, the field strength at the antenna of different receivers required to generate a signal 3 dB above the SINAD ambient will vary according to the characteristics of the receiver. That is not pertinent to this test because the SINAD test measures the *relative* change in the SINAD level.

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(3) EMC tests shall be performed in a manner to simulate a real mission. Signal strength is not always optimum during actual missions. Therefore, the test shall be performed simulating a receiver at the extreme range of its capabilities. The probability is that most, if not all, EMC problem areas will be discovered when the received signal level is at a minimum.

2. TESTING METHODS.

The method described in this TOP works well for small systems and is the method generally used for EMC testing. However, for very large systems that have many subsystems, the test time increases. An alternative method is to turn on and stabilize the victim subsystem. Next, turn on all other subsystems and observe the victim subsystem for any signs of anomalous operation. If there are no anomalies, the victim is finished for this test. If there are anomalies, the step by step procedure described in the TOP must be followed to determine the actual source of interference. A risk of missing an EMC problem is present using this method. Two or more areas of interference may cancel each other.

APPENDIX B. SAMPLE DATA SHEETS

	DC Resistance to Reference Point (mΩ)
Subsystem A	
Subsystem B	
Subsystem D	
Subsystem C	
Subsystem E	
Subsystem F	
Subsystem G	
Subsystem H	
Subsystem I	

Figure B-1. Sample grounding and bonding data sheet.

APPENDIX C. REFERENCES

1. MIL-B-5087, Bonding, Electrical, and Lightning Protection for Aerospace Systems, 31 August 1970.
2. MIL-E-6051D, Electromagnetic Compatibility Requirements, 7 September 1967.
3. Defense Directive 3222.3, Electromagnetic Compatibility Program (EMCP), 20 August 1990.

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