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

Nick DeMinco
U.S. Department of Commerce
Institute for Telecommunication Sciences
NTIA/ITS.E
325 Broadway
Boulder, Colorado 80305-3328
303-497-3660
ndeminco@its.bldrdoc.gov

Institute for Telecommunication Sciences
Boulder, Colorado

Outline

- Statement of the Problem
- Objectives
- Predicted and Measured Mutual Coupling Between Two Collinear Antennas
- NEC Wire Model of Coast Guard Vessel
- Original Antenna Configuration with Measured and Predicted Mutual Coupling
- Three Alternative Antenna Configurations That Could Reduce Mutual Coupling
- DF Antenna System to Communication System Predicted and Measured Mutual Coupling
- Conclusions

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.

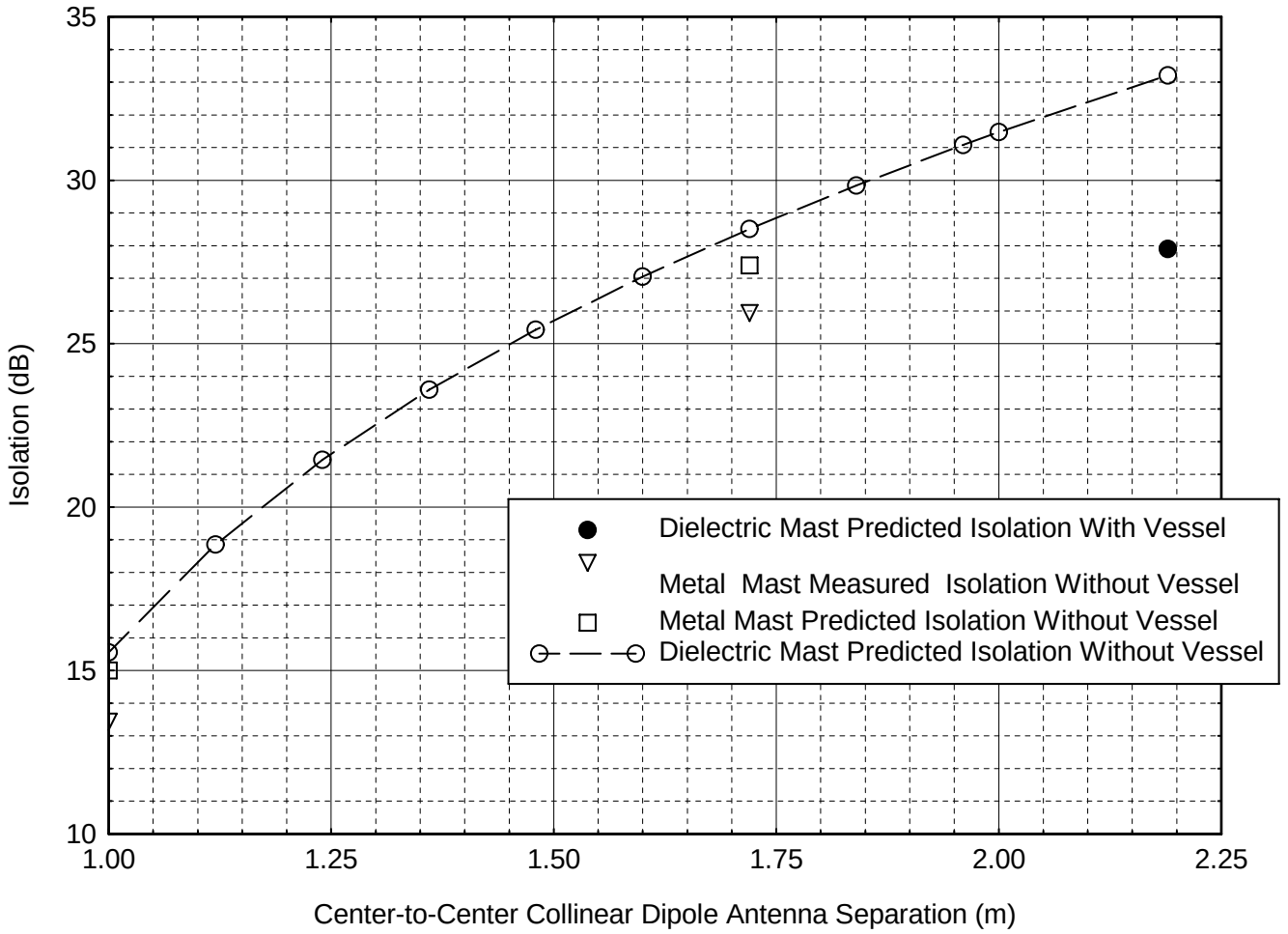
NEC Modeling

- 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



Institute for Telecommunication Sciences
Boulder, Colorado

47-Foot Coast Guard Vessel

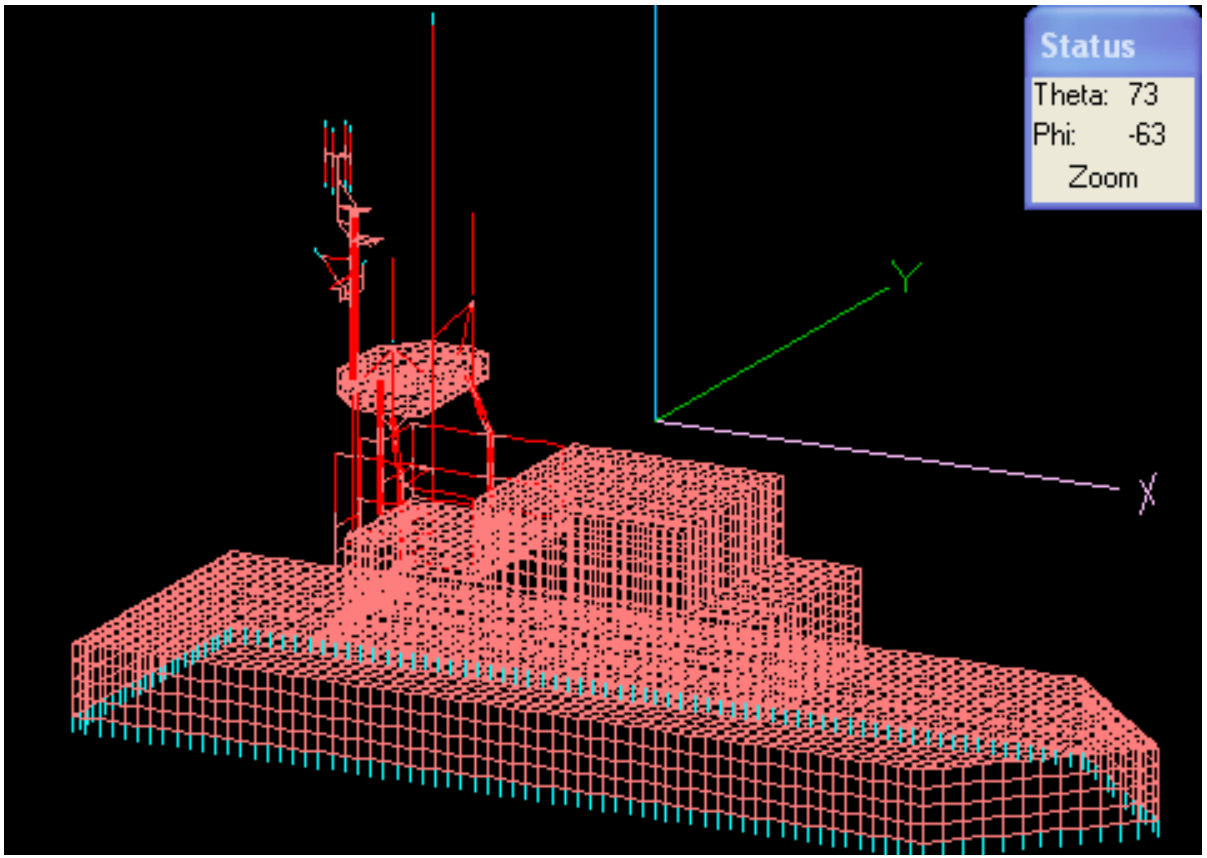
ITS Institute for Telecommunication Sciences
Boulder, Colorado

47-Foot Coast Guard Vessel

Institute for Telecommunication Sciences
Boulder, Colorado

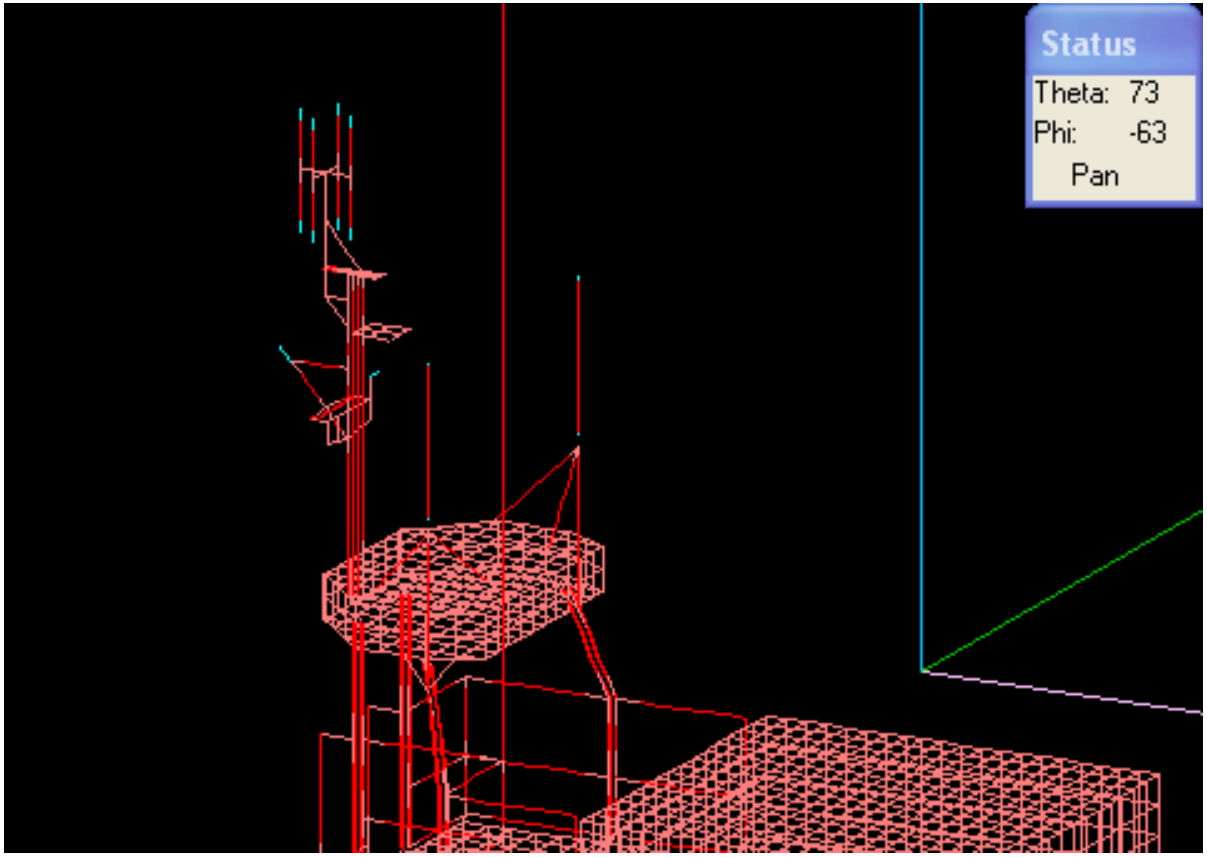
Antennas on 47-Foot Coast Guard Vessel

NEC Model of Coast Guard Vessel

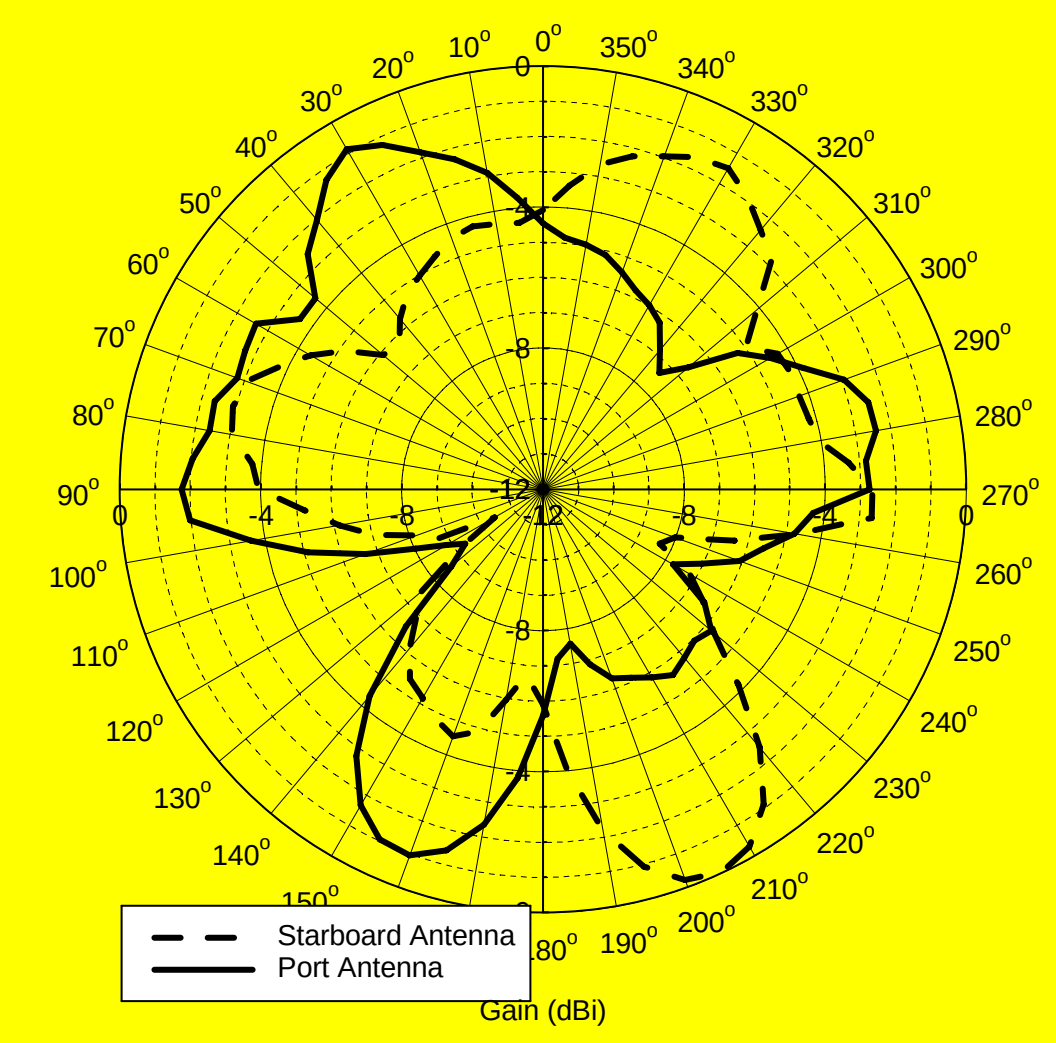


Institute for Telecommunication Sciences
Boulder, Colorado

Original Antenna Configuration
(Predicted Isolation = 21.5 dB)
(Measured Isolation =22.5 dB)

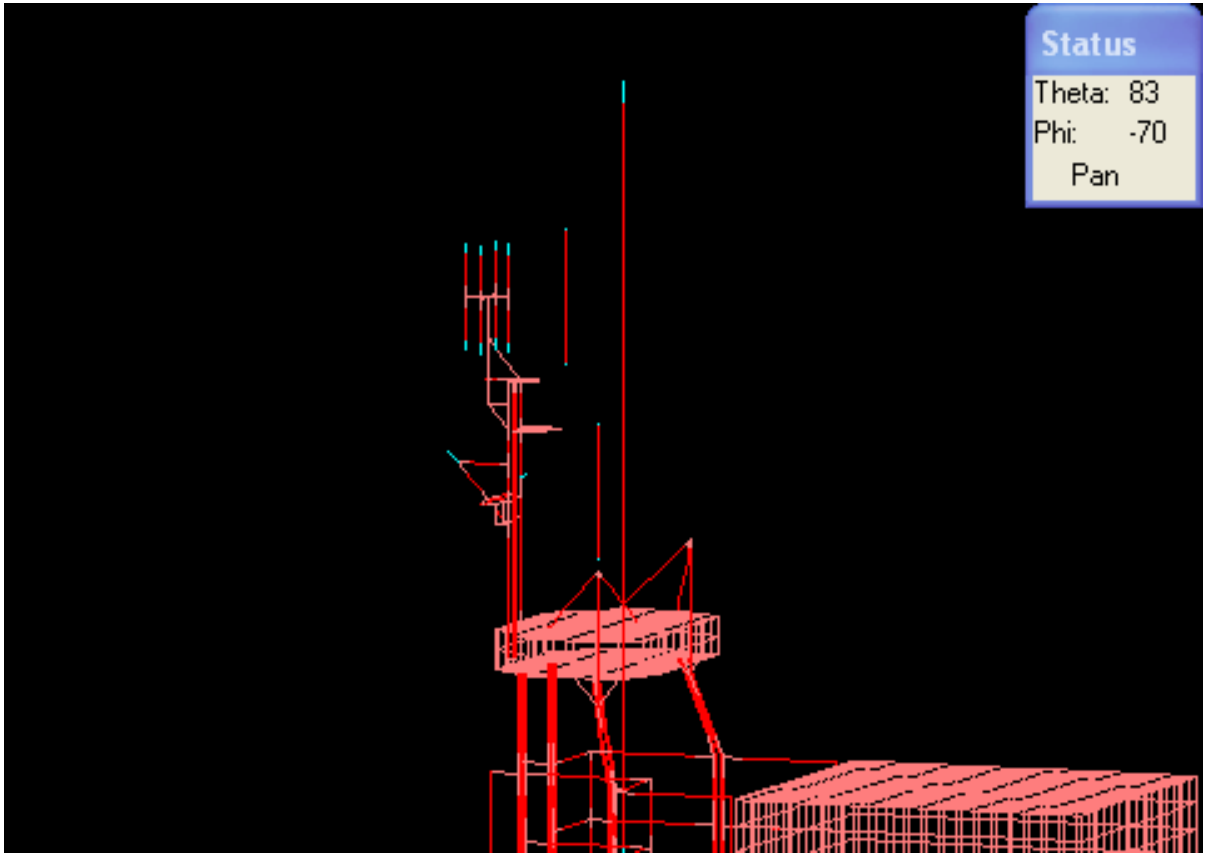


Azimuth Antenna Patterns of Original Antenna Configuration



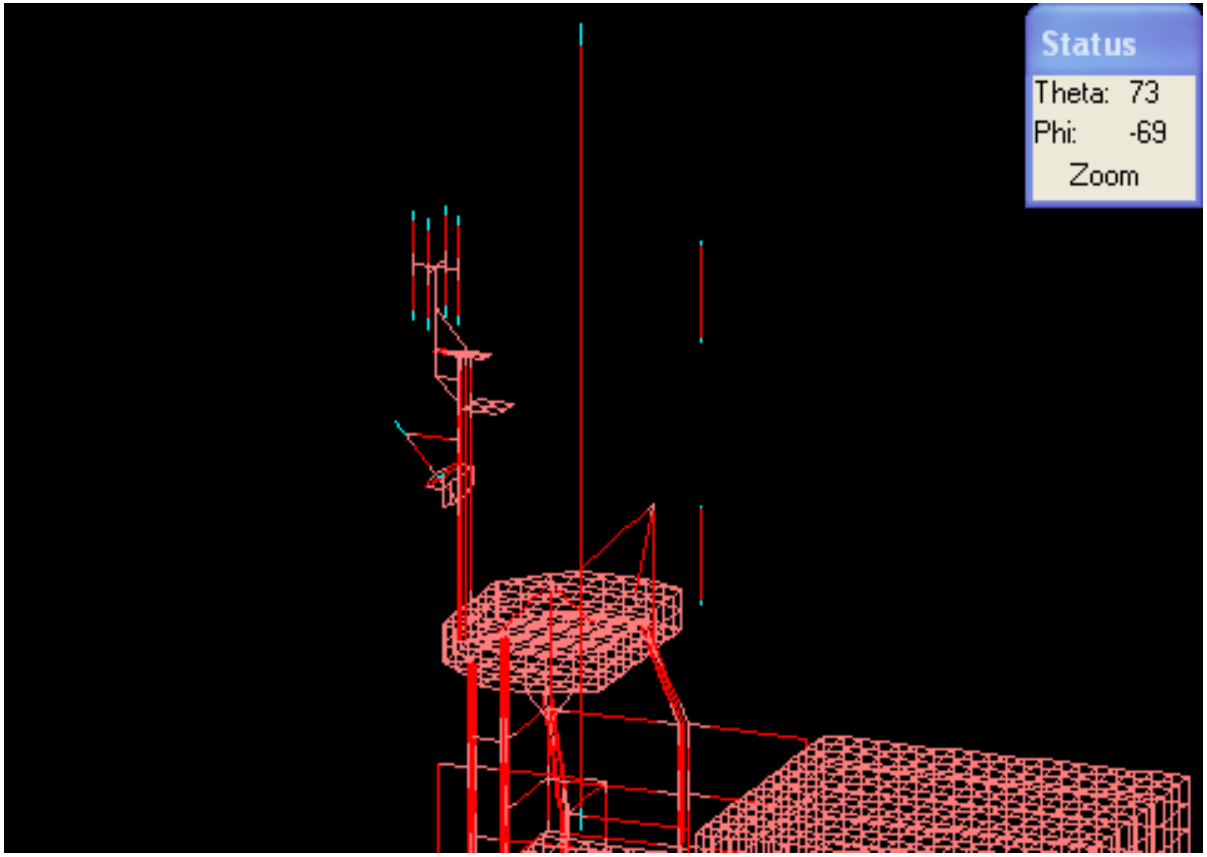
Institute for Telecommunication Sciences
Boulder, Colorado

Antenna Configuration for Scenario 4
(Predicted Isolation = 25.9 dB)



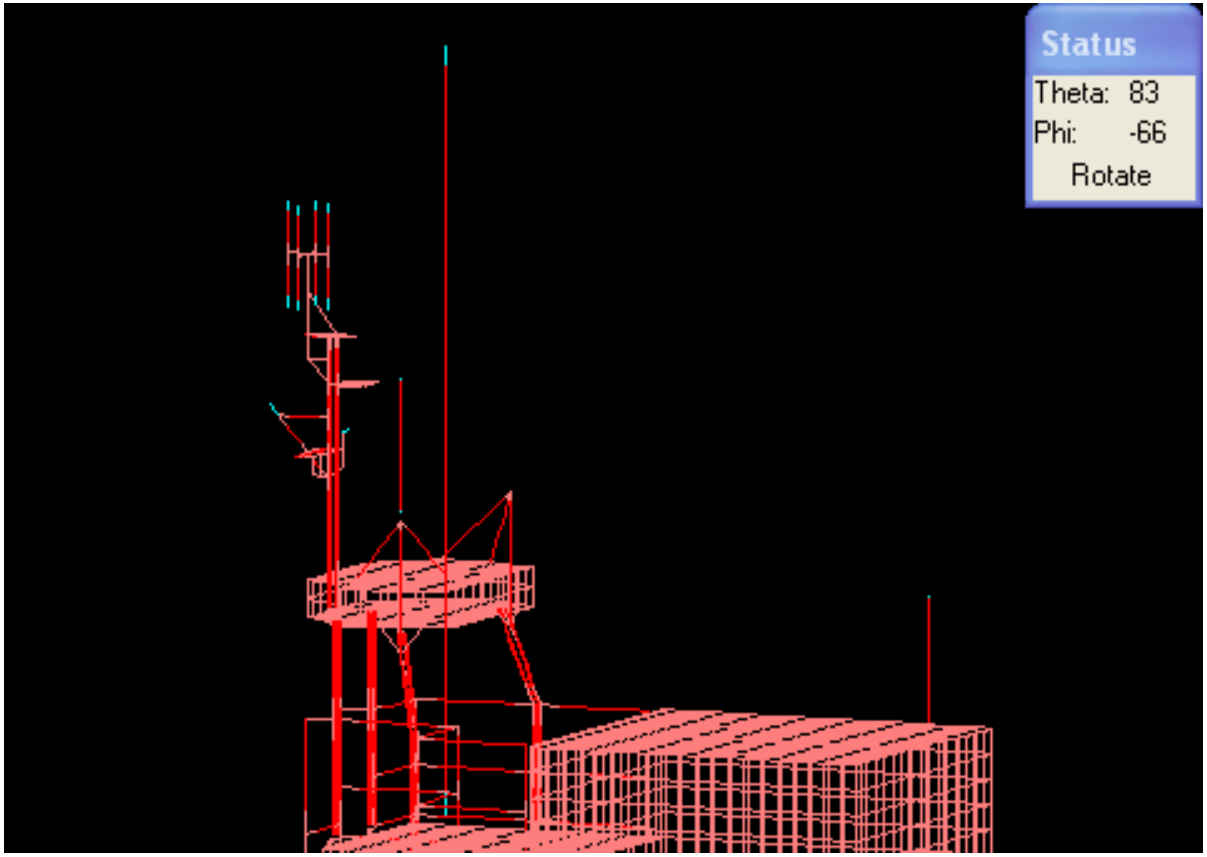
Institute for Telecommunication Sciences
Boulder, Colorado

Antenna Configuration for Scenario 8
(Predicted Isolation = 27.9 dB)



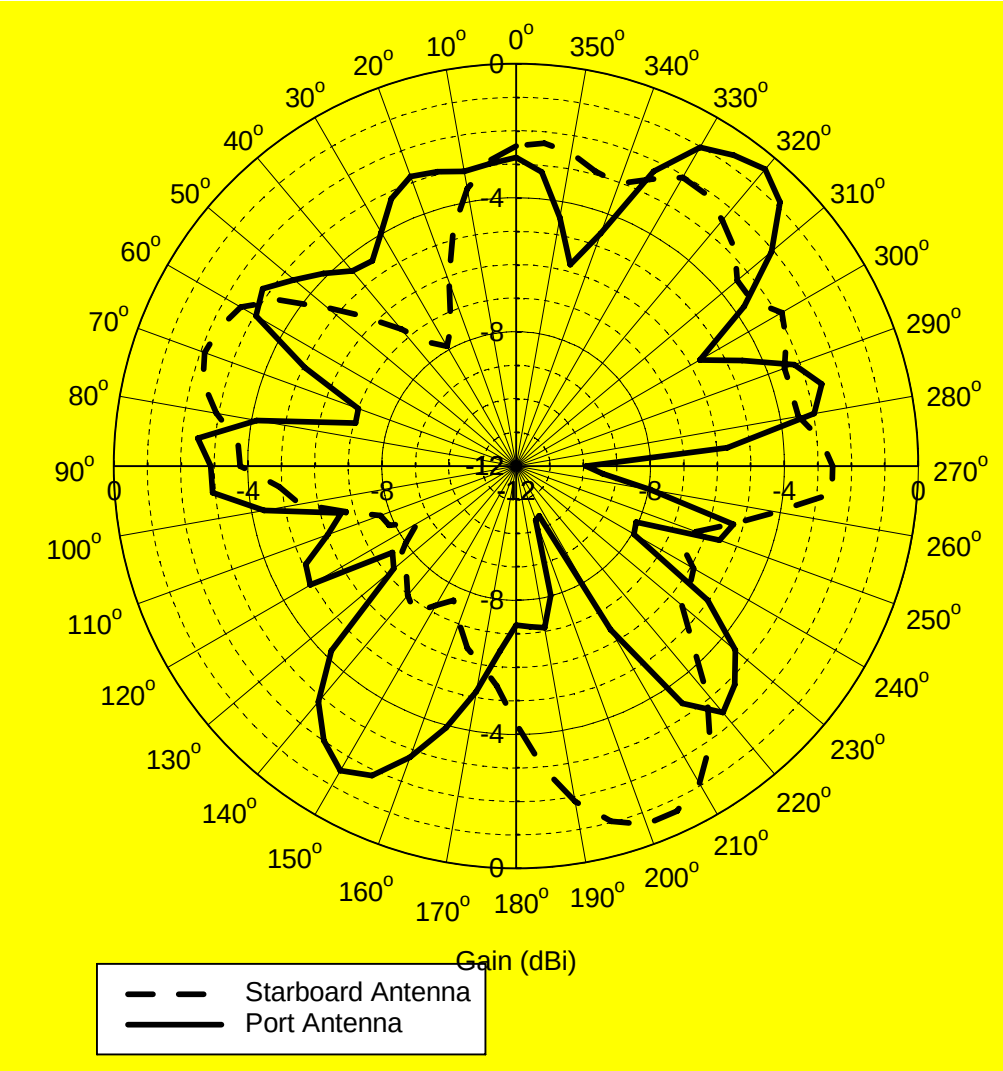
Institute for Telecommunication Sciences
Boulder, Colorado

Antenna Configuration for Scenario 9
(Predicted Isolation= 35.9 dB)



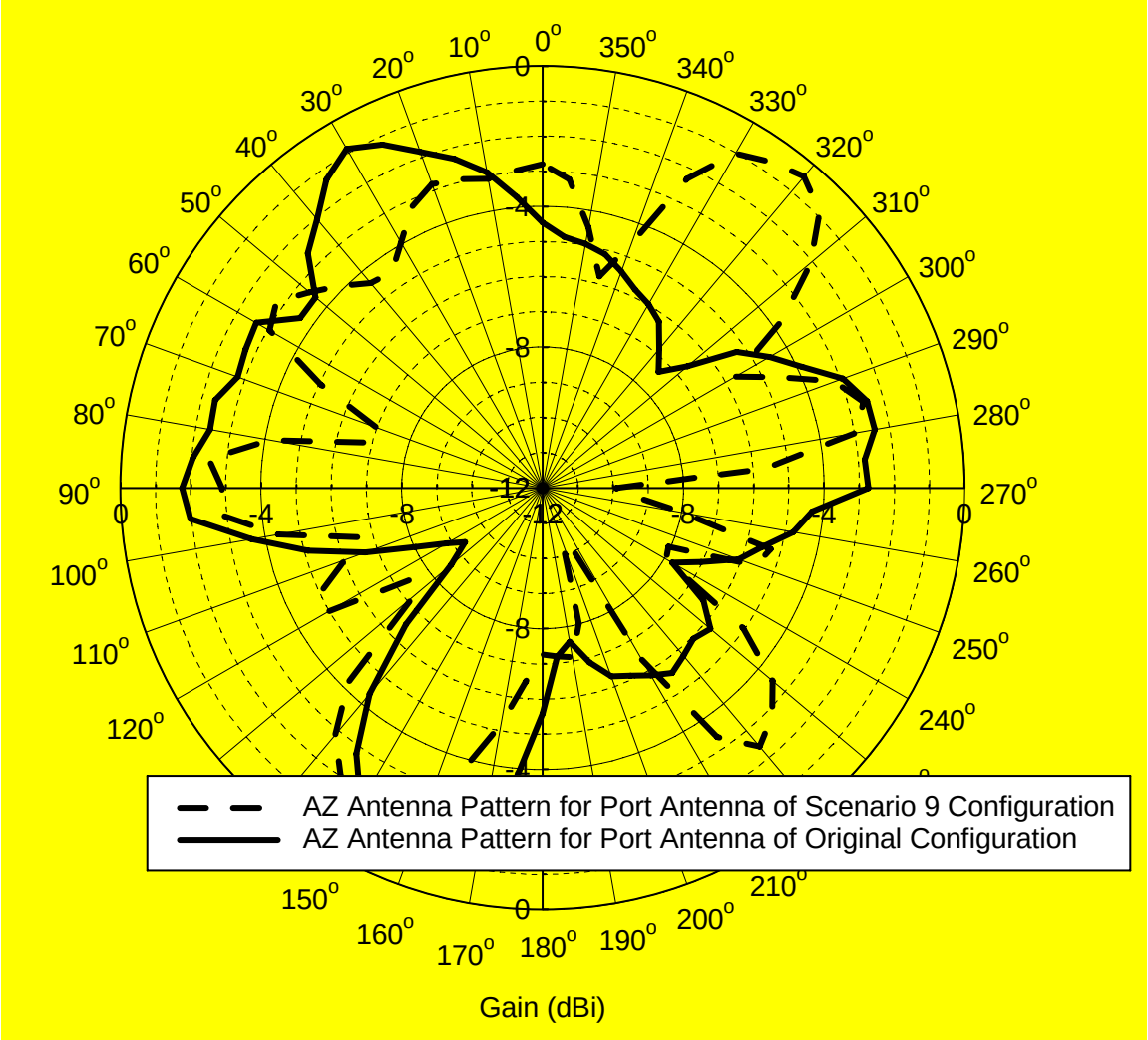
Institute for Telecommunication Sciences
Boulder, Colorado

Azimuth Antenna Pattern for Scenario 9

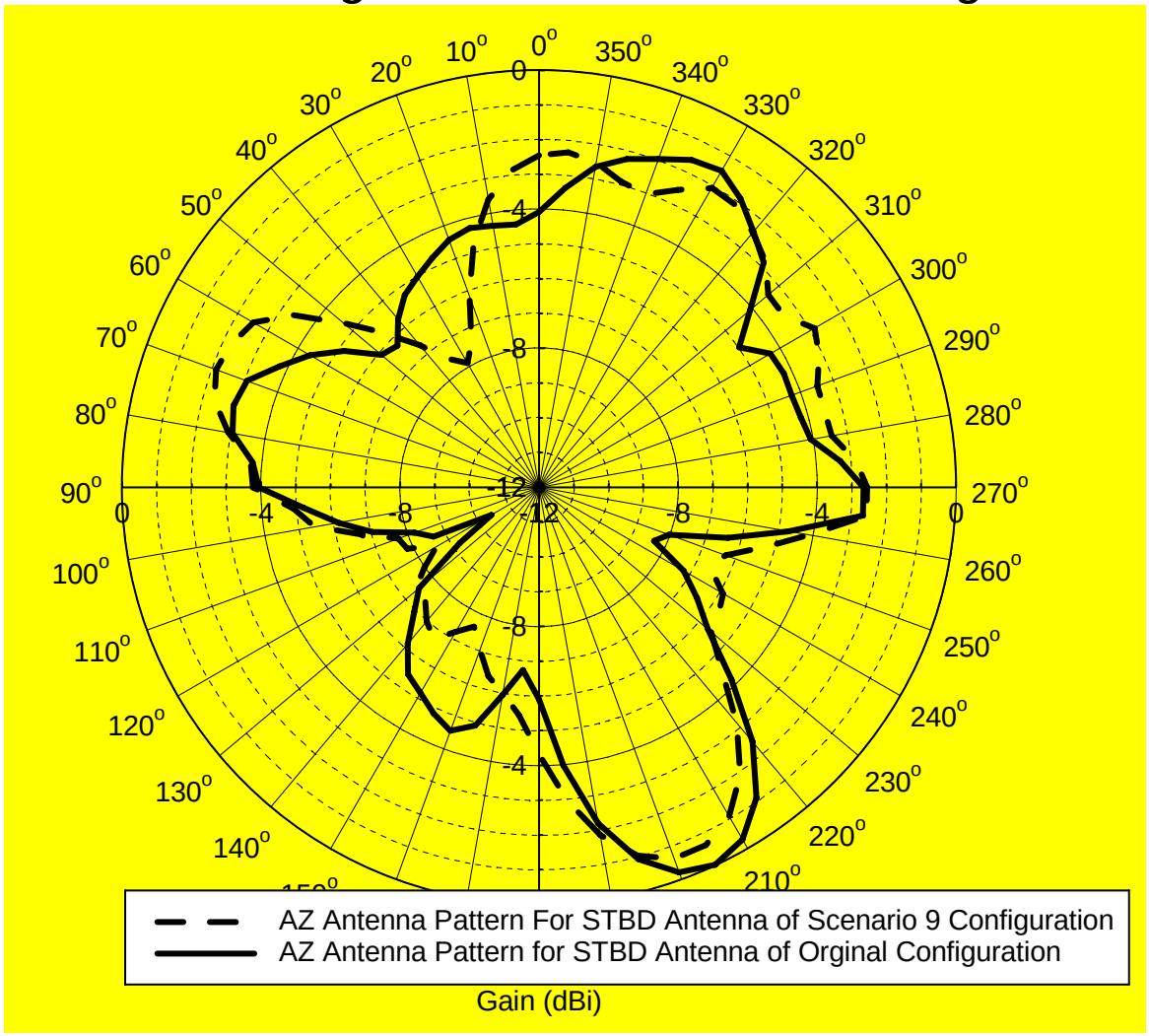


Institute for Telecommunication Sciences
Boulder, Colorado

Comparison Between Port Antenna Azimuth Patterns of Original and Scenario 9 Configurations



Comparison Between STBD Antenna Azimuth Patterns of Original and Scenario 9 Configurations



Institute for Telecommunication Sciences
Boulder, Colorado

DF to Communications Antenna Mutual Coupling

- 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.