A Virtual and Simulated Topside EM Modelling Environment for Early Stages of Ship Design

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1. Background

The topside of a warship contains numerous antenna systems which are used for the purpose of communication, navigation, direction finding, search, detection, tracking and so on. Because the topside of a naval combatant is a confined space, the antennas must be placed at close proximity to each other. (co-site). Some of the transmitting systems such as search and tracking radar antennas are required to emit high level of power (several Megawatts) in particular directions in order to illuminate distant targets. At the same time the topside receivers are required to be highly sensitive in order to pick up weak echoes (up to 10^{-13} dBm in strength). Many of the transmitters, in addition to their fundamental frequencies, emit signals at spurious or undesired frequencies. At the same time the selectivity or reception-bandwidth of the receivers are increased in order not to miss out on information contained in the upper and lower sidebands of the desired signal(s). If the spurious emissions of the transmitters fall within the intermediate frequency bandwidth of the receiver, Electromagnetic Interference (EMI) may result which causes performance degradation of the equipment, blockage of communication channels and impairment of the on-board sensors.

EMI is a particular problem in Concept Phase of Ship Design, in which the designers calculate the ship's weight, stability, survivability, hydrodynamics and so on. However, when they incorporate electromagnetic sensors to the design, the EMI problems are revealed. As a result, the designers have to go back and change the design until an acceptable level of Electromagnetic Compatibility (EMC) is achieved. This process is very tedious and time consuming.

2. Method

One way of predicting the level of EMI in new design would be through the use of Computational Electromagnetic (CEM) tools which can be used to model the platform and the sensors on it. Simulating the sensors against each other on the topside of the platform indicates the interaction between the antennas.

This project has been utilizing Computer Simulation Technology (CST) to model a T22 Batch 2 Frigate along with its antennas, shown below:

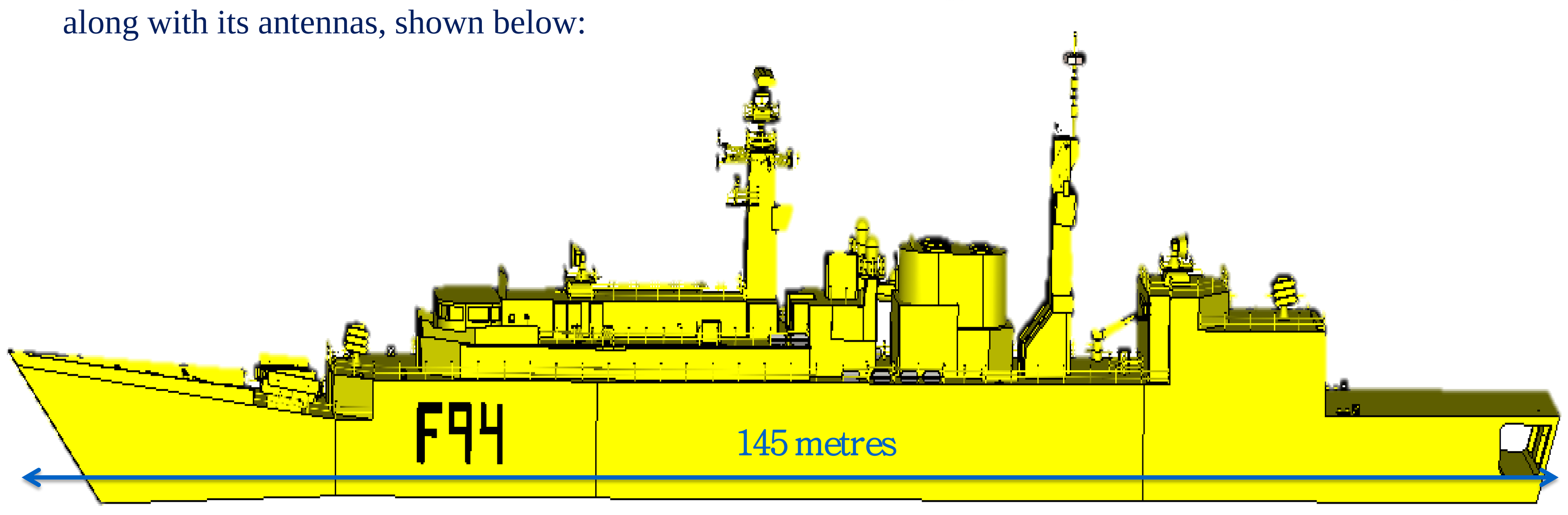

Figure 1: Model for a T22 Batch 2 Frigate (HMS Brave – F94).

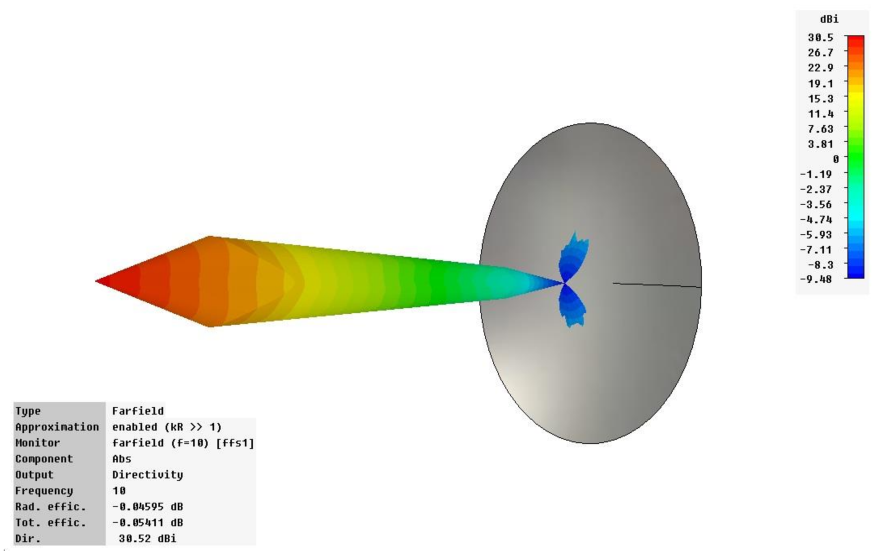

Figure 2: Model for the ship's T911tracking radar .

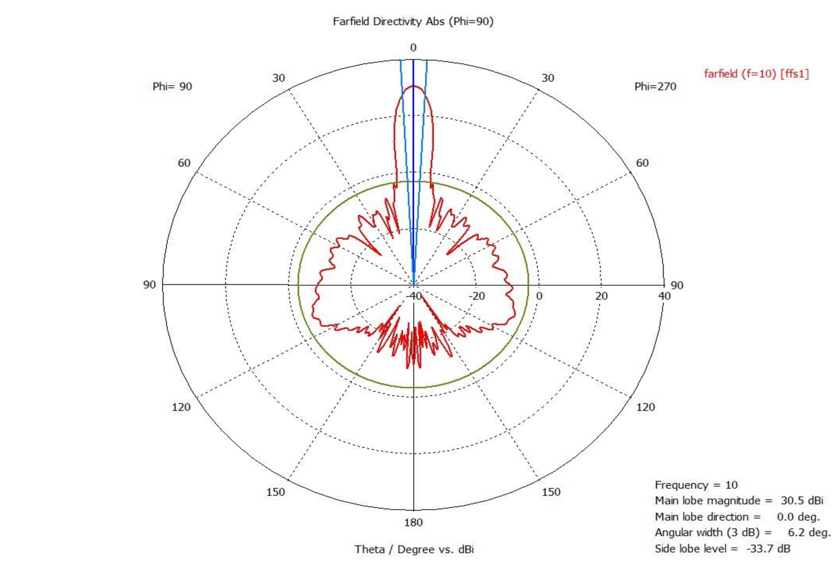

Figure 3: Polar plot for the T911 tracking radar.

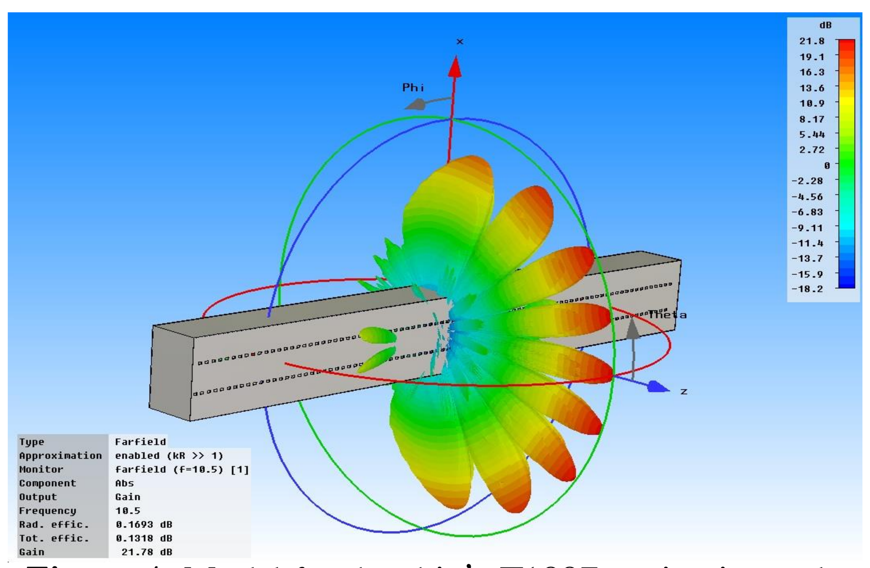

Figure 4: Model for the ship's T1007 navigation radar .

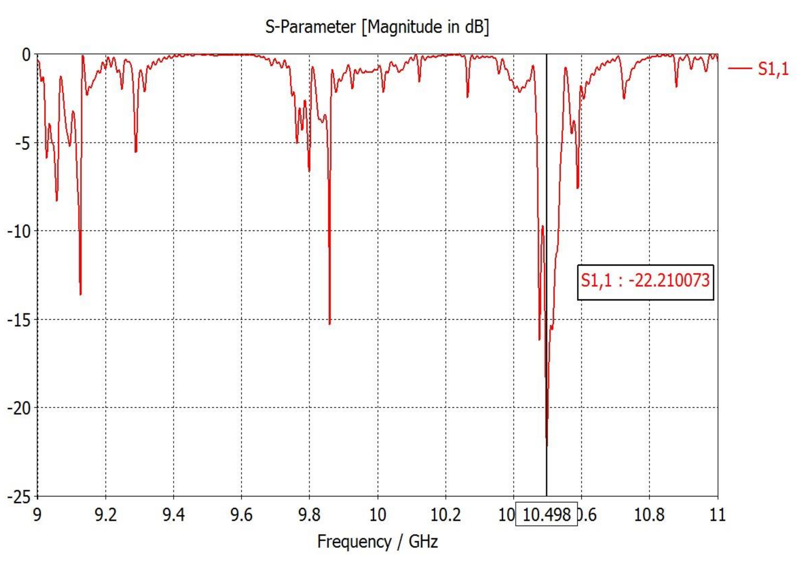

Figure 5: S11 plot for the T1007 navigation radar.

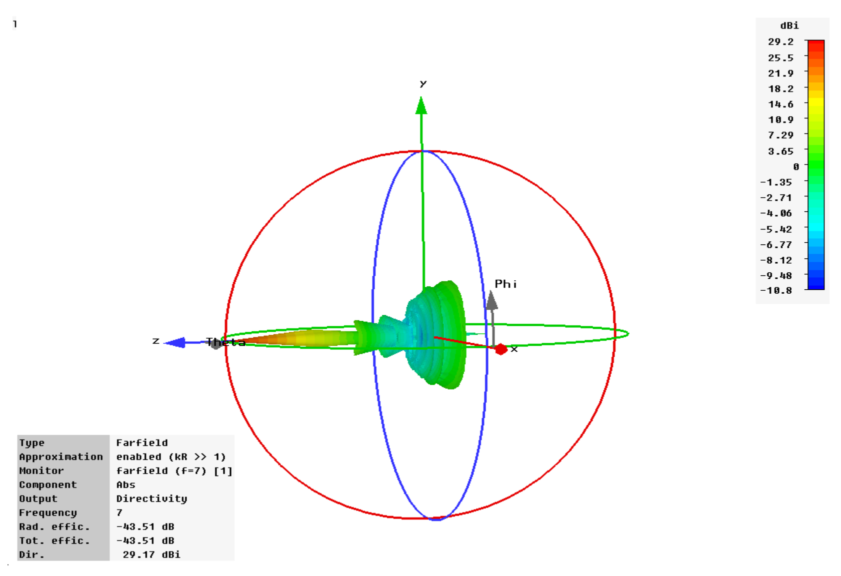

Figure 6: Model for the ship's Scot satcom antenna.

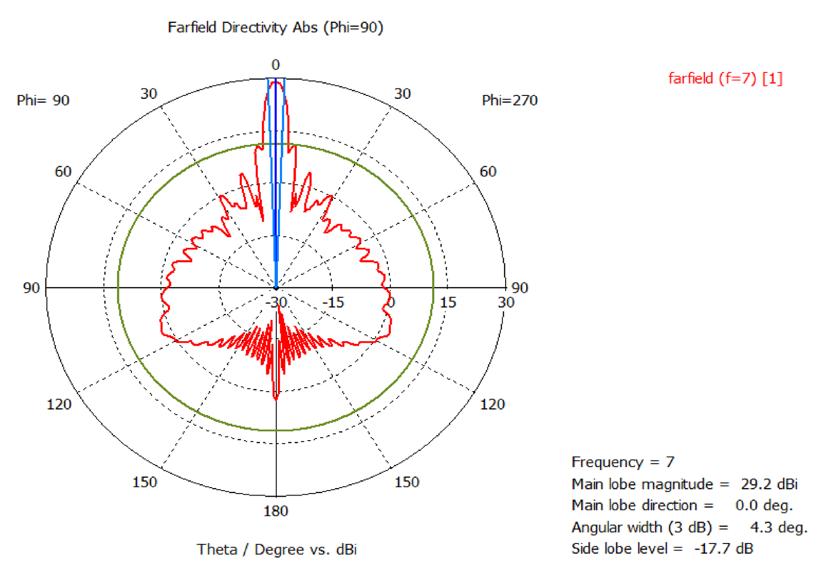

Figure 7: Polar plot for the satcom antenna.

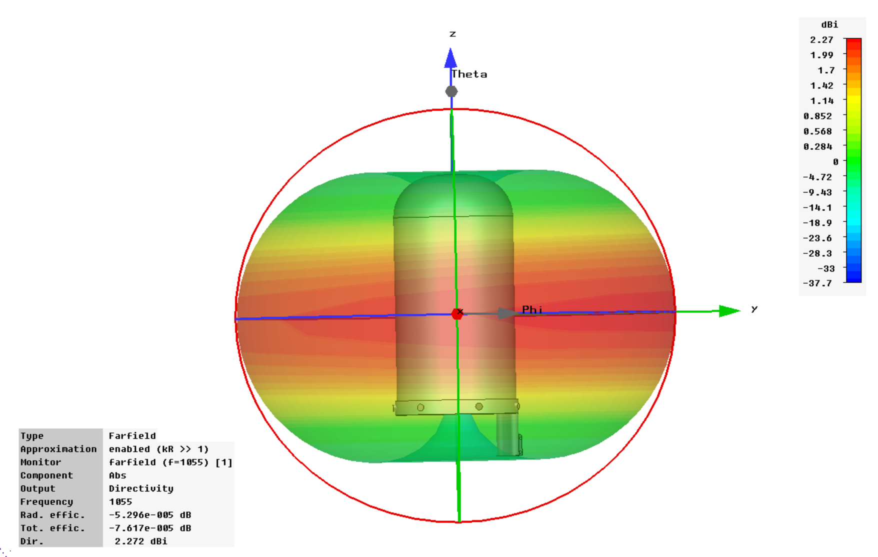

Figure 8: Model for the ship's IFF antenna.

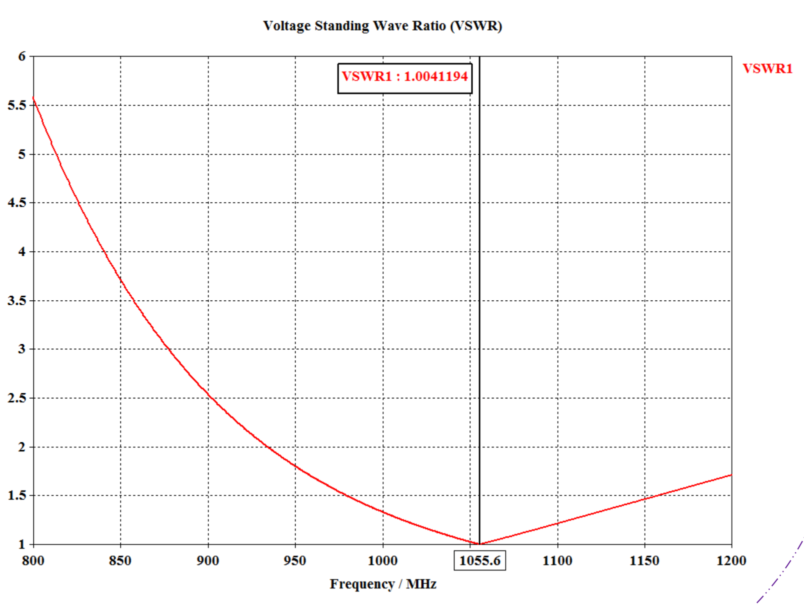

Figure 9: VSWR plot for the IFF antenna.

3. Obtaining Results

After achieving the required performance for each of the antenna system, either the antenna or their far-field sources were exported on the ship model, using a Source – Victim breakdown.

Given the size of the ship, two methods are used to simulate antennas on the ship model – both using CST. The first method employed a Transient Solver with Tetrahedral meshing to calculate broadband coupling between wire and low frequency operating antennas. The second method utilized an Asymptotic Solver with Surface meshing to compute coupling between the antennas, at a single frequency.

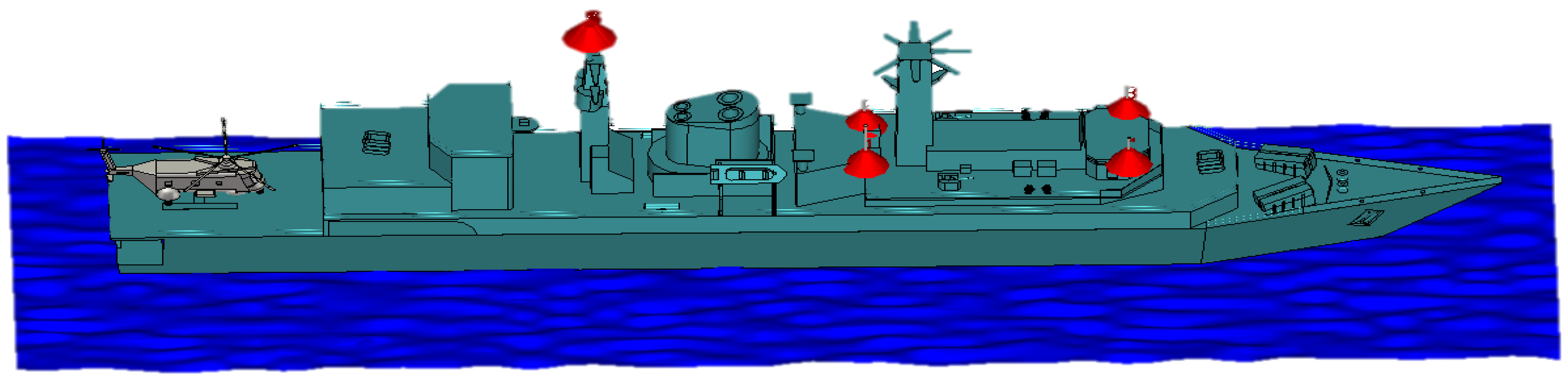

Figure 10: Wire antennas on a T22 Frigate.

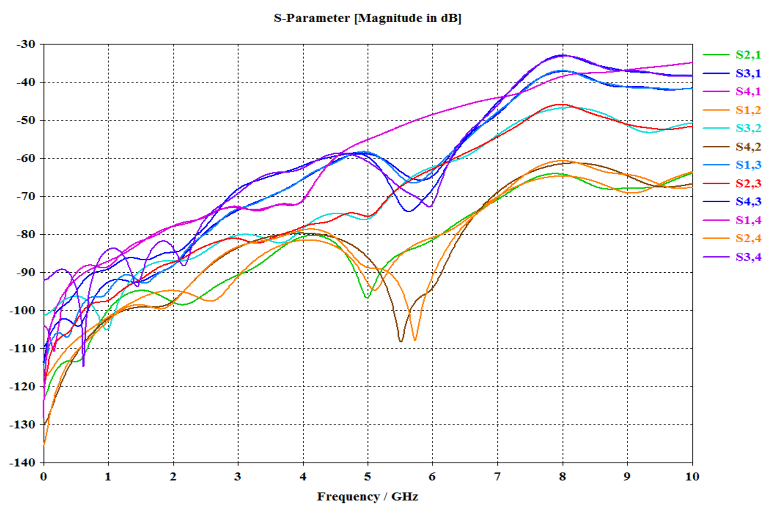

Figure 11: Broadband inter-coupling using Transient Solver.

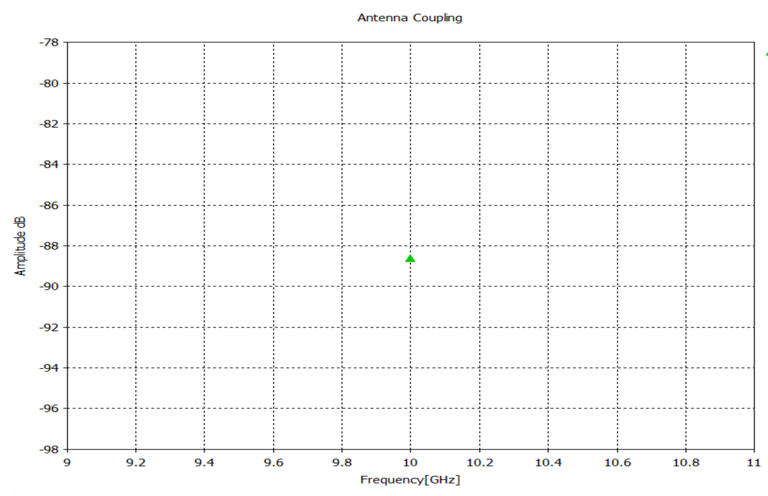

Figure 12: Inter-coupling between two radar systems using Asymptotic Solver.

4.Validation of Simulations

A 1:100 scale model of the T22 Batch 2 ship was constructed out foam which was covered with conductive paint. Three wire antennas, operating at 1.7 GHz, 7.3 GHz and 7.6 GHz, were planted into the ship model with the surface of the ship acting as the ground plane for the antennas. An equivalent model, made of Perfect Electrical Conductor, with the same antennas was developed in CST.

Figure 13: Physical scale model.

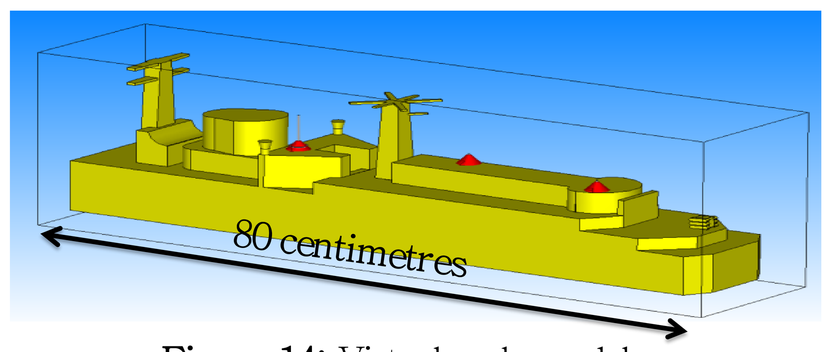

Figure 14: Virtual scale model.

The following comparisons were obtained:

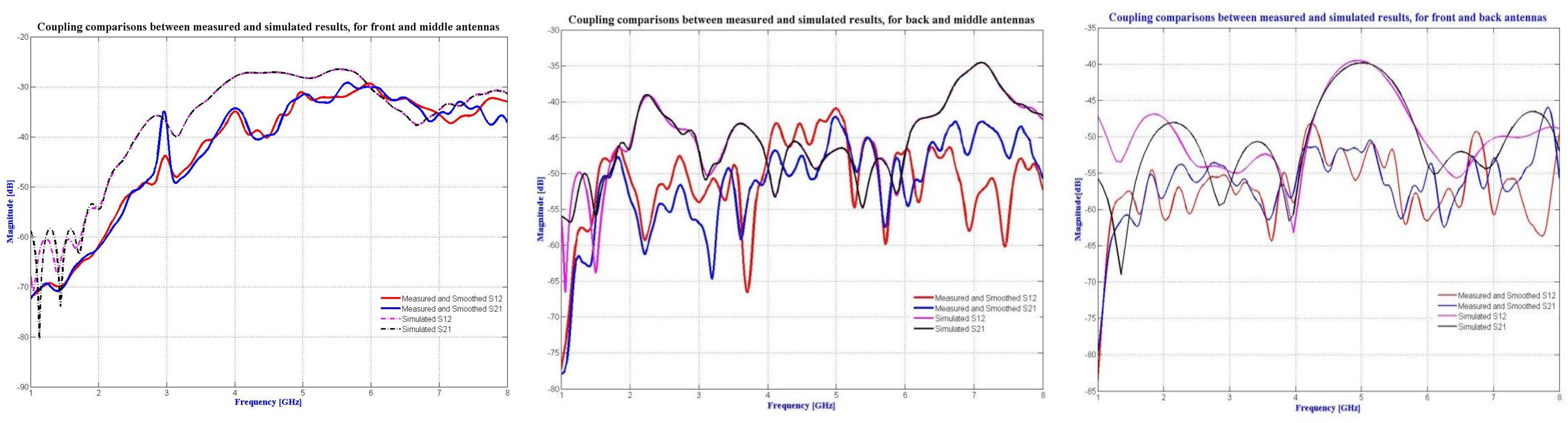

Figure 15: Comparisons between measured and simulated results for three wire antennas on scale ship models.

Overall, there is a fair agreement between the measured and simulated results. However, there are some variations which are thought to be due to differences in the constructed material of the two models.

5. Future Work

- Doing the same analysis carried out on the T22 Batch 2 ship using a new naval ship - based on a new design.
- Conducting validation tests on a 1:50 scale model, see below.

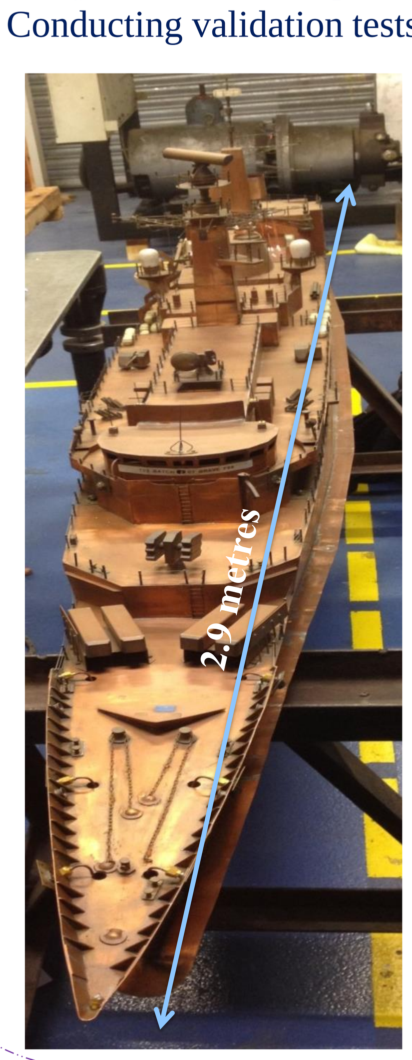

Figure 16: 1:50 Scale model of a T22 Batch 2 Frigate.

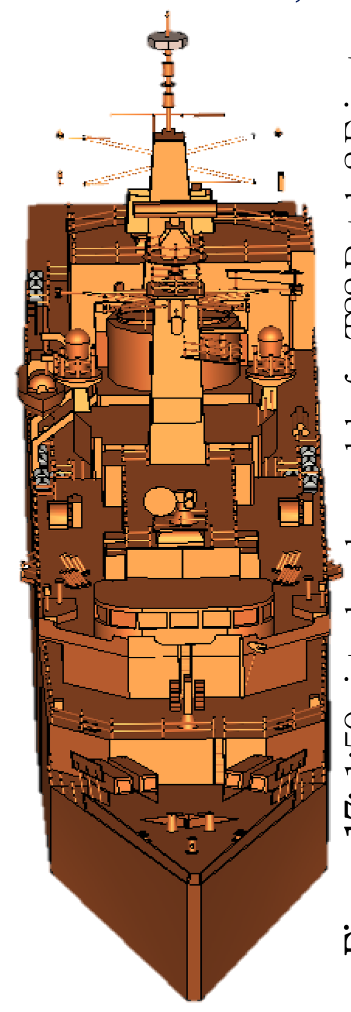

Figure 17: 1:50 virtual scale model of a T22 Batch 2 Frigate.

6. Summary & Conclusions

- EMI is a particular problem in Early Stages of Ship Design. It often makes Ship Designers to change the design a number of times until Electromagnetic Compatibility (EMC) is achieved.
- CEM tools can be used to predict inter-coupling which causes EMI between the antennas systems on the topside of a naval combatant.
- CST, a CEM tool, was employed to model a T22 Batch 2 Frigate and its sensor systems for the work of this project.
- The on-board sensors were simulated against each other, based on the Source-Victim breakdown, using Transient and Asymptotic Solvers of the CST.
- Some of the CST simulations were validated using a 1:100 scale model.
- Further validations will be carried out in the future using 1:50 copper scale model which was borrowed from QinetiQ in London.

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Acknowledgments

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