electromagnetic modeling of composite metallic and dielectric structures

Influence of Helicopter Main Rotor Rotation on Antennas Radiation Pattern

This application note deals with one of standard antenna placement application representing an important aircraft topic. Described scenario includes a helicopter as a platform and three microstrip patch antennas mounted on the upper area of the helicopter surface. Since it is assumed that the antennas radiate upwards, the focus of the document is presenting the influence of the rotation of the main rotor to radiation pattern of the antennas. All of the antennas operate at 2.625 GHz. The radiation patterns related to the three angles of main rotor rotation (namely 0, 12, and 24 degrees) will be investigated.

Beside showing the radiation patterns, the application note will show how WIPL-D *smart reduction* feature can be exploited for efficient calculations.

All the simulations have been carried out using WIPL-D Pro CAD, a full wave 3D electromagnetic Method-of-Moments based software which applies Surface Integral Equations.

Microstrip Patch Antenna

The simply microstrip patch antenna (MPA) shown in Figure 1 is used as a radiating element to be placed on the helicopter platform. The antenna was modeled with low-loss foam with ε_r=1.2 as a dielectric support. The metallic box used as a small platform for mounting the antenna on the aircraft is also included in the model.

The antenna was modeled using WIPL-D Pro CAD. The S_{11} of the antenna and radiation pattern at 2.625 GHz in $\phi = 0$ and $\phi = 90$ planes are shown in the Figure 2. In WIPL-D software, $\theta = 90$ degrees angle refers to the direction of z=+Inf.

MPAs Mounted on the Helicopter

The CAD model of the helicopter is imported into WIPL-D Pro CAD software. The model has been adjusted to enable the main rotor to be rotated for three different angles: 0, 12, and 24 degrees so that the influence of the main rotor rotation to radiation patterns can be investigated. Furthermore, three antennas (copies of the antenna shown in Figure 1) are mounted on the upper part of the helicopter fuselage. The antenna placement scenario for 0 degrees main rotor rotation within WIPL-D Pro CAD preview is shown in Figure 3. The positions and the numeration of the antennas are also shown in Figure 3.

In order to decrease number of unknowns and reduce simulation time while preserving accurate results, a *smart reduction* feature in form of *Antenna placement reduction* and *Shadow* reduction is applied.

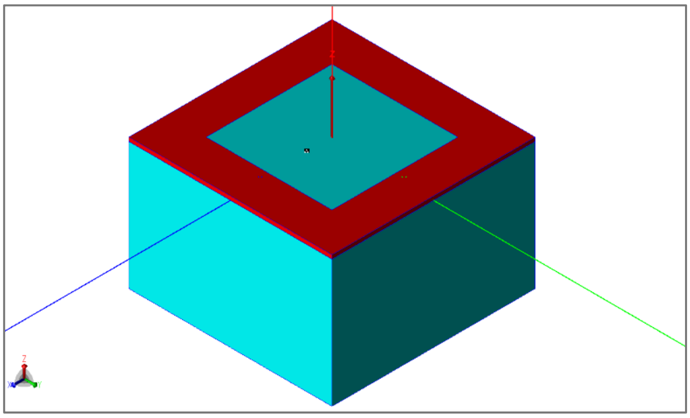

Figure 1. MPA with metallic box in WIPL-D Pro CAD

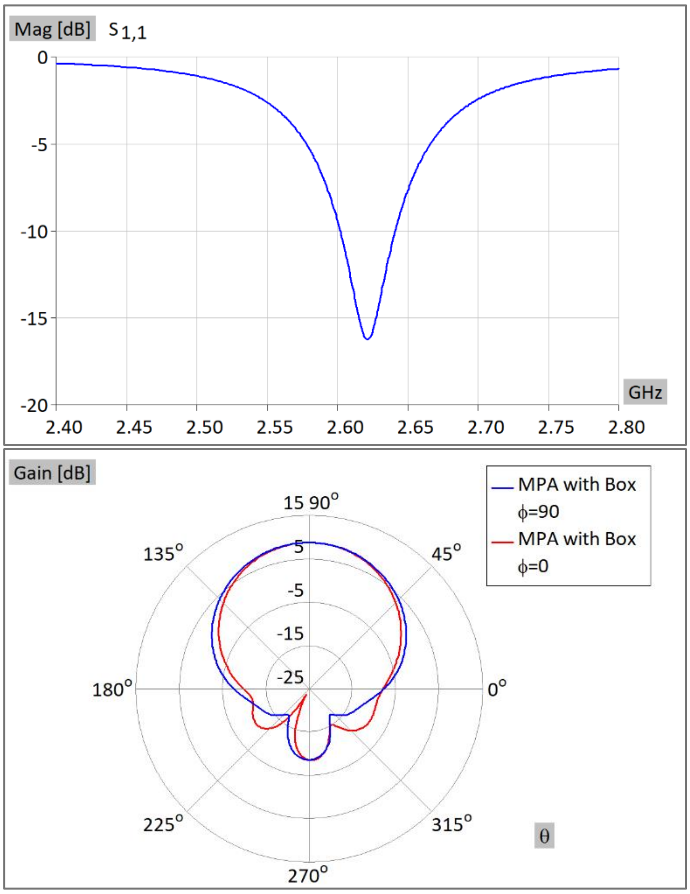

Figure 2. S_{11} and radiation pattern

The *smart reduction* is a feature which is very suitable for antenna placement problems such as this with three antennas on the helicopter. It is based on reduction of current expansion orders. Applying *smart reduction*, the number of unknowns can be significantly reduced, while very good accuracy of calculated radiation pattern or coupling between multiple antennas is preserved.

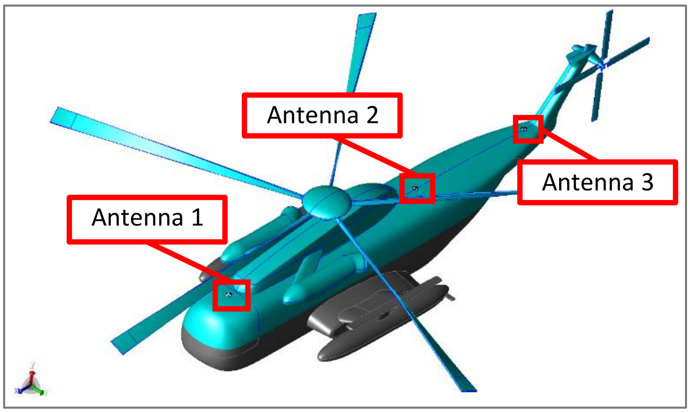

Figure 3. The MPAs mounted on the helicopter. WIPL-D Pro CAD model

The *Antenna placement reduction* represents adaptive reduction of current expansion orders over parts of the model which are distant from the antennas. Furthermore, another kind of the reduction can be applied to the regions of the platform which a user declares to lay in a shadow. The *Shadow* reduction could be additionally applied to such regions.

Owing to application of these sophisticated techniques, very large structures can be simulated on PCs or relatively inexpensive workstations. The application of *smart reduction* usually requires increasing *Integral accuracy*, a WIPL-D numerical kernel control parameter.

The reduction settings were applied within WIPL-D Pro CAD and these settings are shown in Figure 4. The particular reduction settings were applied after a short convergence study. Namely, the position of *Shadow* assuming distance from the coordinate origin and angles defining shadow plane rotation were set considering that lower part of the helicopter with containers mounted on the left and the right side of the aircraft are not in the line of sight with the antennas. This means that the mentioned parts of the aircraft are simply immersed into the shadow. The percentage of the reduction (100% *Antenna placement reduction* and 100% *Shadow* reduction) were set after comparing radiation pattern results with the results obtained after applying the same *Shadow* plane position with 70% *Antenna placement reduction* and 70% *Shadow* plane reduction. The value of 70% has been chosen for comparison as it is usually considered that it represents the optimal trade-off between accuracy and simulation time in the majority of antenna placement scenarios (see next section and Figure 6). The convergence study was performed on the model with 0 degrees rotor rotation.

Parts of WIPL-D structure which are in shadow are colored in gray while the *Shadow* plane is previewed as finite size gray surface (Figure 5). For example, containers mounted on the left and the right side of the aircraft are in shadow and it is clearly recognized by their color.

The three WIPL-D Pro CAD models (with rotation of the rotor equal to 0, 12, and 24 degrees, respectively) are converted to WIPL-D Pro native format and simulated. The helicopters in WIPL-D Pro native format are shown in Figure 5. Figure 5 also displays *Shadow* plane and the rotation of the main rotor.

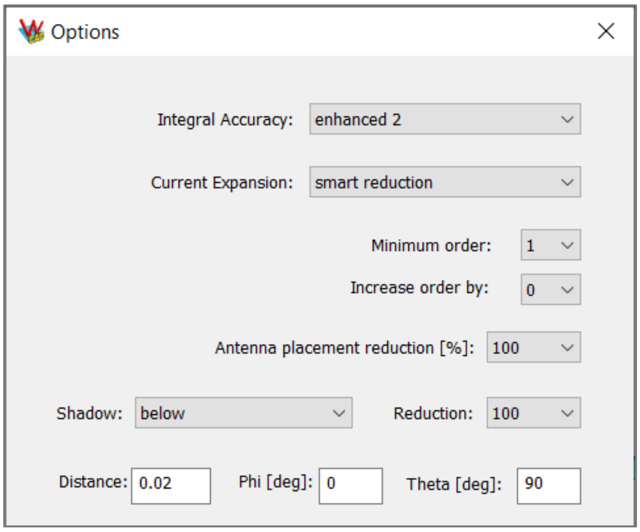

Figure 4. Smart reduction settings

MPAs Mounted on the Helicopter - Simulations and Results -

The whole antenna placement scenario encompassing the helicopter and three antennas was simulated at 2.625 GHz in *One generator at time* operating mode. The manipulations of the models and the simulations were performed on a workstation with hardware specifications presented in Table 1.

Table 1. Workstation used

Hardware	Description
Processor	Intel® Xeon® Gold 6248R CPU @ 3.00GHz 3.00 GHz (2 processors)
RAM	768 GB
GPU	2 cards NVIDIA GeForce RTX 3080

The workstation was equipped with GPU cards while a particular WIPL-D software suite includes *GPU Solver*. The *GPU Solver* is used for matrix inversion, while all other computations were performed on CPU. The usage of the *GPU Solver* enables the user to perform extremely fast simulation even where a number of unknowns is very high. The *GPU Solver* primarily accelerates system matrix inversion through usage of graphical processing units. The *GPU Solver* is very suitable and very efficient for simulations of electrically large antenna placement problems.

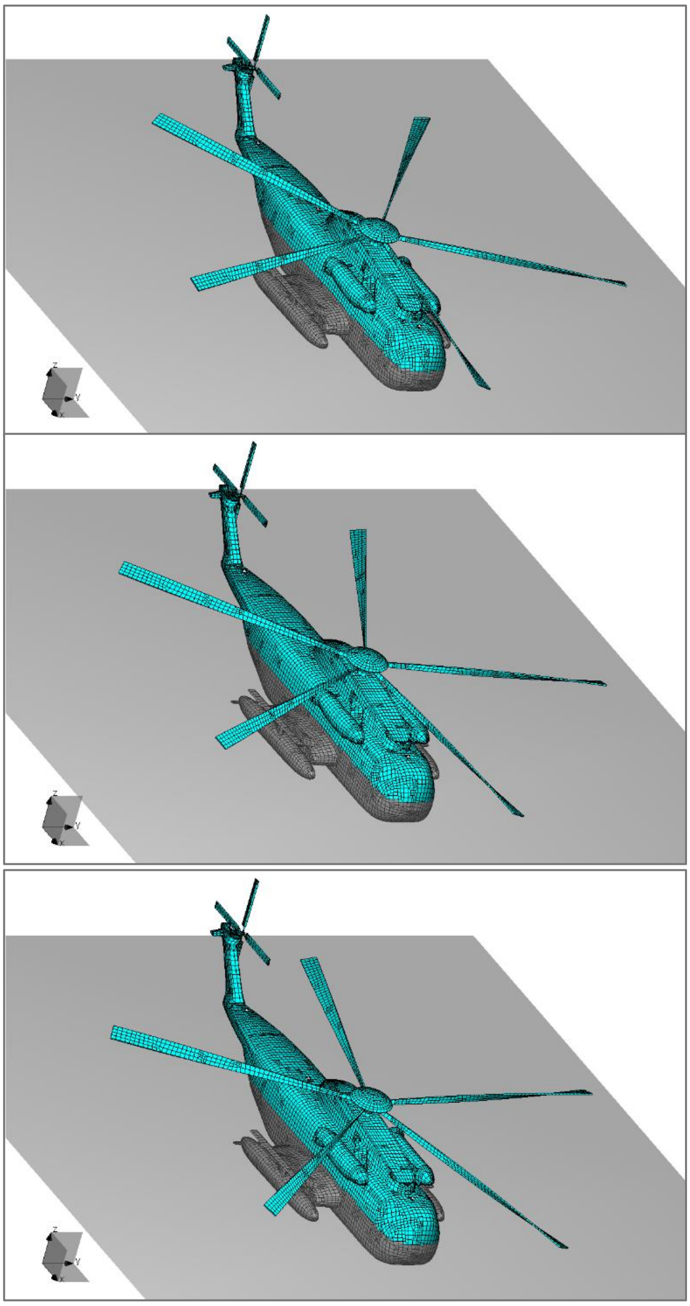

Figure 5. Helicopter in WIPL-D Pro native format with rotated main rotor for 0, 12, and 24 degrees (from top to bottom)

The first set of simulation included a convergency study of radiation pattern results as described in $\phi = 0$ plane between models with 100% and 70% reduction. Both models keep main rotor rotated for 0 degrees. Model with 100% reduction requires 456,268, while the model with 70% reduction requires 521,669 unknowns.

According to the results of the simulation presented in Figure 6 considering there is not any notable difference regarding the calculated radiation patterns, and considerable difference in the number of unknowns, the subsequent simulations were performed with 100% reduction.

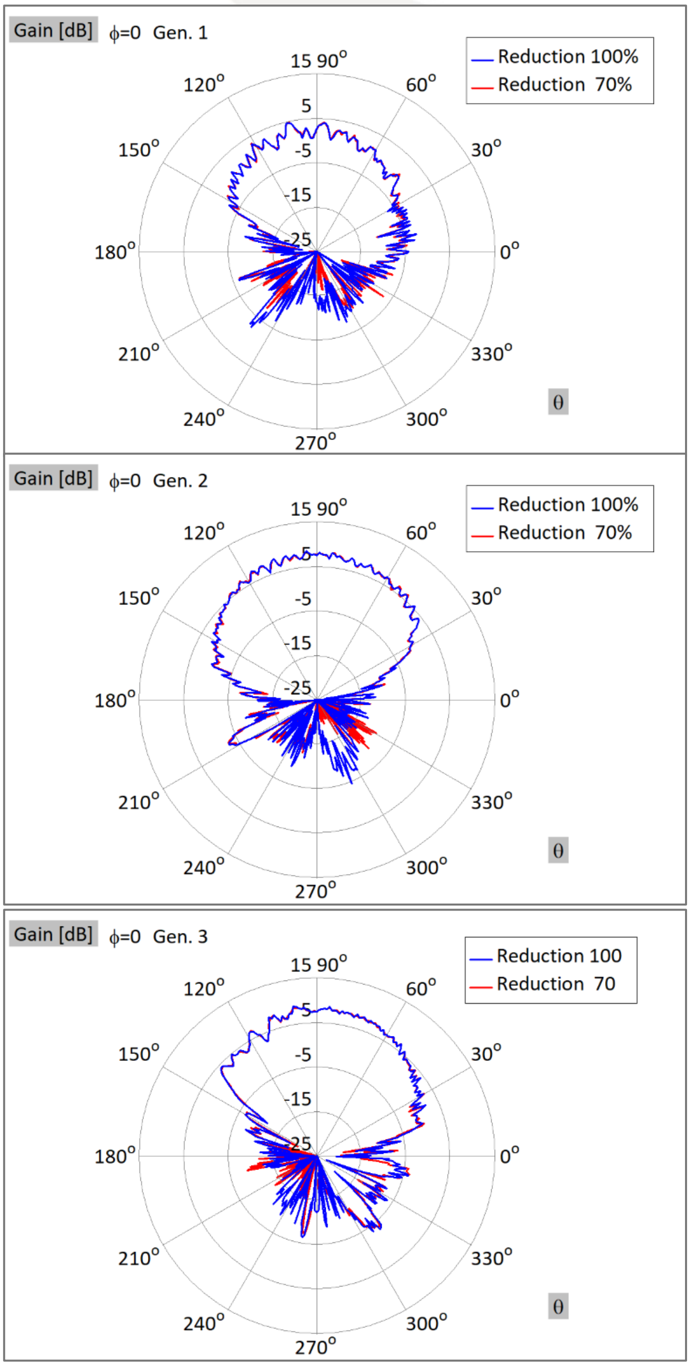

Figure 6. Comparison between 100% and 70% reduction in ϕ = 0 plane

Radiation pattern results for the models of the helicopter with antennas and three rotor positions calculated at 2.625 GHz are presented and compared in Figures 7-12. Number of elements, number of unknowns, and total simulation times are presented in Table 2. Number of unknowns and number of elements do not change significantly with changes in antenna placement model. In that sense, we can select one to represent all of the cases.

Table 2. Number of elements, number of unknowns, and total simulation time

Model	Number of elements	Number of unknowns	Simulation time
MPAs Mounted on the Helicopter	19,459	456,268	4 hours

Conclusion

This application note presents one of the standard antenna placement scenarios. An important aircraft topic containing a helicopter as a platform and three microstrip patch antennas mounted on the upper area of the helicopter surface was investigated. The main topic of the note is examining the influence of the rotation of main rotor to the radiation patterns of all of the antennas. The chosen antennas operate at 2.625 GHz. Three angles of main rotor rotation (0, 12, and 24 degrees) were investigated.

The successful application of *smart reduction* feature can be easily understood. According to the data following comparison of 100% and 70% reduction as well as Figure 6, it can be concluded that the reduction of unknowns can be successfully applied enabling significant saving of computational resources.

In addition, the usage of *GPU Solver* enabled relatively fast matrix inversion cutting down total simulation times to be around 4 hours, which is very efficient considering a large number of unknowns.

Finally, Figures 7-12 showed the influence of rotor rotation to antennas radiation patterns. The results are expected since it is straightforward to understand that the rotor rotation influences *Antenna 1* radiation pattern the most, while the radiation pattern originating from the Antenna 3 is the one which is least affected.

The simulations were carried out using WIPL-D full wave 3D electromagnetic Method-of-Moments based software which applies Surface Integral Equations. The simulations are very efficient even when simulating large platform.

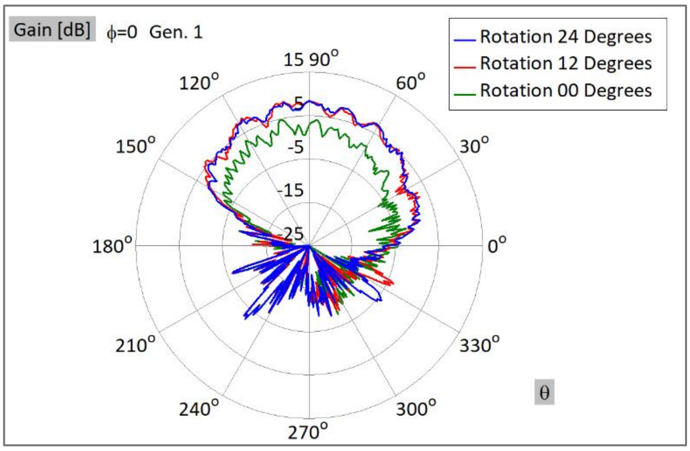

Figure 7. Plane phi=0 degrees; operating *Antenna 1*

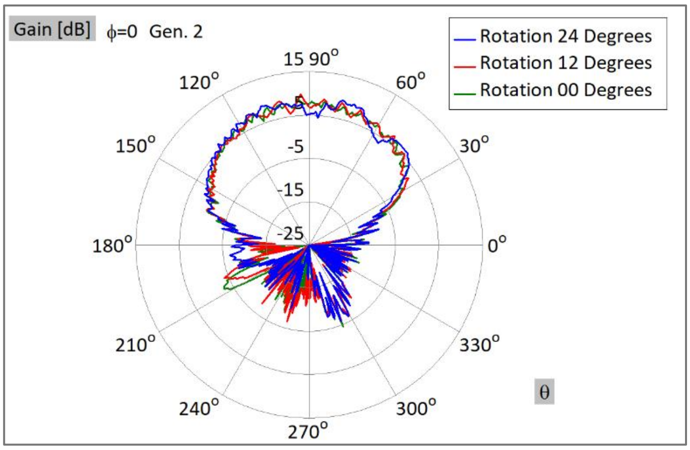

Figure 8. Plane phi=0 degrees; operating *Antenna 2*

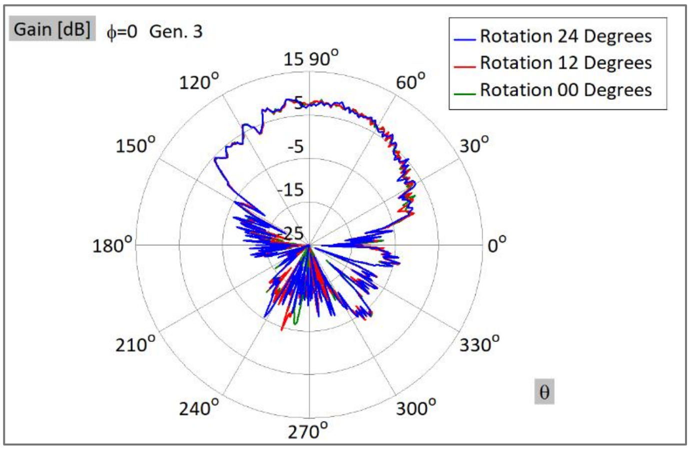

Figure 9. Plane phi=0 degrees; operating *Antenna 3*

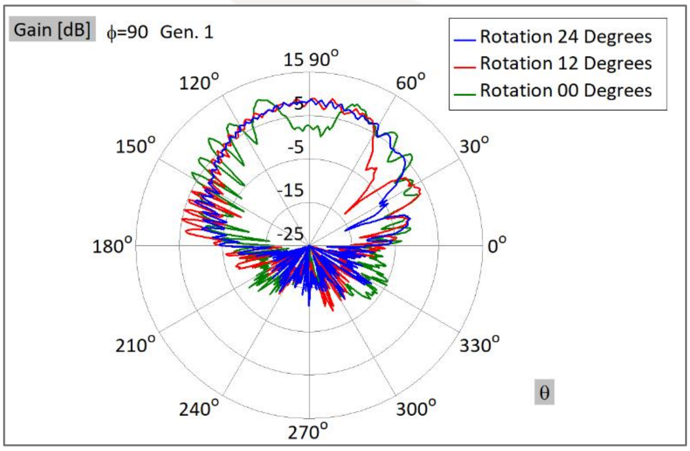

Figure 10. Plane phi=90 degrees; operating *Antenna 1*

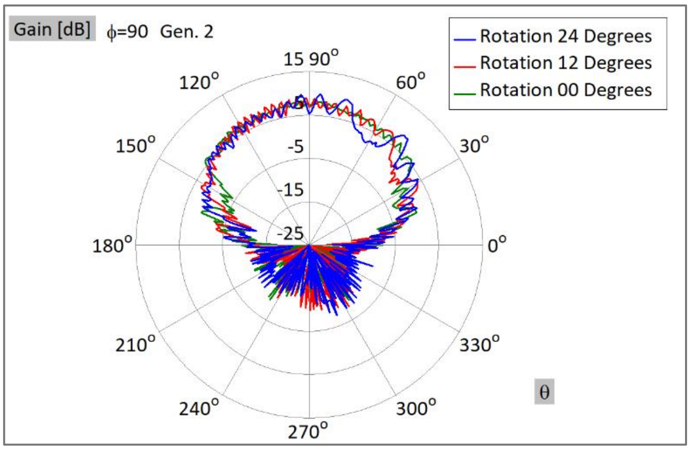

Figure 11. Plane phi=90 degrees; operating *Antenna 2*

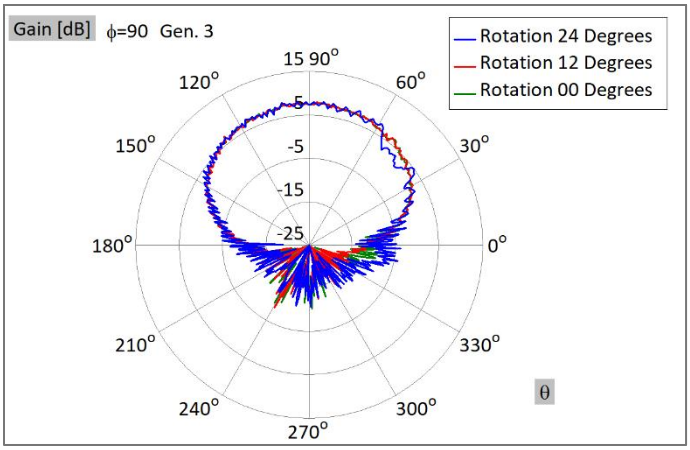

Figure 12. Plane phi=90 degrees; operating *Antenna 3*