A Computer-Aided Design Technique for EMC Analysis

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Abstract — This paper presents the results of an electromagnetic compatibility (EMC) analysis of an HF communication antenna system on a Navy ship using computer-aided design tools and engineering workstations. Shipboard EMC computer modeling techniques are addressed. Geometric representation of the ship and antenna system is extracted from a 3-D solid drawing. The geometry and segmentation pre-processing checks of the wire grid model are color-coded by the numerical electromagnetic code (NEC4). The predicted antenna performance results are post-processed by NEEDS 3.0, which provides two- and three-dimensional plots for visualization. Co-site EMC analysis of the HF communication system is determined by the Communication Engineering Design System (COEDS 2.0) running the Cosite Analysis Model (COSAM 3.0).

INTRODUCTION

The Navy ship installation is based on the Non-Developmental Item (NDI) and Commercial Off-The-Shelf (COTS) programs. The initial ship installations used the “Proof of Concept” approach. The topside antenna placement decisions were based mostly on locations still available. The COTS equipment selections were based upon availability, size, weight, cost, and performance. No formal shipboard topside design study (scale brass model or computer-aided design [CAD] techniques) was performed to determine the EMC of the communication system and the best antenna locations for the installations.

Due to the lack of a topside design study, the existing primary and secondary HF transceiver systems exhibit severe loss of system capability that preclude simultaneous use. The objective included analyzing the existing baseline HF topside antenna placement, defining and evaluating the antenna isolation deficiencies, and proposing solutions to any identified deficiencies using CAD techniques.

THE APPROACH

Computer modeling of antennas and communications equipment has become a powerful engineering tool for the design and arrangement of shipboard antenna systems. Under the NAVSEA Electromagnetic Engineering (EMENG) Program, several workstation tools have been adapted for designing the exterior RF systems of the naval systems for Navy ships. The complementary CAD workstation pair used for this study are the Numerical Electromagnetic Engineering Design System (NEEDS 3.0) and the Communications Engineering Design System (COEDS 2.0) [1-3]. The NEEDS 3.0 workstation supports the topside engineer in the application of the Numerical Electromagnetic Code-Moment of Moments (NEC-MoM) to determine the antenna performance parameters for EMC. The COEDS workstation supports the topside designer in the application of the Co-site Analysis Model (COSAM3) to determine the co-site communication system interferences for EMC. COEDS workstation was used to determine the required antenna to antenna isolation, and NEEDS workstation was used to predict the achieved antenna to antenna isolation.

Given a proposed RF system design, a topside designer sets the requirements for isolation between transmit and receive antennas. The required antenna isolation is based on the assumption that a receiver is operated in a noise-limited environment, and every co-site interference should be less than the maximum of either receiver or ambient noise. In the case of HF, usually ambient noise is the limiting condition.

The most labor-intensive part of any NEC-MoM modeling is in setting up the wire grid geometry in a form the computer can use. To be cost-effective in the construction of the NEC-MoM model, an efficient method is needed to obtain the geometrical representation of the ship. Recent advances in the CAD graphical drawing package allow the architectural drawings and engineering systems of the naval ships to be put together using solid modeling. Figure 1 is a snapshot of the CAD solid drawing of the ship obtained from the Navy shipyard. Various commands of the Intergraph Engineering Modeling System (EMS) 2.2 on the CAD-II workstation were used to create the wire elements. One set of commands was used for extracting wire segments from certain solid model surfaces. To maintain connectivity to adjacent wire elements, some wires were redrawn after extraction from the surface. Solid surfaces with high degrees of curvature, such as the ship hull, required that another set of commands be used. These commands involved creating an intersecting plane drawn through the solid surface, and a wire element was created on the plane at the point of intersection. The 1,820-element wire grid model of the ship was extracted from the CAD solid drawing. This is the first successful project to use a CAD solid model representation of a naval ship to create a wire grid model. This technique resulted in the most accurate and cost-effective wire grid model developed for a ship in numerical modeling history.

The NEEDS 3.0 workstation supports the topside engineer in the application of the NEC-MoM to determine the shipboard antenna performance parameters for EMC. Pre- and post-processing tools in the form of two-dimensional plots, three-dimensional displays, and color-coded visualization are available in NEEDS to help the topside designer in rapid wire grid model inspection and manipulation of NEC4 results. A three-dimensional wire grid model of the ship with segmentation color-coded preprocessing display is given in figure 2. With NEEDS aid in the wire grid model connection and segmentation checks, the antenna performance parameters were predicted by NEC4 with confidence. Current distribution, impedance, near-field, far-field, and antenna isolation results were post-processed by the NEEDS workstation, which then provided visualization. The volumetric results of the near-field analysis indicating the Hazardous Electromagnetic Radiation to Personnel (HERP) is given in figure 3. The magnitude of 57,120 individual near-field points is displayed by color-coded spheres. Using the NEEDS, a coupling loss study is performed to predict the achieved antenna-to-antenna isolation.

The COEDS 2.0 workstation supports the topside designer in the EMC analysis of the communication system in the co-site environment. The analysis is performed using Co-site Analysis Model (COSAM) 3.0. Two major co-site interference interactions that have the greatest impact in the topside design are Receiver Adjacent Signal (RAS) and Transmitter Adjacent Signal (TAS) or broadband transmitter noise. The COEDS EMC mathematical model database was developed from the measurement data obtained from the manufacturer. The measurement data included insertion loss and selectivity curves for antenna coupler and pre/post selector filters, broadband noise for transmitter, and adjacent signal for receiver. The required antenna isolation is calculated in terms of the interference generated from the communication system. Using the COEDS, an EMC study is performed to calculate the required antenna-to-antenna isolation.
amplifier, and a transceiver. An optimal EMC tradeoff matrix (figure 5) indicates required antenna space isolation for various receiver and transmitter configuration, including the effects of additional filtering and transmitter power management. Minimum achievable frequency separation assignment is indicated for each receiver and transmitter pair.

### EMC Mitigation Techniques

![EMC Mitigation Techniques](image)

1. Change Antenna Locations
2. Attenuation Antenna Isolation
3. Additional Filtering
4. Power Management
5. Change Requirements

### EMC Interaction Matrix (Deficiency in dB)

![EMC Interaction Matrix](image)

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<th>Source Frequency Separation</th>
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### REFERENCES

