Analysis of Mutual Coupling of Antennas on a 47-Foot Coast Guard Vessel

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Statement of the Problem

- Interference is present between communications transmitter and receiver on vessel.
- Interference is present between Direction Finding (DF) system and communications receiver on vessel.
- Current antenna configuration does not provide adequate isolation between transmitter and receiver VHF antennas.
- Antenna locations of alternative antenna configurations had to be confined within a certain volume on board vessel.
Objectives

- To predict and measure antenna-to-antenna mutual coupling in the presence of vessel and sea water for original antenna configuration.
- To attain confidence in analysis technique from comparisons of mutual coupling predictions with available measurements.
- To predict by numerical EM analysis techniques the mutual coupling of alternative antenna configurations on vessel that would have the potential to increase isolation between antennas.
- To Propose alternative antenna configurations from analysis results that would increase isolation and reduce interference on board the Coast Guard vessel.
Analysis

- Antennas on a metallic Coast Guard vessel on the sea do not perform as if they were in free space or over a perfectly conducting ground plane.
- The vessel structure and sea have a very significant effect on the performance of a shipboard antenna.
- Computational electromagnetics using analytical mathematical expressions are difficult to apply to these practical problems.
- The use of numerical techniques such as method-of-moments with the Numerical Electromagnetics Code (NEC-4) makes the solution of this analysis problem more tractable.
NEC Modeling

• NEC-4 can model near and far fields and can also be used to predict mutual coupling between antennas on a metallic structure.
• The method-of-moments analysis technique in NEC-4 requires that antennas and related structures be modeled with wire segment lengths of one-tenth wavelength or less.
• Only wire segments were used, since there is more flexibility and freedom in building the model structure.
• Engineering drawings of the vessel were used to create the wire model.
• The boat model includes a detailed simulation of the antennas on the vessel.
• Just under 10,000 wire segments were used to create the model.
Computation of Mutual Coupling

- Mutual coupling calculations require using multiple runs of the NEC model of the entire vessel plus antennas.
  - Determine impedance of the antenna in the complex environment.
  - Match the antenna impedance for the environment.
  - Load the receiver antenna with a suitable load.
  - Compute the induced current in the receiver antenna and load impedance with interference source energized.
  - Compute the received power in the load using the NEC determined current.
  - Compute the ratio of received power to transmitted power to determine the mutual coupling.
Mutual Coupling Between Collinear Dipoles

Dielectric Mast Predicted Isolation With Vessel
Metal Mast Measured Isolation Without Vessel
Metal Mast Predicted Isolation Without Vessel
Dielectric Mast Predicted Isolation Without Vessel

Center-to-Center Collinear Dipole Antenna Separation (m)

Isolation (dB)
47-Foot Coast Guard Vessel
47-Foot Coast Guard Vessel
Antennas on 47-Foot Coast Guard Vessel
NEC Model of Coast Guard Vessel
Original Antenna Configuration
(Predicted Isolation = 21.5 dB)
(Measured Isolation = 22.5 dB)
Azimuth Antenna Patterns of Original Antenna Configuration
Antenna Configuration for Scenario 4
(Predicted Isolation = 25.9 dB)
Antenna Configuration for Scenario 8
(Predicted Isolation = 27.9 dB)
Antenna Configuration for Scenario 9
(Predicted Isolation= 35.9 dB)
Azimuth Antenna Pattern for Scenario 9
Comparison Between Port Antenna Azimuth Patterns of Original and Scenario 9 Configurations
Comparison Between STBD Antenna Azimuth Patterns of Original and Scenario 9 Configurations

AZ Antenna Pattern For STBD Antenna of Scenario 9 Configuration
AZ Antenna Pattern for STBD Antenna of Original Configuration

Gain (dBi)
During on board measurements of the VHF communication system, significant interference from the DF system was observed. An analysis of the mutual coupling between the DF antennas and the current communications antenna configuration was performed. The isolation was determined by analysis to be 23.9 dB between the DF antennas and the communications receiver antenna. The isolation was measured on board the vessel to be 23.0 dB. This information can be used to perform an interference analysis.
Conclusions

• Antenna-to-antenna mutual coupling on board a Coast Guard vessel can be predicted by numerical analysis techniques with reasonable accuracy.
• Confidence in the analysis technique was obtained by comparing predictions to measurements.
• Mutual coupling between antennas on board the vessel for proposed alternative antenna configurations can be obtained without having to build them and measure performance.
• Antenna patterns of antennas in the presence of the vessel and sea can also be obtained by analysis.