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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Provides methods for determining the electromagnetic vulnerability of communications-electronics (C-E) equipment. Describes procedures to determine (a) whether C-E systems or equipments possess inherent deficiencies which can be intentionally exploited by enemy electromagnetic means and (b) whether the contribution of the systems or equipments to the electromagnetic environment can be used to detect their presence and location.

US ARMY TEST AND EVALUATION COMMAND
TEST OPERATIONS PROCEDURE

DRSTE-RP-702-105
*Test Operations Procedure 6-2-508
AD No.

12 September 1977

VULNERABILITY, ELECTROMAGNETIC

1. SCOPE.

1.1 Objective. The objective of this TOP is to determine (a) whether communications-electronics (C-E) systems or equipments possess inherent deficiencies which can be intentionally exploited by enemy electromagnetic means and (b) whether the contribution of the systems or equipments to the electromagnetic environment can be used to detect their presence and location.

1.2 Limitations. Since many of the specific procedures of vulnerability testing are classified, the amount of information provided in this TOP is limited and is intended as general guidance only. Each test may require some tailoring so as to accommodate the characteristics of the particular system under test. Prior classified test plans and test reports on similar test items remain the best source of specific procedures. In addition, countermeasures depend to a high degree upon the skill of the operators. There is no substitute for experience in test planning or in the operation of equipment. The probability of providing information to an unauthorized party when cryptographic equipment is used is not discussed in this TOP.

*Supersedes MTP 6-2-508, 13 June 1968. — AD — 718648

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3. PREPARATION FOR TEST.

3.1 Prechecks. Make the following prechecks and arrangements:

a. Assurance checks that test equipment and accessories are available, are operational, and meet certified calibration requirements. Checks that the necessary test procedures and software for automatic test equipment are available.

b. Operational check of the test item(s) to ensure normal, correct functioning.

c. Final arrangements for provisions of supporting and participating agencies, activities, and facilities as required.

d. Test personnel briefing and provision of required instructions, manuals, and data collection material.

3.2 IWS Tests.

a. Simulation in the IWS may require obtaining tapes of the expected operational electromagnetic environment so background conditions can be established.

b. Investigate the specified parameters and test conditions. Representative considerations are--

(1) Desired signal (S) and jamming signal (J) frequencies

(2) Calculated S and J signal levels representative of tactical ranges

(3) Jammer modes

(4) Test item operational modes

(5) Combinations of 1, 2, 3, and 4 above represent selected electronic countermeasures (ECM) conditions

(6) Possible electronic counter-countermeasures (ECCM) techniques

(7) Data to be recorded and recording method

(8) Scoring method and/or equipment

c. Set up the test item and test equipment within or near the IWS as required for each measurement or condition.

2. FACILITIES AND INSTRUMENTATION.

a. The facilities and instrumentation of the Army Electronic Proving Ground (AEPG) for vulnerability testing have been used as an example to indicate requirements. AEPG's Electromagnetic Environmental Test Facility (EMETF) is described in detail in appendix C. Related major instrumentation is indicated also.

b. Briefly, the EMETF comprises the following:

(1) The Instrumented Workshop (IWS). Provides the capability to conduct electromagnetic vulnerability tests under precisely controlled conditions and provides degradation data for use in the computer analysis. The IWS includes the Digital Scoring System, the Automatic Data Collection System (ADCS), and the Voice Interference Analysis System (VIAS).

(2) The Spectrum Signature Facility (SSF). Provides spectrum signature data compilation in accordance with MIL-STD-449D[1] and analytical reports on electromagnetic characteristics, deficiencies, and remedial design recommendation.

(3) The Scoring Facility. Provides a means of scoring the effect of interference on voice communications equipment and systems. This facility measures information transfer by use of phonetically balanced (PB) words and a trained listener crew and permits the establishment of equipment performance under conditions of interference and jamming.

(4) Weapon System Electromagnetic Environment Simulator (WSEES). Provides the capability of simulating under precise control duplicates of radio frequency (RF) signals which are representative of those found in the real world and would be associated with tracking, air defense, artillery, and combat surveillance radars, and any other signal within the range of 2-18 GHz.

(5) Field Facility. Provides a capability to field validate laboratory data, measure antenna characteristics and propagation factors, and test equipment that cannot be brought into the laboratory.

(6) Library of Computer Programs. Provides a selection of computer programs which are used as analytic tools for analyses of operational concepts, systems, and equipment. The primary testing tool is the Environmental Interference Effects Model (EIEM).

1/ Military Standard Radio Frequency Spectrum Characteristics, Measurement of, 22 February 1973.

d. Provide artificial antennas (dummy loads) and signal sampling devices; do not use system antennas.

3.3 Field Tests.

a. Normally, test situations will be simulated as indicated in paragraph 3.2. In certain instances, however, field tests may be necessary. In these instances, use methods similar to those indicated but deploy the test item(s) and operate them in an authorized open land area at tactical ranges under operating conditions approximating tactical employment of the item. Create an active ECM electromagnetic environment by use of a ground-based, mobile ECM simulator deployed and operated to realistically represent enemy ECM systems. Conduct passive ECM [interception and direction finding (DF)] tests utilizing mobile instrumentation having the requisite intercept-DF and measurement capabilities.

b. Through special interagency coordination, the field test may be designed to employ actual active and passive ECM systems in lieu of the simulator instrumentation; however, the latter provides more test flexibility and more comprehensive test results.

c. Configure field tests to provide data from all applicable physical and electromagnetic relationships of the test item and the ECM instrumentation. Make extensive arrangements to assure appropriate items are obtained for deployment in the field.

d. Make early contact with the responsible frequency management agency to ensure authorization for radiation in the required frequency bands during the anticipated test interval.

4. TEST CONTROLS.

To assure uniform and repeatable results, consider the following actions and controls as appropriate to the test item:

a. Determine the degree of variance permissible on parameters such as frequency, power level, and sensitivity, and include limits in the appropriate software programs.

b. Approach performance thresholds with increasing J levels followed by decreasing J levels to determine differences in performance.

c. Consider keying sequences; i.e., desired signal on first or jammer on first.

d. Use at least three desired signal levels between minimum sensitivity and receiver saturation to simulate long, medium, and short link lengths.

e. Select low, medium, and high frequencies in the test item frequency band(s).

f. Use three degrees of test link information transfer; i.e., acceptable, marginal, and not acceptable.

g. When required by a specific test plan, or for a full evaluation, include application of the most probable ECCM techniques appropriate to the test item.

h. To reduce the effect of the jamming signal,

(1) Utilize test item receiver adjustments such as detuning RF/AF gain control and bandwidth control.

(2) Increase the test item transmitter power (burn-through).

(3) Set the S level to produce correct information transfer or a normal performance index in the jammed condition. Set the J level to produce effective jamming.

i. Record in detail any ECCM technique or combination of techniques which reduces the degradation caused by jamming. Effective ECCM methods are those which cause a significant increase in performance index.

5. PERFORMANCE TESTS.

5.1 IWS Tests.

5.1.1 Vulnerability of Communication Systems to Electronic Countermeasures (ECM).

5.1.1.1 Objective. The objective of this subtest is to determine whether the test item is vulnerable to electronic countermeasures when operating in its normal configuration, in a simulated environment (utilizing both the unenciphered and enciphered modes, when appropriate to the item).

5.1.1.2 Method.

a. Initially, conduct a search t determine the potentially most effective jamming modulation. Employ various combinations of frequency, modulation index and modulation frequency, pulse width, and pulse repetition rate in each mode of operation appropriate to the item to determine the combinations which cause the worst signal degradation, as measured by the appropriate performance indicator: articulation index (AI) for analog links, bit error rate (BER) for digital links, articulation score (AS) for analog or digital links, or percentage of correct copy (PCC) for teletypewriter links. Use values which correspond to existing data for the test item, or similar items, as a starting point. However, do not limit the methods or procedures to predetermined data but vary them as much as possible to determine the worst case performance. As appropriate, and as a minimum, for all pulse modulations include data stream bit rates or clock frequencies (if clock frequencies and bit rates are not the same) and their multiples. Take precautions to prevent burnout or other damage to the test item.

b. Simulate an appropriate test link configuration with predetermined signal levels providing a specified signal plus noise-to-noise ratio [(S+N)/N)] at the terminal receiver output. Simulate long-, medium-, and short-range links for communication items.

c. Test each link with no jamming present and with worst case jamming. Apply tape recordings of phonetically balanced word lists as the modulating signal to the terminal transmitter. Record the terminal receiver output at each jamming-to-signal ratio (J/S).

d. Evaluate these output recordings with a team of trained listeners to obtain AS. Determine the relationship between AS and AI or AS and BER (see app D).

e. Apply ECCM operational techniques as a separate action following the preceding tests. Repeat the effective jamming using ECCM as applicable to the test item.

5.1.1.3 Data Required. Record the following:

a. Equipment nomenclature

b. Worst case modulating signal characteristics for each ECM mode

c. All S levels (dBm)

d. Appropriate performance indicator (BER, AS, PCC, AI) versus S

e. J value for criterion AI, AS, BER, or PCC, or value 1 dB above loss of synchronization (dBm).

f. J/S (dB)

g. AS versus AI or BER.

h. Record in detail any effective ECCM.

5.1.1.4 Analytical Plan. Prepare a graph of the range of performance versus effectiveness for each ECM mode. Prepare a graph of the range of performance versus the effectiveness of ECCM against the jamming signals. See figure 1 for sample graphs.

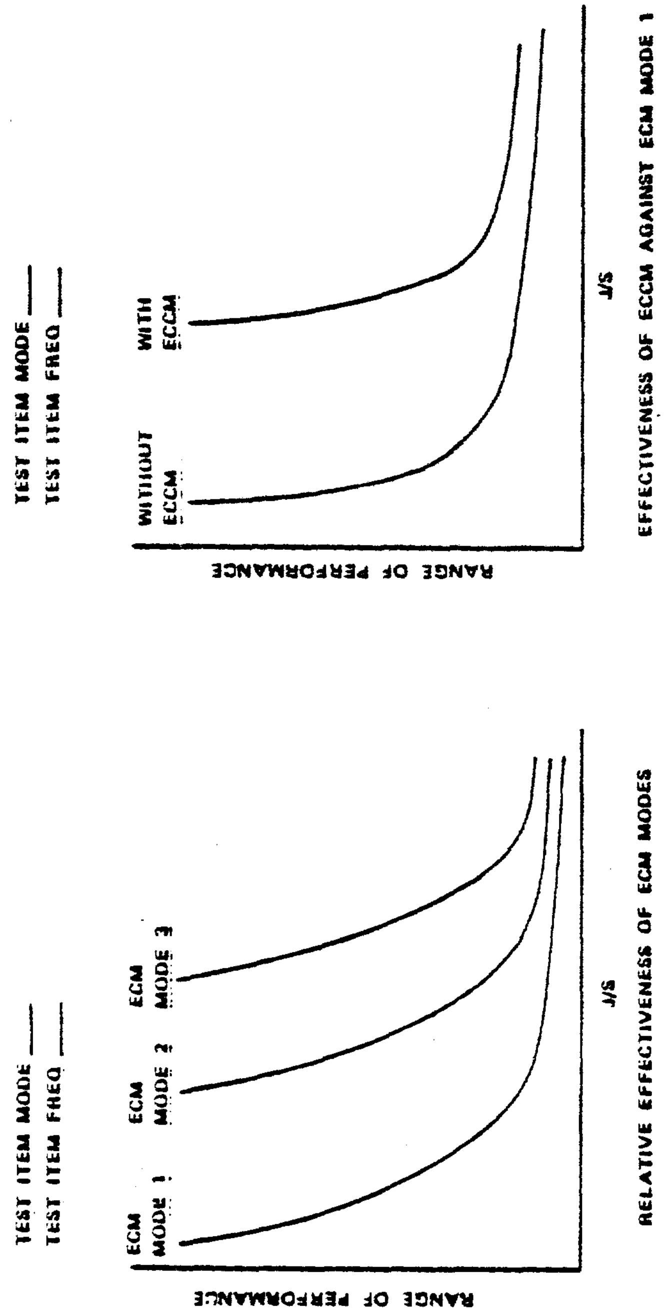

Figure 1. Sample graphs of effectiveness of ECM and ECCM modes.

do not limit the methods or procedures to predetermined data but vary them as much as possible to determine the worst case performance. As appropriate, and as a minimum, for all pulse modulations include data stream bit rates or clock frequencies (if clock frequencies and bit rates are not the same) and their multiples. Take precautions to prevent burnout or other damage to the test item.

b. Simulate an appropriate test link configuration with predetermined signal levels providing a specified signal plus noise-to-noise ratio [(S+N)/N)] at the terminal receiver output. Simulate long-, medium-, and short-range links for communication items.

c. Test each link with no jamming present and with worst case jamming. Apply tape recordings of phonetically balanced word lists as the modulating signal to the terminal transmitter. Record the terminal receiver output at each jamming-to-signal ratio (J/S).

d. Evaluate these output recordings with a team of trained listeners to obtain AS. Determine the relationship between AS and AI or AS and BER (see app D).

e. Apply ECCM operational techniques as a separate action following the preceding tests. Repeat the effective jamming using ECCM as applicable to the test item.

5.1.1.3 Data Required. Record the following:

a. Equipment nomenclature

b. Worst case modulating signal characteristics for each ECM mode

c. All S levels (dBm)

d. Appropriate performance indicator (BER, AS, PCC, AI) versus S

e. J value for criterion AI, AS, BER, or PCC, or value 1 dB above loss of synchronization (dBm).

f. J/S (dB)

g. AS versus AI or BER.

h. Record in detail any effective ECCM.

5.1.1.4 Analytical Plan. Prepare a graph of the range of performance versus effectiveness for each ECM mode. Prepare a graph of the range of performance versus the effectiveness of ECCM against the jamming signals. See figure 1 for sample graphs.

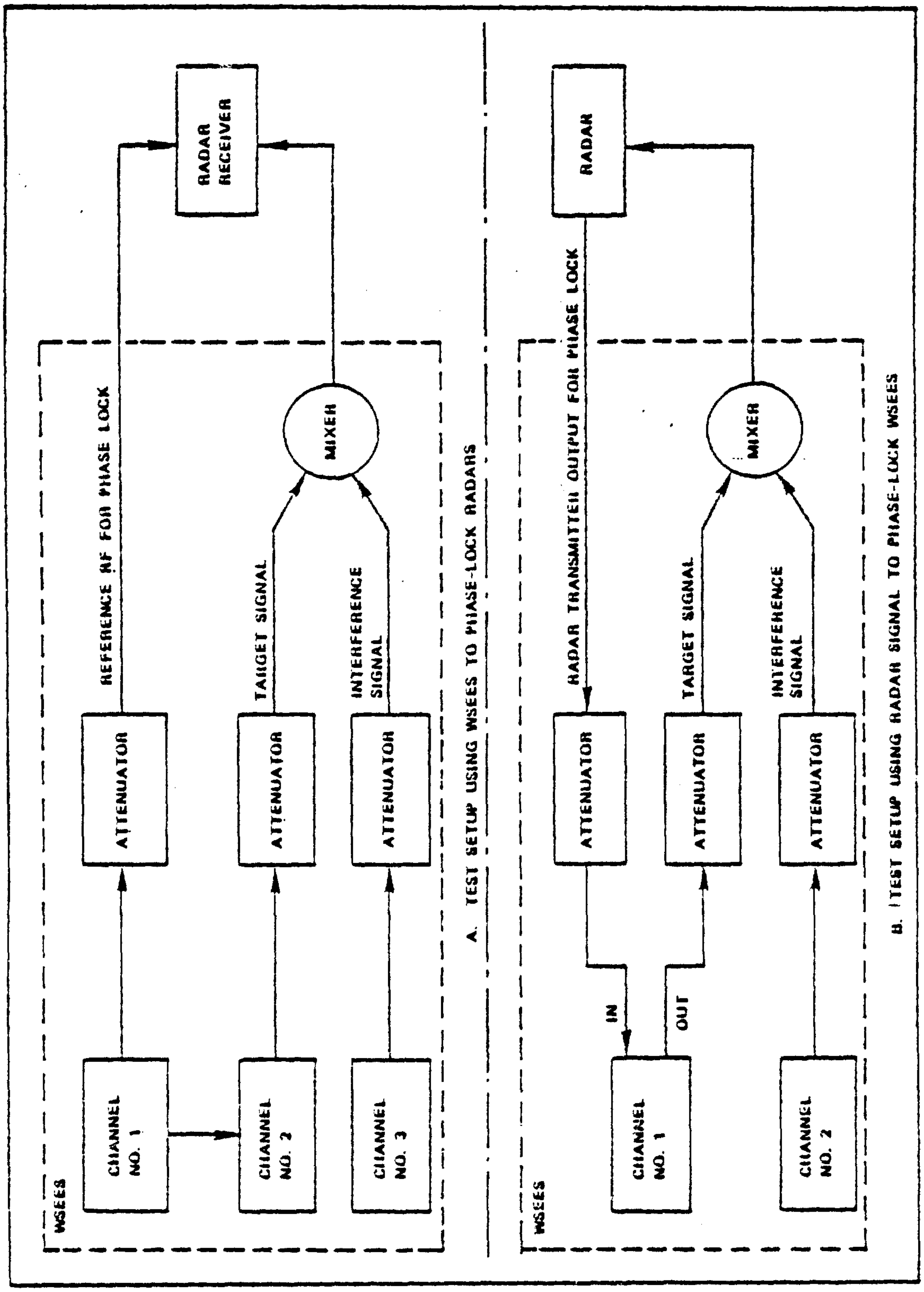

Figure 2. Block diagram of electronic warfare vulnerability test setup.

5.1.2 Noncommunication Systems.

5.1.2.1 Objective. The objective of this subtest is to determine whether the test item's performance in its intended operational electromagnetic environment is (1) degraded in the presence of jamming and (2) vulnerable to detection.

5.1.2.2 Method.

a. Initially, conduct a search to determine potentially effective jamming modulations as indicated in paragraph 5.1.1.2a. Examine equipment characteristics and, based on past experience and engineering judgment, select the jammer characteristics most likely to be effective against noncommunication systems. A radar is specified here as an example of the most common type of noncommunication system. (Navigation systems, distance-measuring systems, remote control systems, and telemetry systems are also noncommunication systems.) Set up the radar or other device as shown in figure 2. Simulate target returns appropriate to the specified ranges of the radar. Subject the radar to jamming with the series of modes determined in the initial search to be effective.

b. Simulate two target types (missile, aircraft, etc.), using a small moving target located at one-half the stated range from the test item and a large moving target located at full range from the test item.

c. Select jamming levels on the basis of interfering power densities at the radar receiver required to produce conditions of jamming threshold and 100-percent jamming. Test a nonjamming (clear-channel) signal condition for each target type and at least five ranges (desired signal levels). Introduce jamming levels in small increments starting at the clear-channel condition, but close to jamming threshold, and determine the J/S at which the criterion performance degradation (10 percent below clear-channel performance) is reached. Continue to increase jamming levels until 100-percent jamming is achieved. Select a number of jamming levels large enough to describe the range of J/S versus degradation.

d. If radar performance cannot be determined automatically, use three different radar operators in each test run. Compare their performance scores. If the individual scores differ by 5 percent or more, rerun the test.

e. Use each combination of variable parameters which comprises a test run until all individual combinations are tested. Include a run with both targets visible to determine the affect on jamming threshold.

f. For each test run, request the radar operator to search in range and judge whether a target is detected in the radar output. The operator will be unaware of the conditions prevailing for any test run. For each set of jamming levels, include two target conditions—target present and no target present—to provide an indication of false targets.

established in paragraphs 3 and 4 by use of the EIEM. In the analysis, evaluate the detectability by a hostile electronic warfare support measures (ESM) activity and account for the nature and extent of the hostile EW threat as determined by the appropriate test bed deployment.

c. After establishing the vulnerability to detection of the test item in its intended environment, determine the electromagnetic compatibility (EMC) as a baseline. Then determine the EW susceptibility data to determine the change in probability of satisfactory operation of the test item when a jammer is turned on. List the probability of target detection scores as a function of J/S level and jamming modulation types.

d. Use RF, power output, and antenna pattern data for the jammers contained in the existing files of information for foreign equipments to determine the jamming levels at the test item. By use of the EIEM and the modified Longley-Rice irregular-terrain propagation model,2/ determine jammer distances for 5-, 50-, and 95-percent jamming effectiveness (see fig. 3).

e. Assure that intercept equipment used in the analysis has sensitivities and antenna gains comparable to those of enemy equipment in the time frame of interest. Calculate the distance to the test item for each intercept equipment and use the EIEM and the modified Longley-Rice irregular-terrain propagation model to determine the probability that the intercept receiver will detect the test item in its operational environment.

f. Evaluate the photographs to determine whether distinctive RF characteristics exist that might aid the enemy.

5.2 Field Tests.

5.2.1 General. Normally, field conditions will be simulated, as in the preceding subtests. However, if simulation facilities are not available or if a validation test is required, a field test may be necessary.

5.2.2 Objective. The objective of this subtest is to determine whether the test item is vulnerable to electronic countermeasures when operated in a representative field environment under representative conditions.

5.2.3 Method.

a. Active Tests

(1) Establish a ground test link with two test item samples, one to function as a victim receiver (VR) located at the test facility

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2/ Longley, A. G. and P. L. Rice, "Prediction of Tropospheric Radio Transmission Loss Over Irregular Terrain—A Computer Method--1968," ESSA Technical Report ERL 79-ITS 67, July 1968 (Revised September 1972).

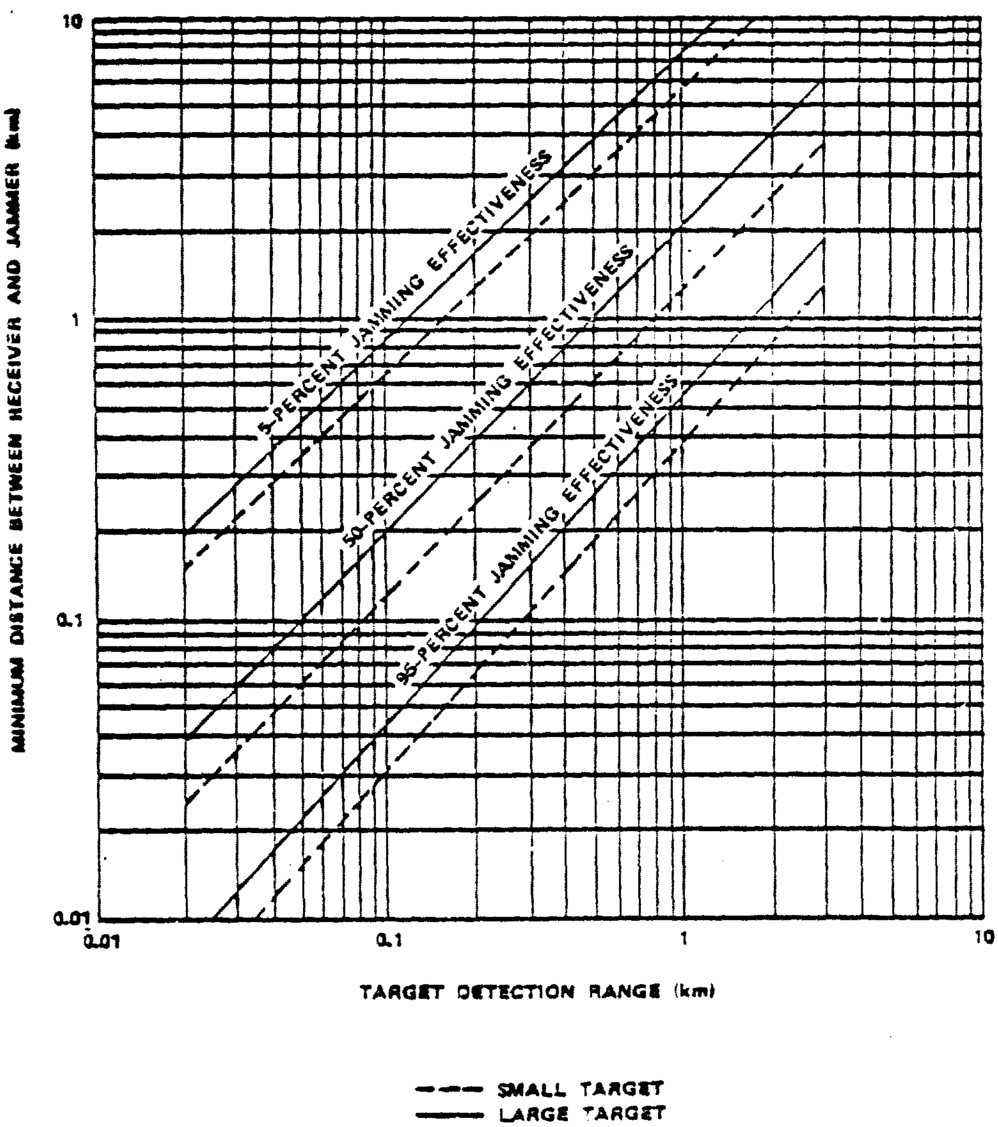

Figure 3. Sample graph of jamming effectiveness as a function of range.

fixed test site and the other to function as the test link transmitter (TLT) deployed at distances representing short, medium, and maximum ranges. In case the longer ranges cannot be obtained within the test facility, reduce the TLT power in calculated increments without degradation of test signal characteristics in order to simulate the longer ranges while the TLT remains at a practicable midrange location. Establish ground radar system test links by providing an appropriate passive target.

(2) For airborne systems, operate the victim receiver of a ground-to-air test link in an appropriate aircraft, which shall fly a prescribed course and altitude. For avionics systems having no ground-based component, such as navigation, altimeter, and surveillance systems, fly the test item and its passive target comprising the test link in appropriate patterns through the ECM environment.

(3) With the VR outputs indicating correct information transfer, measure, at the VR location, the signal levels in the unjammed test link conditions. Designate them S1, S2, and S3. Record the respective ground ranges or slant ranges as R1, R2, and R3 for ground and airborne systems.

(4) Operate the test item at low, center, and high frequencies of its operating band unless it is a single frequency device.

(5) If the test item has the capability of operating in more than one modulation mode, test it in each mode.

(6) For the test link modulation signal, approximate the normal signal form, consistent with the scoring system.

(7) Locate an ECM environmental generator (ECM-EG) with respect to the test link and victim receiver to provide a representative ECM mean field strength at the victim receiver.

(8) If the system has directional characteristics, vary the angular relationship of the ECM-EG and the VR by relocating the ECM-EG to several positions on a 180° arc. Make certain the ECM-EG antenna is pointed toward the test item from any location. To test the system in azimuth, use an airborne ECM-EG. Fly it at several altitudes above ground level (AGL) and from various angles to the test item. Determine the number and location of ECM-EG positions from a study of the test item's antenna pattern and the test area terrain, selecting vulnerable points in back- and side-lobe areas in addition to the angle of attack.

(9) For ground test items/links and for each test condition, vary the ECM-EG power output to produce a decremental change in the test link performance index in a minimum of five steps from threshold to total jamming.

(10) At each step, measure and record the J level at the VR and the test item performance.

(11) For airborne test items, hold the ECM-EG output constant as the aircraft is maneuvered on a prescribed course which provides varying slant ranges to the ECM-EG and TLT. Measure and record the power outputs of the desired transmitter and the jammer and the test item performance in the aircraft at prescribed space positions along the slant range (data points) as determined, called out, and recorded by the test facility tracking radar system. By use of propagation equations, calculate J and S values at the test item.

(12) Specify the number of space position data points to encompass the range from VR threshold to maximum jamming. Select a minimum of five J levels producing decremental performance indexes for use in the data reduction process.

(13) Conduct airborne radar tests at a minimum of three altitudes representing three slant ranges: R1, R2, and R3. Measure and record the power outputs of the desired transmitter and the jammer and the test item performance in the aircraft at prescribed space position data points. By use of propagation equations, calculate the J and S values at the test item.

(14) Modulate the ECM-EG carrier in that mode determined to be most effective in the laboratory test or use all modes which, in the judgment of the test engineer, will approximate a potential ECM environment for the item under test. Use the same mode or combination of modes throughout the test series.

b. Electronic Counter-Countermeasures (ECCM).

(1) Apply ECCM operational techniques during the jamming phases of each active ECM field test. Employ techniques and devices identified in laboratory tests, if available.

(2) Record the results of any ECCM technique or combination of techniques which reduces the degradation caused by any class or level of jamming. Consider this an effective ECCM method.

(3) If the "burn-through" techniques are applicable to the test item, take precautions to prevent damage to the test item.

c. Passive Tests.

(1) Perform these tests with an intercept and direction finding (DF) team located at positions that approximate possible enemy positions and distances.

(2) Using the intercept/DF team, attempt to identify the test item by frequency and test signal.

(3) Obtain bearing and S level measurements on the test item under no-jamming conditions.

(4) Record data for each attempt, including frequency, signal level, bearing, time, and pertinent operational notes.

(5) On directional-type test items, follow a test comparable to the steps in paragraph b above with the following exceptions:

(a) Rotate the test link transmitter (TLT) antenna or complete unit in discrete steps from 0° to 180° with respect to the DF equipment location while maintaining the original (TLT-VR) elevation angle.

(b) With the TLT, transmit normal signals on the test frequency for prescribed time periods.

(c) Perform the intercept, DF, and signal level measurement operations as described above.

5.2.4 Data Required. Record the following:

a. Active ECM Test Data. Record test data developed at each test element, e.g., TLT, VR, ECM-EG, in a form and format compatible with the nature of the activity and configuration of the test. For all test data, incorporate a real-time or facility time code for subsequent data correlation and reduction. Data items shall include but not be limited to—

(1) Topological diagram(s) of field test layout showing distances and positions of test elements for each test condition. For airborne tests, complementary data shall include aircraft attitude and radar space position of flight path, altitude, in-flight data points, and time references.

(2) Terrain profile diagram, or descriptive data.

(3) Test item identification and characteristics.

(4) Test frequencies of the test item and ECM-EG.

(5) Test item modes.

(6) ECM-EG modes.

(7) TLT signal levels at VR-clear channel, at all test frequencies, test link modes, ranges, and orientations.

(8) ECM-EG signal levels at VR at all test frequencies, modes, ranges, and orientations.

(9) VR output score or percent correct system operation at each combination of frequency; test link signal level, range, orientation, and mode; and ECM signal level, range, and mode.

(10) ECCM techniques--narrative description with supporting data, to include--

(a) Prevailing test condition(s).

(b) Significant parameter values.

(c) Degree of performance improvement.

(11) Weather conditions--each test phase/location.

b. Passive ECM Test Data. Record data on a tabular log-type form listing intercept/DF attempts in chronological order and include--

(1) Location of intercept/DF team (map coordinates)

(2) Weather conditions

(3) Time and interval of each attempt

(4) Intercepted signal

(a) Frequency (Hz)

(b) Field strength (μV/m)

(c) Bearing (degrees/TN)

(d) Identification/characteristics/readability

(e) Spectrum analyzer photographs and tape recordings if available.

5.2.5 Analytical Plan.

a. Reduce and correlate the raw data items by manual and automatic data processing methods as appropriate for each test condition. Examples are as follows:

(1) Combine longhand tabular data into tables presenting parameter values for each test condition. Expedite this process by transferring the raw data to computer cards, which are then processed to produce the data in any combination of parameters in printed tabular form.

(2) Interpret, scale, and time-correlate magnetic tape recordings, oscillograph recordings, and photographs of airborne test item operation. Reduce the resulting data to tabular form comparable to (1) above.

(3) Convert J and S levels to equivalent distances with consideration of the actual distances and propagation factors employed.

(4) Convert airborne victim space position data to air-ground slant ranges (distances) at the prescribed points in time.

(5) Compute J/S values for each test condition.

b. Assemble and group reduced data to present the most significant relationships which will lead to a comprehensive evaluation of the test item's ECM vulnerability. Express system or equipment performance (performance index) in terms appropriate to the type of test item; for example, analog communication systems in AS and digital communication systems in BER; noncommunication systems, generally, in percent normal system performance, ranging from usable (100) to unusable (0); or simply "go," "no-go" for systems having bistable output characteristics. The applicable performance index shall be clearly defined in supporting narrative.

6. DATA REDUCTION AND PRESENTATION.

Reduce, present, and analyze the data as indicated in paragraphs 5.1.1.4, 5.1.2.4, and 5.2.4. A sample test data form is included as appendix A.

Recommended changes to this publication should be forwarded to Commander, U. S. Army Test and Evaluation Command, ATTN: DRSTE-AD-M, Aberdeen Proving Ground, MD 21005. Technical information related to this publication may be obtained from the preparing activity (U. S. Army Electronic Proving Ground, ATTN: STEEP-MT-M, Fort Huachuca, AZ 85613). Additional copies of this document are available from the Defense Documentation Center, Cameron Station, Alexandria, VA 22314. This document is identified by the accession number (AD No.) printed on the first page.

APPENDIX A

SAMPLE FORM FOR LABORATORY AND FIELD TEST DATA COMPILATION

Test ____________

Test Item (TI) ____________ TI Mode ________ ECM Mode ________ Date ________

Signal Level (dBm)	F_s ____ F_j ____			F_s ____ F_j ____			F_s ____ F_j ____		
	S_1 ____	S_2 ____	S_3 ____	S_1 ____	S_2 ____	S_3 ____	S_1 ____	S_2 ____	S_3 ____
Test Link Clear Channel	*								
J_1 ____	*								
J_2 ____									
J_3 ____									
J_4 ____									
J_5 ____									

F_s = Test link frequencies (Hz); low, medium, and high of test item band.
F_j = ECM frequencies (Hz).
S_1, S_2, S_3 = Desired signal levels (dBm) at VR; short, medium, and long test link ranges.
J_1, J_2, J_3, J_4, J_5 = ECM signal levels (dBm) at VR, from threshold to maximum jamming.

*Enter scores, i.e., performance index or percent correct information transfer and, when applicable, bit error count.

APPENDIX B
CHECKLIST

1. FACILITIES AND INSTRUMENTATION

Which facilities are required for the test? ____IWS
____SSF
____SF
____WSEES
____FF
____EIEM

Are these facilities scheduled for use?

2. PREPARATION FOR TEST

Is all equipment available? ____
Is the equipment within calibration limits? ____
Are test procedures available? ____
Is software available? ____
Has an operations check on the test item been performed? ____
Have final arrangements for facilities, etc., been made? ____
Are manuals available? ____
Have test personnel been briefed? ____
Is the appropriate test bed available? ____ Approved? ____
Has the threat been determined? ____
Have test parameters been determined? ____
Are data sheets available? ____
Have electronic counter-countermeasures (ECCM) methods been determined? ____
Has the scoring method been determined? ____
Is a mobile ECM-EG van needed? ____
Is the field test geometry laid out? ____
Has a frequency authorization been obtained? ____
Have variances in test parameters been determined? ____
Is the keying sequence important? ____
Have signal levels and frequencies been determined? ____

3. PERFORMANCE TESTS

IWS

Have potentially effective jamming modulations been determined? ____
What is the performance indicator? (AI, AS, BER, other) ____
Are tape recordings needed? ____ Labeled? ____
Have all data been recorded? ____
Have all plots been made? ____
Have all photographs been made? ____ Labeled? ____
Are the data in a format usable by a computer? ____

Field

Is the range radar scheduled? ______
Is on-site coordination established? ______
Is instrumentation on board? ______
Are all data recorded? ______
Are all coordination details for data reduction recorded? ______
Have range radar and DF operators been debriefed? ______

4. ANALYSIS

Is the correct test bed being used? ______
Is the correct computer model being used? ______
Is the computer output in a format usable for analysis? ______
Are all threat equipments being considered? ______
Are all raw data reduced? ______
Is analysis output format usable by the customer? ______
Were any additional findings discovered during testing? ______
Have objectives and criteria of test been answered? ______

APPENDIX C
ELECTROMAGNETIC ENVIRONMENTAL TEST FACILITY

1.0 DESCRIPTION OF THE INSTRUMENTED WORKSHOP.

The Instrumented Workshop (IWS) of the Electromagnetic Environmental Test Facility provides the capability of testing military, cryptographic, and commercial communications equipment performance under precisely controlled laboratory conditions. Two general types of tests are performed: parameter tests and link tests. To ensure accurate, repeatable results, calibration tests are also regularly performed on the equipment being evaluated.

Parameter tests are used to determine those equipment operating characteristics which affect equipment performance. These data are used either as input to the Analytical Facility or as an end item to be furnished to the sponsoring agency.

Link tests are conducted to measure system performance in a rigidly controlled electromagnetic environment. The tests provide data on the performance of communications-electronics equipment exposed to the specific types of accidental and intentional interference found in operational conditions. When the performance of electronic countermeasures equipment is reassured, the effects of jamming on links having known characteristics can be accurately established.

The IWS contains three separate test links, each capable of being controlled by the Automatic Data Collection System. In addition, the Voice Interference Analysis System and the Digital Scoring System are available for scoring test link performance. (The term "scoring" numerically relates equipment performance to operator performance for use in subsequent analysis programs.)

As an example of a link test, a transmitter and receiver to be tested are placed in separate shielded enclosures, and an RF link is established through a coaxial cable and appropriate attenuators. A second transmitter-or other source of interference-located in a third enclosure is used as a controlled interferer. Depending upon the individual task requirements, the interference may represent electrical noise within the equipment, other traffic on the same or nearby channels, or jamming.

The receiver output is then scored by an appropriate device—the Voice Interference Analysis System in the case of analog voice communications equipment or the Digital Scoring System in the case of digital communications systems. When transmissions are to be scored in the Scoring Facility, the transmitter is modulated by a phonetically balanced word tape, and the receiver output is recorded on this tape for later playback at the facility.

1.1 DESCRIPTION OF DIGITAL SCORING SYSTEM (Part of IWS).

The Digital Scoring System (DSS) consists of three basic units integrated into a unified system.

The remote unit, which contains six identical independent data channels, receives the digital data from the sensors connected to the device under test. Either serial or parallel data can be accepted by the remote unit. Logic levels up to ±100 volts can be detected without significant loading of the system under test. Any time delay between the various test points is resolved by the remote unit. The detected digital data are transmitted serially through an optical isolator to the central unit at low bit rates. At high bit rates, the data are serially transmitted directly to the central unit.

The central unit also contains six identical independent data channels. In the central unit, data are accepted from the remote unit and assembled into 16-bit parallel words for input to the control unit. This unit serves as the input formatter for the control unit and creates internally all signals necessary for correct transfer of the digital data to the control unit memory.

The control unit performs the actual comparisons between the specified pairs of digital data channels. The control unit consists of a general-purpose stored-program minicomputer with six identical independent parallel data input channels equipped with block transfer adapters. The block transfer adapters allow the system to achieve maximum data input rates.

Comparison of the bits received by the various data channels is accomplished under the control of the DSS Bit Comparison Program. Each pair of channels is compared separately. Any error found results in the execution of a special error analysis routine within the main program. An error is classified according to length. Single bit errors are counted separately. Any string of bits in error is placed in one of these two error categories and counted accordingly. A running total is kept for each error category. At the conclusion of the test run, the totals for each type of error are printed on a Teletype printer.

The DSS Bit Comparison Program processes data from the test link in real time. Data are read into memory in blocks and two memory blocks are assigned to each active data input channel. As soon as a block is filled for all active channels, processing begins. While one set of data blocks is being compared, the block transfer devices on the input channels are filling the alternate data blocks for each input channel. If the data input rate exceeds the speed at which the data can be processed, a message is printed on the teletypewriter and processing is terminated. The actual data processing speed will vary depending on the number of pairs of channels being compared, the data input rate of the link under test, and the number of errors found.

1.2 DESCRIPTION OF THE AUTOMATIC DATA COLLECTION SYSTEM (ADCS) (Part of IWS).

The ADCS automates many of the functions which occur during link testing of communications equipment. In so doing, the time required to perform a particular set of link tests is reduced significantly, test repeatability is improved, and errors associated with manual data taking are eliminated. Output from the system is available in the form of camera-ready printout and, when desired, as magnetic tape recordings which are then scored by trained listeners in the Scoring Facility.

The ADCS is a totally self-calibrating, self-monitoring test control system. As one of its unique features, the system continuously compares all parameters of the test setup against allowable variations. If an unacceptable variation were to occur, the system would halt the test and provide information to the test operator for action.

The primary elements of the automated link are the test console and the automatic spectrum analyzer. The automatic spectrum analyzer makes all frequency and power measurements for an automated test link. The automatic spectrum analyzer contains a digital computer, a control console, and a test equipment rack. The control console will accept up to three tape cassettes containing the control program. It can be operated from standard library programs, from programs which have been adapted from standard programs, or from special-purpose programs which have been entered manually. A keyboard and video display enable the operator to communicate with the computer.

After the operator has entered the control program and such optional data and test parameters as desired, the automatic spectrum analyzer functions automatically. The test operator thereafter controls the test at the test link console. The Teletype located near the test console prints out all system alarms, requests for new data, revised equipment settings, etc.

When articulation scoring of the test link is required, a phonetically balanced word tape and an output tape are loaded on the tape recorder. The automatic spectrum analyzer is programed to operate the word tape automatically, and the receiver output is recorded for later scoring in the Scoring Facility.

Three totally different types of tests can be run sequentially on a block time-sharing system by the ADCS.

1.3 VOICE INTERFERENCE ANALYSIS SYSTEM (Part of IWS).

The Voice Interference Analysis System (VIAS) provides an automated means of scoring analog (voice) communications links by electronic measurement techniques. The output of the VIAS is a numerical value called articulation index. The articulation index is directly correlatable to the articulation scores obtained by trained listeners in the Scoring Facility.

The VIAS consists of seven voice analyzer sets, a self-check signal generator, a test signal generator, a patch panel, a digital voltmeter, and associated amplifiers and power supplies.

In the VIAS method of computation, the speech frequency spectra between 200 and 6100 Hz are divided into 14 bands. The signal-to-noise ratio (S/N) in each band is determined. This ratio is expressed logarithmically on a scale where unity (fully contributing to speech intelligibility) corresponds to an S/N of 18 dB. Ratios above or below these values are rated as unity or zero, respectively. The individual band contributions are summed and divided by 14. The result is the articulation index. Speech power in any given band contributes after calibration as much to the total articulation index as the speech power in any other band. The bandwidth of each of the 14 bands is carefully chosen to permit the articulation index calculation to be made.

No speech is actually transmitted in the VIAS. Instead, a modulated pilot tone located near the peak of the normal speech spectrum is used to provide a reference level. Because the shape of the speech spectrum is known, the levels of speech can be directly inferred for the machine calculation.

Initially, the set level tone (an unmodulated 950-Hz tone) is adjusted to the audio level at the input to the transmitter-to-receiver, voice-modulated radio link under test. The standard VIAS test signal is then applied for system measurement. The operate signal, a 950-Hz tone triangularly amplitude modulated at 5 Hz, modulates the transmitter. The average output level of the operating waveform corresponds to the average power of the speech waveform. The output voltage of a receiver under test includes components of the pilot tone which represent the speech output and noise components related to the interference.

A filter then separates the pilot tone components from the noise components. The tone provides a slowly varying direct current which controls the gain of the log amplifier. Since the 950-Hz pilot tone has been removed by filtering, the actual output of the log amplifier is the noise component of the received signal. The gain of the amplifier is being controlled by the 950-Hz reference, and therefore the noise amplitude is proportional to the signal-to-noise ratio.

Two shaping networks weigh the frequency distribution of the noise in a manner inversely proportional to the method used with the normal speech spectrum. Thus, at this point in the system, the noise spectrum level at any frequency is made proportional to the noise-to-speech ratio for the same frequency at the input to the system under test.

2.0 DESCRIPTION OF THE SPECTRUM SIGNATURE FACILITY.

The Spectrum Signature Facility provides measurements of C-E equipment characteristics. These measurement data include detailed characteristics of transmitters, receivers, and antennas, all of which can be obtained at all appropriate points in the equipment life cycle.

Measurement capabilities include a fixed laboratory with screen enclosures and mobile (van-type) laboratories for field work. Both the fixed and mobile facilities are equipped as needed to perform all spectrum signature and specialized data measurements under either closed-system or open-field conditions. The mobile laboratories include a high-power signal source (a modified AN/MSM-63), which performs such types of antenna measurements as close coupling, gain, and beamwidths, and also performs high-power effects tests on equipment and systems.

Data are obtained on such receiver characteristics as—

Sensitivity	Pulse and CW Desensitization
Selectivity	Dynamic Range
Spurious Response	Oscillator Radiation
Overall Susceptibility	Audio Selectivity
Intermodulation	Discriminator Bandwidth
Adjacent Signal Interference	

Typical transmitter data include—

- Power Output
- Emission Spectrum Characteristics
- Modulation Characteristics
- Intermodulation
- Modulator Bandwidth
- Carrier Frequency Stability

These data may be used as input to the SIEM computer models and as basic data for EMETF and sponsor development programs.

3.0 DESCRIPTION OF THE SCORING FACILITY.

This unique facility enables us to consider the human operator and his responses to equipment operating characteristics. Listener subjects, under the supervision of a test controller, listen to recordings of a specially selected group of phonetically balanced words mixed with interfering signals. Their responses provide scores for analysis by the sponsoring agency or for input to the Environmental Interference Effects Model.

The Scoring Facility consists of two eight-position listener facilities: one fixed and one mobile. The mobile (van-type) facility is particularly useful in scoring communications equipment when specially trained listeners are available only at the sponsoring agency's location. Each facility is acoustically insulated and contains appropriate high fidelity tape reproducers and headsets. The listener stations are fitted with consoles containing 50 pushbuttons, each representing a test word.

During testing, the tape-recorded material (in the form of spoken test words, or "carrier phrases" containing the test words, which have been mixed with interfering signals) is presented to each listener, who presses the pushbutton next to the test word he thinks he hears. A forced-choice mode of operation demands a response from each listener for each test word, even if it is only a guess, by holding up the next test word or phrase until all listeners have responded.

Performance is measured through use of an articulation score (AS), which is a measure of the percentage of phonetically balanced words in a test message correctly received by a team of trained listeners. These responses are automatically scored by automated equipment associated with the Scoring Facility. Voice communications equipment being scored automatically by the Voice Interference Analysis System (VIAS)—part of the Instrumented Workshop—requires correlation between the results of human scoring (articulation score) and VIAS scoring (articulation index).

Human factors are carefully considered in the selection and training of listener teams. Audiometer tests eliminate subjects having undesirable hearing characteristics. During a 3-week training period, the listener teams are trained on a series of 42 tapes for which standardized scores exist. Thus, as the teams learn scoring techniques, they are also "calibrated."

During subsequent scoring programs, the teams are periodically retested on a no-notice basis with standardized tapes to ensure consistent results and to account for "learning curve" effects. Each team is used for only a limited time, after which the individual members are not used for at least a year. This further eliminates any possibility of undesirable bias in results caused by team members memorizing test word lists.

4.0 DESCRIPTION OF THE WEAPON SYSTEM ELECTROMAGNETIC ENVIRONMENT SIMULATOR

The Weapon System Electromagnetic Environment Simulator (WSEES) was developed to enable controlled and repeatable testing of radars and weapon systems in closed-link configurations similar in concept to communications testing.

The WSEES has the capability of simulating under precise control duplicates of radio frequency (RF) signals which are representative of those found in the real world and would be associated with shell and mortar tracking, air defense, artillery, and combat surveillance radars and any other RF signal within the frequency range 2-18 GHz. These signals include pulse; continuous wave (CW); both pulse and CW doppler; pulse burst pattern; chirp; and pulse, CW, and swept jamming. Up to 32 different pulse signals can be simulated at any one time. These signals may be combined into a single output or individually distributed to any of 12 separate outputs.

Control information is provided to the digital interface by the manual input device, the real-time controller, or the tape units. The digital interface stores control information on as many as 32 emitters and passes these data on to the RF generators when needed. Digital control information is also provided to the power and pulse controller and the remote output signal control. The combination of these three elements produces RF signals with the desired frequency, amplitude, and time and pulse characteristics, switched to the proper output port.

Future weapon systems may have a multiple reaction capability. They will be able to adapt to interference or jamming by changing frequencies and control modes and other electronic counter-countermeasures (ECCM) techniques. To permit rapid testing of these advanced systems, a real-time controller and a steerable platform are incorporated in the WSEES.

The real-time controller operates in a feedback loop with the system under test. In its normal mode of operation, the WSEES generates a signal environment as commanded by precalculated tapes for the operational situation being simulated. When the operational mode for the system under test changes, the real-time controller senses this change and alters, as appropriate, the signals being generated. To accomplish the signal changes or modifications required, the real-time controller must not only sense that a change in the operational situation has occurred, but also adjust the signals to reflect the chan_ .

The steerable platform permits simulation and control of the spatial position of a missile. The real-time controller (by monitoring the signals to the missile control surfaces in respect to the calculated space position and speed of the missile) can change signal simulation and steerable platform parameters to reflect changes in missile position.

The basic characteristics of the RF signal-generating capability of the WSEES are indicated in figure 4.

SIGNALS

- 12 SIGNALS – INTERNAL PRF GENERATORS
- 20 SIGNALS – EXTERNAL PRF GENERATORS
- TOTAL SIGNALS – 32

PULSE GENERATION CHARACTERISTICS

• WIDTH	0.1 TO 200 μs
• RISE TIME	20 TO 300 ns
• FALL TIME	40 TO 600 ns
• REPETITION RATE	20 TO 60,000 p/s
• DOPPLER RANGE	30 Hz TO 100 kHz
• CHIRP	MAXIMUM RATE 2.5 MHz/μs
• PULSE BURST	3 SELECTABLE PATTERN GENERATORS
• CW EMITTER	3 MAXIMUM

FREQUENCY RANGE

(2 TO 18 GHz)

RANGE	
1	2 TO 4.0
2	4.0 TO 8.0
3	8.0 TO 12.4
4	12.4 TO 18

OUTPUT CHARACTERISTICS

• POWER OUTPUT	+16 dBm
• AMPLITUDE CONTROL	0 TO 120 dB

Figure 4. WSEES signal characteristics.

5.0 DESCRIPTION OF THE FIELD FACILITY

The Field Facility has access to an area approximately 40 miles by 60 miles to conduct electromagnetic environmental tests under controlled conditions while retaining the principal elements of operational realism. The area is sparsely populated and is shielded from the urban areas of Phoenix and Tucson, Arizona, by mountain ranges. Other populated areas are sufficiently distant to avoid appreciable electromagnetic interference.

Mobile test instrumentation and a locale with a year-round, near-perfect climate permit the deployment of typical Army systems, subsystems, and equipment in accordance with the situation being analyzed. Testing capabilities include cosite interference evaluations, open-field emission tests, and susceptibility measurements. The Field Facility also provides realistic field conditions for acquiring empirical data in support of computerized analysis.

6.0 LIBRARY OF COMPUTER PROGRAMS.

The Library of Computer Programs of the EMETF provides the capability of computer simulation and analysis of the electromagnetic environment. Representative computer models are—

a. The Environmental Interference Effects Model (EIEM) is a group of analytic routines designed to predict the performance of communications-electronics (C-E) equipments in tactical military deployments. The deployment of military C-E equipments in a tactical situation is called a test bed and provides the location, netting, and equipment employed. The EIEM provides a methodology for the following:

(1) Communicability - How well communications links perform, considering only atmospheric noise.

(2) Compatibility - How well communications links perform with unintentional interference from other spectrum users.

(3) Vulnerability - How well communications links perform under conditions of intentional jamming.

(4) Interceptibility - How well intercept systems (friendly or enemy) receive opposing forces C-E signals.

(5) Total electromagnetic compatibility (EMC) - How well communications links perform with the total interfering environment.

b. The Electromagnetic Radiation (EMR) Model is used to determine electromagnetic radiation levels at specific sites in a deployment of C-E equipment. It provides maximum levels of field strength sorted by frequency band and modulation type. Frequency bands can be specified as input data and can be any width. The model can also be used in a form which finds any signal exceeding threshold levels specified for each band and identifies the source of the signal.

c. The Spectrum Integration Model is used to provide calculated scoring data for input to other interference identification schemes. The Spectrum Integration Model uses measured or predicted transmitter emission spectrum and receiver selectivity curves as input and performs a convolution integral to provide the calculated scoring data.

APPENDIX D
SCORING OF VOICE COMMUNICATIONS EQUIPMENT

The determination of the performance of a voice communications link requires the evaluation (scoring) of the audio output of the link under conditions of controlled interference. This is accomplished by monitoring the audio output to determine the effect of various signal-to-interference ratios (S/I) on the quality of this output. Two types of scoring are generally used for this type of analysis: the articulation index (AI), which is a numerical output from an electronic voice analyzer; and the articulation score (AS), which is determined by a human operator.

AI is a derived measure of intelligibility for analog systems based on weighted S/I in several audio frequency bands of equal intelligibility contribution. AI is measured by means of an electronic voice analyzer that outputs a score from 0 to 1.0 as a measure of the quality of a test tone sent over the test link. If no degradation to the test tone exists, the analyzer assigns an AI of 1.0; if the test tone is completely masked by interference, the analyzer assigns an AI of 0. The AI, monitored and recorded during the conduct of the test, becomes a record of the effect of each interference condition on the analog voice link.

The AS is a measure of the percentage of phonetically balanced words in a test message correctly interpreted by a team of trained listeners. In practice, team members listen and respond to recordings of the test message derived from the output of an analog or digital voice test link into which interference has been interjected. Team subjects are screened to eliminate those whose hearing characteristics are nonrepresentative of the norm and trained on a series of tape message for which standardized scores exist. The purpose of this training is to "calibrate" the response of each team member. Phonetically balanced words are used to the test message so as to be representative of English language sounds. The test message, consisting of word-group recordings, each containing 50 monosyllabic words per group mixed with interfering signals, is played to the listeners and their response is observed. Upon hearing a word, each listener and their response is observed. Upon hearing a word, each listener presses a button on his console corresponding to the word he thinks he hears. After all isteners have responded, the responses are automatically scored by automated equipment. The final result is the AS. The system insures against the memorizing of word lists by using each team member for only short periods of time with at least a year between each period of duty. The system provides for the evaluation of test links under closed-link conditions in a workshop, or recordings taken at remote sites under field conditions may be evaluated at the listener facility.

For communications equipment that has no previous testing history, it may be necessary to establish a correlation between the AI and AS values. This correlation provides a check of the performance of the equipment, in terms of effect on a human operator's understanding, at various

AI and S/I levels. To accomplish this, tape recordings at specific S/I levels are scored by listener teams to obtain the corresponding AS values. It has been found that an AI score of 0.3 generally represents 50-percent intelligibility (AS), and an AI score of 0.7 represents a signal that is nearly 100 percent intelligible.

APPENDIX E
DEFINITIONS

Barrage Jamming - The simultaneous jamming of a number of adjacent channel frequencies.

Burn-through - The ability of both communications and noncommunications systems to operate in a jamming environment due to higher transmitter power output. This enables a radar to overcome the interference and detect a target up to a certain range and enables a communications system to override jamming signals.

Electromagnetic Compatibility (EMC) - A measure of the ability of communications-electronics (C-E) equipments, subsystems, and systems, together with electromechanical devices, to operate in their intended operational environments without suffering or causing unacceptable degradation because of unwanted electromagnetic radiation or response.

Electronic Countermeasures (ECM) - That major subdivision of electronic warfare involving actions taken to prevent or reduce the effectiveness of an adversary's equipment and tactics employing or affected by electromagnetic radiations and to exploit the enemy's use of such radiations.

Electronic Countermeasures Vulnerability Test - A test to determine the ability of C-E equipments and systems to operate in their intended electromagnetic environments at designed levels of efficiency without experiencing unacceptable degradation due to enemy ECM.

Electronic Counter-countermeasures (ECCM) - That major subdivision of electronic warfare involving actions taken to ensure our own effective use of electromagnetic radiations despite the enemy's use of countermeasures.

Electronic Jamming - The deliberate radiation, reradiation, or reflection of electromagnetic signals, including window jamming, with the object of impairing the use of electronic devices by the enemy.

Electronic Warfare (EW) - That division of the military use of electronics involving actions taken to prevent or reduce the effective use of radiated electromagnetic energy and actions taken to insure the effective use of radiated electromagnetic energy.

Electronic Warfare Support Measures (ESM) - That division of EW involving actions taken to search for, intercept, locate, record, and analyze radiated electromagnetic energy for the purpose of exploiting such radiation in support of military operations. Thus, ESM provides a source of EW information required to conduct ECM, ECCM, threat detection, warning, avoidance, target acquisition, and homing.

Lookthrough -

a. When jamming, a technique whereby the jamming emission is interrupted for short periods to allow monitoring of the victim signal during jamming operations.

b. When being jammed, the technique of observing or monitoring a desired signal during interruptions in the jamming signal.

Performance Index - The measure of a test item's capability to perform its design mission under normal, clear-channel conditions and in the presence of fortuitous or intentional electromagnetic interference. The measurement method and index vary with the class of test item; expressed in general terms as percent correct information transfer, percent correct copy, percent accuracy of results, percent correct interpretation of results, or, in some cases, usable-unusable operational results.

Spot Jamming - The jamming of a specific channel or frequency.

Sweepthrough Jamming - A means of jamming over a frequency band wider than that of a spot jammer; that is, by sweeping the carrier frequency of a tunable ECM transmitter over a given band. A single sweepthrough jammer attempts to sequentially jam many different victim systems operating at different frequencies.

Test Link - The RF path established by the test item(s). For communication systems in general, one test item unit operating as the test link transmitter (TLT) and a second as the test link receiver (TLR) or victim receiver (VR).

Vulnerability - A measure of the degradation of the ability of C-E equipment, subsystems, and systems, together with electromagnetic devices, to operate in their intended operational environment because of unwanted response to intentional electromagnetic radiation utilized in electronic warfare.

APPENDIX F
ABBREVIATIONS

AI	articulation index
AS	articulation score
BER	bit error rate
EG	environmental generator
EIEM	Environmental Interference Effects Model
EMR	Electromagnetic Radiation
FF	Field Facility
IWS	Instrumented Workshop
J	jamming signal
J/S	jamming-to-signal ratio
PCC	percentage of correct copy
P_d	probability of target detection
S	desired signal
S/N	signal-to-noise ratio
(S+N)/N	signal plus noise to noise ratio
SSF	Spectrum Signature Facility
TI	test item
TLR	test link receiver
TLT	test link transmitter
TN	true north
VIAS	Voice Interference Analysis System
WSEES	Weapon System Electromagnetic Environment Simulator