Radome Run Applied to Transparent Radome over Field Generators

Introduction

In realistic antenna placement problems, most of the outdoor mounted antennas are covered with radomes. These structures most often protect the antenna from physical damages and various environment conditions. Typically, the radome should affect antenna performances as little as possible. The antennas are mostly designed without radomes, and the influence of the radome is investigated only at the final stages, without including it in the designing process. Radome volume and surface can be even order of magnitude larger than the antenna itself. Thus, the typical phases of simulation scenarios for radomes are:

- Design of the antenna in free space,
- Design of the radomes which influence the antenna performances as little as possible and
- Simulate the antenna with radome to confirm that antenna maintains its characteristics under the radome.

WIPL-D team has significant experience in simulation of antennas with radomes. Since radomes are often electrically large in volume and surface, Method of Moments (MoM) codes (such as WIPL-D Pro) are very suitable for radome simulations. In addition, WIPL-D state-of-the-art MoM implementation offers some unique advantages for simulation of electrically large structures. Namely, WIPL-D kernel uses quadrilateral mesh of structures, compared to more commonly used triangles. This significantly reduces the simulation requirements, but more important, the advantage is the use of Higher Order Basis Functions (HOBFs). They enable the usage of larger mesh elements, up to 2 wavelengths. In case of radome simulations, the radome surface is usually smoothly curved or flat which is ideal for very large mesh elements supported in WIPL-D Pro. Hence, there are 3-10 times less unknown coefficients in MoM matrix compared to the low order triangular mesh based MoM matrix.

However, all of the aforementioned would not be enough for radomes with multiple layers whose dimensions are measured in hundreds of wavelengths since these scenarios are very demanding when it comes to the required number of unknowns. The basic quality of radome surfaces is that they affect antenna performances very little. This property is used to significantly reduce the simulation requirements. WIPL-D software suite offers several techniques to reduce number of unknowns on parts of the model. Combining these techniques along with extensive experience in radome simulations which WIPL-D support team has gathered through years, we can greatly reduce the number of unknowns on large radome surfaces. The current distribution on such surfaces changes very smoothly, so instead of using higher orders of polynomial degrees representing those currents (orders 5,6,7) we can use much lower orders (2,3,4) and preserve the accuracy.

For simulation of electrically large structures, WIPL-D recommends usage of inexpensive GPU platforms. A regular desktop PC can be turned into GPU platform by adding 1-3 GPU cards. On the other hand, for largest problems we offer Domain Decomposition Solver (DDS), which works very efficiently on desktop computers with multiple threads.

This application note focuses to reducing number of unknowns for single layer highly transparent radome by using Run Radome feature. For most practical cases a radome is highly transparent. The idea behind the method is to use the high transparency of the radome to reduce the antenna-radome structure. The analysis is performed in two steps. In the first step, the antenna is analyzed as in free space, i.e. ignoring the presence of the radome. Based on the results obtained in the first step, and using a special technique, parts of radome having insignificant influence to the accuracy are identified. These parts are excluded in the second step where antenna is analyzed together with the remaining parts of the radome.

The method used to identify which mesh elements should be preserved and which should be ignored is rather simple. The significance of a mesh element to the accuracy of the analysis is determined based on the power illuminating the element. The powers are arranged in a decreasing order and summed until the value of the sum reaches some predefined power factor, i.e. a percent of total power. Mesh elements with powers included in the sum are marked as significant, while the remaining elements are considered insignificant.

The power factor can be set by user. We suggest starting with 90% of power illuminating the radome, and then trying 95%, 99% etc. 90% usually yields

In addition to elements determined as significant following the procedure described above, each insignificant element having a common edge with a significant element has also been included in the analysis to avoid the effect of diffraction in the calculation.

Case Study

The described reduction technique will be illustrated on the model of single-layer radome, placed above 2D antenna array. Array elements are modeled as far-field sources. Elements are theta polarized, where antenna radiation pattern is defined as: $E\theta=\cos(\varphi)\cos(\theta)$ for $\theta \geq 0°$ and $E\theta=0$ for $\theta \leq 0°$, where

θ angle is measured from x0y plane. Entire array is rotated for 90 degrees around y-axes, so main lobe of radiation pattern has z-direction. Array is uniformly fed. Frequency of interest is 3 GHz. Distance between elements of the array is 0.05 m in both, x and y, directions. Number of antennas is 20 in x-direction, and 40 in y-direction.

Radome is made of lossless dielectric with relative permittivity of 1.2. Radome has semi-ellipsoidal shape with semi-axes of: $ax=ay=5.625m$ and $az=3.375m$. Therefore, diameter of ellipsoid in x0y plane is equal to 112.5 wavelengths. Thickness of the radome layer is equal to 0.05 m.

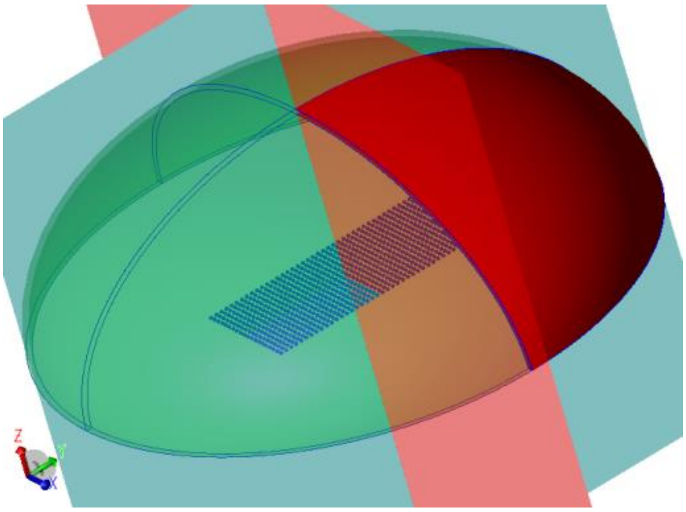
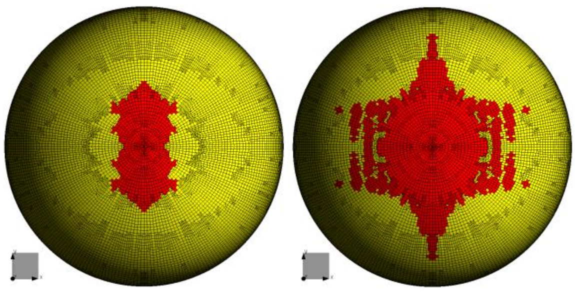


Fig. 1. Radome above antenna array.

A partition of the radome mesh elements to significant (red) and insignificant (yellow) is illustrated in Fig. 2 for two values of power factor. It is evident that even with power factor equal to 99% a substantial number of radome mesh elements is excluded from the analysis. It is due to the fact that the analyzed array is highly directive and majority of its irradiated power is concentrated in a very narrow zone.



a) Power Factor=95% **b) Power Factor=99%**

Fig. 2. Omitted elements (shown in yellow) for different values of power factor.

Simulation details are listed in Table 1.

Table 1. EFFICIENCY OF REDUCTION.

Power factor	Number of mesh elements	Number of unknowns	Simulation time [s]
100% (no reduction)	5,946	191,060	6,949
99%	1,428	39,366	707
95%	536	13,780	293

All simulations where carried out using the following computer configuration:

Intel® Xeon® CPU E5-2650 v4 @ 2.20 GHz (2 processors) with 256 GB RAM and four GPU cards NVIDIA GeForce GTX 1080 Ti, 6 SATA HDDs configured in RAID-0.

CPU and GPU accelerated kernel was used for all simulations. In order to reduce number of unknowns 2 symmetry planes were used.

The results shown in Table 1 confirm that proposed reduction technique enables huge reduction in number of mesh elements and number of unknowns. Simulation time has been reduced dramatically.

Simulated radiation patterns in ϕ=90° plane for different values of power factor are shown in Fig. 3.

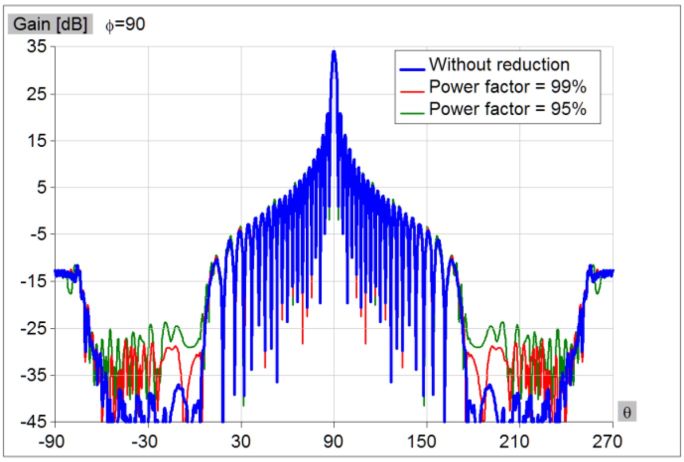


Fig. 3. Radiation pattern of the array.

Analyzing the graphs from Fig. 3, it can be concluded that the model with proposed reduction and power factor equal to 99% has almost identical radiation pattern as for the case where the reduction has not been applied. A noticeable difference occurs only on very low radiation pattern levels, i.e. about 60 dB below the main lobe. Results obtained for power factor of 95% are also acceptable.

Conclusion

In this application note we have demonstrated that for radome simulations number of unknowns can be significantly reduced by using WIPL-D built-in techniques without impacting the accuracy of the results. Typical reduction in terms of number of unknowns is several times.

A method for reduction of number of unknowns for transparent radomes has been described. The feature is named Radome Run. Numerical results presented in the paper confirm that the method enables huge reductions in a number of unknowns and simulation time. Accuracy of the method is verified by simulation results.