A METHODOLOGY TO ENHANCE ELECTROMAGNETIC COMPATIBILITY IN JOINT MILITARY OPERATIONS

Lieutenant Colonel William R. Buckellew, Director of Engineering
Office of the Secretary of Defense (OSD)
Joint Electromagnetic Interference (JEMI)
Joint Test Force (JTF)
Eglin Air Force Base, Florida 32542

ABSTRACT
Electromagnetic interference (EMI) among mutually supporting friendly weapons systems has adversely affected several recent joint service military operations. The Office of the Secretary of Defense, Deputy Director for Defense Research and Engineering (Test and Evaluation) (OSD/DDDRE(T&E)), directed that a study be made of the feasibility of a joint test and evaluation (JT&E) to develop a methodology to identify, characterize, and resolve joint EMI between friendly communications-electronics (C-E) systems using the RF spectrum. Based on the feasibility study, the OSD Senior Advisory Council recommended that a JT&E be conducted. On 7 October 1988, OSD/DDDRE(T&E) chartered the JEMI JT&E. The Air Force was designated as lead service with active participation of the Army, Navy, and Marine Corps.

INTRODUCTION

Increased emphasis by world governments on command, control, communications, and intelligence; precision guided weapons; and an all-weather, operational capability for their military forces in a day or night environment has accelerated the proliferation of electronic systems on war fighting platforms. The Western World's reliance on technological superiority to offset the numerical superiority of the Eastern Block military forces has further increased the West's dependence on electronic systems as force multipliers. In the race to insert electronic systems on existing US platforms or weapons systems in development, the integrators considered interface criteria limited only to those parameters required to accomplish the specific function of the individual "black box."

Intraplatform electromagnetic compatibility (EMC) was the integrators' primary concern. Within individual military services, some integrators went further and investigated interplatform EMC with peripheral systems on other platforms for limited operational scenarios. But, until recently, interplatform EMC responsibility was limited to intraservice consideration. There were no provisions for joint service EMC.

The limited scope of previous EMC considerations has adverse consequences when a multiservice, multiplatform strike force executes a military contingency operation. Depending on the scenario, an operation could require a mix of land, sea, and air platforms of all the services under a joint force commander (JFC).

The JFC must ensure the interoperability of forces
before mission execution in order to apply forces in the most efficient and effective manner. The mix of aircraft, ships, and land units, each with particular electronic warfare (EW), electronic support measure (ESM), electronic countermeasure (ECM), and electronic counter-countermeasure (ECCM) systems, presents a complex array of military electronics for EMI considerations. A methodology needs to be developed for use by developers, planners, and operators to minimize EMI in a multiservice, multiphase strike force. The development, validation, and application of a JEMI methodology would allow:

1. Prediction of EMI between specific systems in a joint scenario mix of land, sea, and air platforms.

2. Testing specific pairs of systems to confirm that joint EMI occurs and develop potential solutions to enhance EMC.

3. Testing and implementation of solutions to prevent adverse effects of joint EMI prior to operational employment.

**JEMI METHODOLOGY**

The potentially large number of DoD systems that can interact to produce EMI would take years to investigate on a one-on-one basis. A logical process must be developed to provide a plan of attack and starting point from which resolution of a joint EMI problem can begin. To be effective, such a process must:

1. Select possible joint EMI source/victim pairs from the number of systems that have a potential for interference.

2. Ensure that a joint EMI problem selected for evaluation is one with operational impact whose resolution would be of significant benefit in joint operations.

3. Allow the evaluation of systems of interest such as those under development or those reported from joint field operations or historical data.

The JEMI methodology, developed during the JEMI feasibility study, has been expanded and continues to undergo refinement during the course of the JEMI JT&E. The JEMI methodology identifies potential EMI problems using results from field operations, historical data bases, and analytical modeling. Operational expertise, engineering analysis, and testing are used to characterize and prioritize the potential EMI problems. The results of the application of the JEMI methodology can be used to resolve EMI problems during the development and acquisition of new systems and to develop engineering fixes or operational workarounds for systems already in the field/fleet. The analytical portion of the methodology is a predictive process that uses progressive refinement during the course of the JEMI JT&E. The JEMI methodology identifies potential EMI problems using results from field operations, historical data bases, and analytical modeling. Operational expertise, engineering analysis, and testing are used to characterize and prioritize the potential EMI problems. The results of the application of the JEMI methodology can be used to resolve EMI problems during the development and acquisition of new systems and to develop engineering fixes or operational workarounds for systems already in the field/fleet. The analytical portion of the methodology is a predictive process that uses progressive refinement of the analysis and the selected operational environment to eliminate noninterfering pairs, defer further analysis on pairs lacking operational significance, and resolve the joint EMI problems for those remaining. The analysis may require a limited number of one-on-one/one-on-few tests to resolve interference issues and validate the predictions. The JEMI methodology can be applied to any scenario such as a joint test, joint exercise, or joint operations plan. The following description of the methodology is presented with consideration of a large-scale joint scenario.

The expanded JEMI methodology shown in Figure 1, consists of 17 steps grouped into three phases. The phases are: (1) identify electronic equipment pairings with potential interference, (2) characterize and prioritize the potential joint EMI interactions, and (3) resolve the interference.

**Phase 1. Identify.** This phase of the methodology initially identifies the equipment to be considered for investigation. It includes parametric analysis and operational assessments to reduce the possible equipment combinations to a workable number of predicted potentially interfering equipment pairs.

1. Apply Scenario (Steps 1-4). The steps include: Step 1 - selecting the specific scenario for application of the JEMI methodology; Step 2 - compiling a list of C-E equipment used in the scenario; Step 3 - identifying equipment of interest for management emphasis, such as equipment under development, or equipment introduced into joint operations; and Step 4 - compiling the concepts of employment (COEs) for the scenario.

2. Identify Potential Pairings (Step 5). Potentially interfering equipment pairs may be identified from field/fleet reports, historical data, or analysis. For a large-scale scenario, potentially interfering pairs are identified based on the frequency occupancy of individual systems. Frequency occupancy is defined to include the tuning range, a tolerance added to the tuning range to account for adjacent signal interferences, harmonics, and broadband noise. The frequency occupancy of transmitters and receivers are compared for overlap to identify potentially interfering equipment pairs.

3. Confirm Tactical Employment (Step 6). The equipment frequency occupancy and the possible employment variations are refined for the operational environment. The range of frequency occupancy for equipment is refined by identifying those portions or slices of the tuning range required in a tactical situation. This information reduces the occurrences of overlap and allows elimination of noninterfering equipment pairs. COEs are used to assess the range of tactical employment possibilities. Equipment pairs that are tactically unsound and/or unlikely to occur are deferred from further analysis.

4. Predict Significant Interference (Steps 7 to 11). In these steps, equipment characteristics are used to identify the frequency separation and spatial relationships that result in predicted interference between equipment pairs. Harmonics and spurious emission products are considered. In Step 7, the equipment parametric data required to determine the frequency and distance separation relationships are obtained and assessed for subsequent analysis. Step 8 establishes receiver degradation criteria. Initial interference thresholds for receivers can be derived from C-E receiver performance degradation handbooks or available measured data. Interference thresholds relate receiver performance degradation to the ratio of interference-to-noise (I/N) at the input to the receiver detector. In Step 9, the frequency distance (F/D) separation relationships required to avoid interference are determined for the potentially interfering equipment pairs. The DoD Frequency-Dependent Rejection Calculation (FDRCAL) model is used to determine F/D separation criteria, which are presented as F/D curves.
The JEMI Methodology

1. Select Scenario
2. Compile / Review Equipment Lists
3. Identify Equipment of Service Interest
4. Compile Concepts of Employment
5. Identify Potential Pairings
6. Confirm Tactical Employment
7. Data Assessment
8. Establish Degradation Criteria
9. Parametric Analysis (FDRCAL)
10. Sort F/D Curves
11. Introduce Antenna-to-Hardware (Back door) Interference

Apply Scenario
   Identify Potential Pairings
   Confirm Tactical Employment
   Predict Significant Interference
   Confirm Significant Interference Prediction
   Refine Significant Interference Prediction
   Prioritize Significant Interference
   Analyze/Test Unresolved Issues
   Identify and Develop Alternative Procedures

12. Confirm Significant Interference Prediction
13. Detailed analysis/Refine F/D curves
14. Scenario Analysis
15. Prioritize Significant Interference
16. Analyze/test unresolved issues
17. Develop alternative procedures, guidelines, and employment concepts that deconflict, control or minimize friendly EMI in joint operations.
The F/D curve shows the frequency and distance separation requirements for two pieces of equipment (source/victim) to operate without interference. Figure 2 presents a sample F/D curve. Although there is some uncertainty due to equipment operating parameters, victim degradation criteria, predicting propagation conditions, and observing interference in the victim equipment, EMI would be expected in the area below the curve and not in the area above. In Step 10, the equipment pairs, F/D separation curves, and operational information are sorted to facilitate the subsequent ranking. Step 11 is used to introduce antenna-to-hardware (back door) interfering pairs obtained from historical records.

![Figure 2. Sample F/D curve](image)

**Phase II, Characterize and Prioritize.** In this phase of the methodology, the operational significance of the potentially interfering equipment pairs is confirmed. Parametric analysis is performed using refined interference thresholds to resolve some predicted interferences and reduce the number of equipment pairs. The remaining interfering pairs are prioritized in the context of the scenario.

1. **Confirm Significant Interference Predictions (Step 12).** Not all predicted interferences are operationally significant. In this step, the extent and operational impact of remaining potentially interfering equipment pairs are assessed. Equipment pairs considered operationally significant progress to subsequent steps in the methodology.

2. **Refine Significant Interference Predictions (Steps 13-14).** In these steps, sufficient information on each potentially interfering pair is compiled to support a decision of its operational priority. In Step 13, the initial interference levels defined for receivers in Step 8 are refined to a level that reflects system performance degradation. In Step 14, refined separation criteria for an equipment pair are compared with examples from the scenario to assess the occurrence and impact of each predicted interference, and the difficulty in resolving it. Specific details are determined from the scenario laydown and dynamics. This assessment serves to determine, for each predicted equipment pair, whether the interference occurs (when interference criteria are met) and its impact on operations. Feasibility of frequency deconfliction, tactical deconfliction (spatial or temporal), and alternative procedures or workarounds are assessed as potential resolutions to the joint EMI.

3. **Prioritize Significant Interference (Step 15).** The list of equipment pairs and associated information (interference impact, possible workarounds, etc.) is reviewed to determine operational priority.

**Phase III, Resolve.** In this phase of the JEMI methodology, equipment pairs are tested to confirm and characterize predicted interference and alternative operational procedures, guidelines, and employment variations that control or minimize friendly interference in joint operations are developed.

1. **Analyze/Test Unresolved Issues (Step 16).** After the methodology has predicted interference for an equipment pair and the pair is prioritized as operationally significant, testing may be required to verify or better characterize the interference or the impact of the interference. Test candidates are chosen based on operational priority, resources (funds and time) available, and cost/benefit of the test.

2. **Identify and Develop Alternative Procedures (Step 17).** Using the test data and refined predictions of the potentially interfering pair, possible measures to reduce or eliminate the potential for joint EMI problems are investigated. These include frequency and time-sharing considerations and operational restrictions regarding power, antenna coverage, and location. Potential solutions to resolve joint EMI for an equipment pair are options for consideration in operational employment. When required, a test is executed to verify the feasibility of an employment variation.

**JEMI JT&E ACTIVITIES**

The primary task of the JEMI JT&E is to validate the JEMI methodology. The JT&E intends to conduct a series of one-on-one tests of predicted interfering equipment pairs and a large-scale operational test to support the validation task. The equipment pairs were identified by the application of the JEMI methodology to a large-scale scenario, chosen for the JT&E because it contains equipment and mixed-force operations representative of most joint scenarios. The results of the one-on-one tests will be used to validate the JEMI methodology and develop methods to reduce the effects of the identified EMI.

Following these tests, the large scale operational test will be conducted using the one-on-one test pairs and additional equipment resident on the test equipment platforms. The large scale test will verify (1) one-on-one test results in a more dense, operationally representative environment, (2) interference predictions on the untested equipment, (3) predictions of both interference and noninterference, and (4) alternative procedures and workarounds developed to reduce the effects of joint EMI. The results of the large scale test will be used to validate the JEMI methodology.

Upon completion of the JEMI JT&E, the JTF will turn over the JEMI methodology, analytical tools, procedures, and data bases to an organization to provide institutionalized management for the joint EMI problem. This organization will assist developers, planners, and operators in minimizing the impact of EMI on joint operations.
SUMMARY

With increasing employment of electronic systems, joint EMI will continue to be a concern. The JEMI methodology is designed to identify and characterize interference between friendly systems likely to be employed in joint operations. The methodology prioritizes the interference so resources can be efficiently used to minimize the impact of joint EMI.

Once validated, the JEMI methodology will be a tool that can be applied to the development, acquisition, and employment of electronic systems to enhance the electromagnetic compatibility in joint operations.

REFERENCES