Lowering Ship RCS

Realistic combat scenarios include ships, as extremely important part of striking, offensive military groups. The special role is reserved for relatively small ships with average length of about 100 meters which can carry various, lethal weapons and operate in the vicinity of a coastline. It is important for these ships to achieve very low probability of detection during operations conducted in a battle theater through: hidden communication links, low acoustic signature, low RCS… The focus of this application note will be on RCS.

The stealth capabilities in terms of lowering an object RCS are usually achieved through introducing special shaping of the object and/or including radar absorbing materials in the object design. This application note will try to describe how some relatively small modifications of the shape of a demonstration model of a pure metallic corvette can decrease its RCS signature. Thus, the main topic of this application note will be lowering ship RCS by introducing a small modification of the shape of the ship.

Although some frequencies used for ship detection are around 20 MHz and in higher bands around 3 GHz and 10 GHz, we will choose a value of 1 GHz for the operating frequency which is “in between” and can be used to represent several characteristic effects. The conclusions which will be derived here for the particular ship model can be to some extent applicable to more general case.

WIPL-D Pro, a full wave 3D electromagnetic Method-of-Moments (MoM) based software will be used for simulation of the models throughout this application note.

WIPL-D Models of the Ship

Three demonstration models of a ~90 meters corvette are created and discussed. All models’ manipulations were performed using WIPL-D Pro Software. The models are symmetrical and one type of symmetry plane (so called *(A)Symmetry* plane) is applied in order to decrease number of unknowns and simulation time. The sea water is approximated by involving infinitesimally large, flat PEC plane.

The first model of the ship is shown in Figure 1. It is named “Classic design”. It will be referred to as the *Version 1*. Such constructions were common in early days when stealth characteristics of a ship were not in the design focus. In order to understand the particular design of the ship shape, front view of the ship is also shown in this figure.

The second model of the ship is shown in Figure 2. It will be referred to as “Advanced design”, or *Version 2*. Such construction represents a transition between previously described design and the next design. The front view of the ship is also shown in this figure.

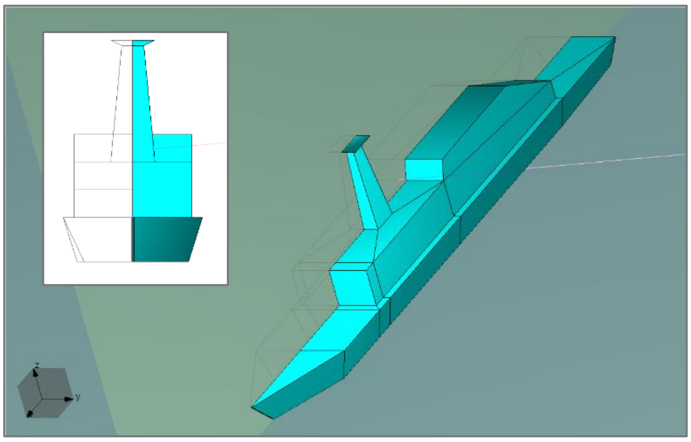

Figure 1. Classic design of the ship-*Version 1*. Only half of the ship is shown

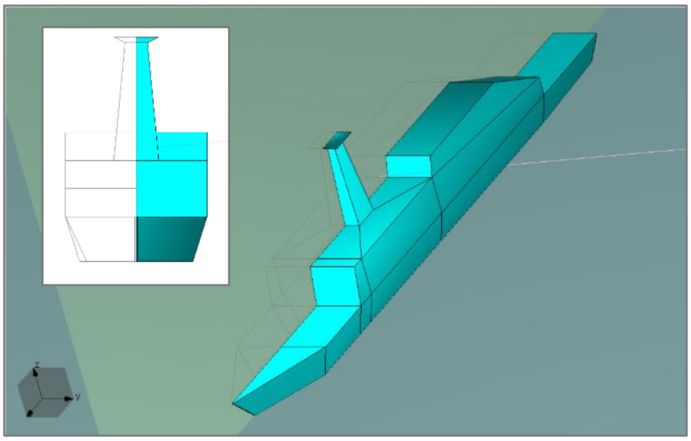

Figure 2. Advanced design of the ship - *Version 2*. Only half of the ship is shown

The third model of the ship is shown in the Figure 3. It will be referred to as “Stealth design” or *Version 3*. The front view of the ship is also shown in this figure.

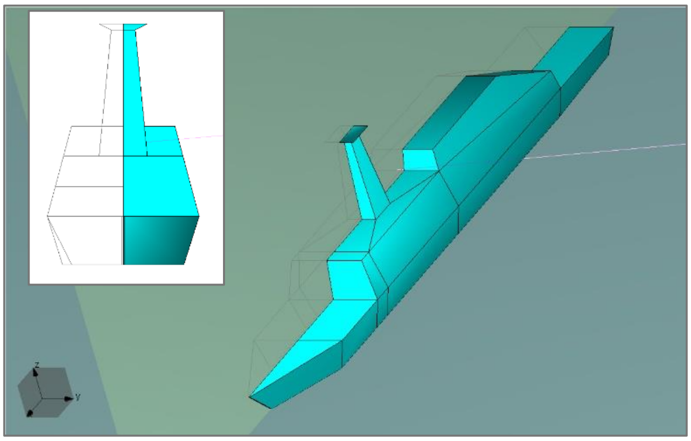

Figure 3. Stealth design of the ship - *Version 3*. Only half of the ship is shown

Simulations and Results

Coordinate system applied here is explained in Figure 4. Phi angle (blue axis in Figure 4) equal to 0 degrees is aligned to x axis. This means that y axis is aligned with phi=90 degrees. Plane z=0 determines elevation angle of 0 degrees (red axis in Figure 4). The models of the ship are simulated for phi angle set to 90 degrees and elevation angles between 0.1 degree and 60 degrees in 600 equidistant points.

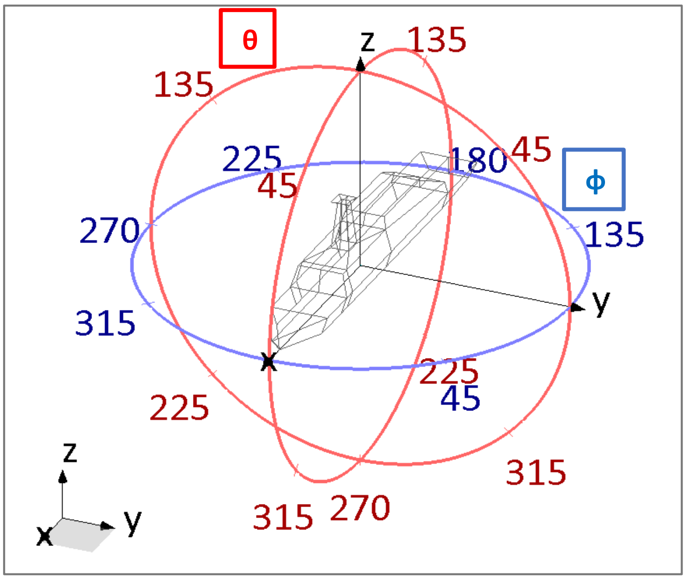

Figure 4. Coordinate system with respect to the ship

The models of the ship were simulated at frequency of 1.00 GHz in monostatic RCS operating mode. Numerical kernel parameter *Maximum patch size* is set to 1.83 x wavelength. The simulations were performed using a workstation with the hardware specification given in Table 1. GPU cards are used for matrix inversion. Number of elements, number of unknowns and total simulation times for the simulated models are listed in Table 2.

Table 1. Workstation used for the simulations

Hardware	Description
Processor	Intel® Xeon® CPU E5-2650 v4 @ 2.20 GHz 2.20 GHz (2 processors)
RAM	256 GB
GPU	NVIDIA GeForce GTX 1080 Ti (4 cards)

Table 2. Number of elements, number of unknowns, and simulation times required for the simulations

Model	Number of elements	Number of unknowns	Total simulation time
Version 1	28,725	396,395	9.6 hours
Version 2	27,794	390,784	9.3 hours
Version 3	26,098	367,027	8.2 hours

RCS results are shown and compared in Figure 5.

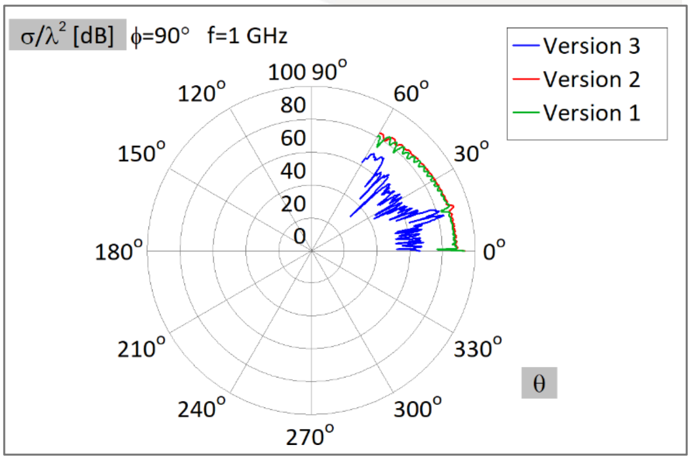

Figure 5. Compared RCS results

Conclusion

This application note outlines utilization of WIPL-D Pro Software, a full wave 3D electromagnetic Method-of-Moments (MoM) based software. The software is used to simulate three models of the electrically large ship in monostatic scattering operating mode at the operating frequency of 1 GHz without any reduction applied.

Obtained results could be very useful for studying the influence of the ship shape to RCS. Monostatic RCS calculated for the first two versions of the shape is unacceptably high, while the third version brings significant reduction. The significance of this results is that the RCS of the ship can be reduced with relatively simple modification of the shape of the ship contour without any radar absorbing materials involved and could indicate a good point to start a ship design.

In spite of very large electrical size of the ship models, all the results were calculated in relatively short time. In addition, the workstation used for the calculations was powerful but affordable desktop PC empowered with GPU cards.