

## Domain Decomposition Solver in Simulation of the Electrically Large Reflector Antenna

One of WIPL-D Company flagship products is **WIPL-D Pro**, a full wave 3D electromagnetic Method-of-Moments (MoM) software. Although WIPL-D Pro represents a state of the art, it is empowered with another product of WIPL-D Company, the **Domain Decomposition Solver (DDS)** which is intended for solving **electrically very large problems**, the ones beyond the reach of the direct MoM Solver. **The basic idea behind DDS is to divide the original problem into a number of groups.** A group is composed of a number of neighboring plates and wires. Basis functions, which correspond to plates and wires from the same group, are grouped into a macro-basis function (MBFs). All MBFs are multiplied by corresponding weighting coefficients, then replaced into full MoM matrix and residua of all equations are calculated. Weights of MBFs are determined by minimizing residuum of full MoM matrix. The residuum of the final solution in each iteration is used as the excitation in the next iteration. MBFs excited by low values of residua can be eliminated in iterative procedure. **The entire iterative procedure finishes when the total residuum becomes smaller than the predefined threshold.** Generally, DDS converges rapidly and the solution with acceptable accuracy is typically found after 1 to 3 iterations.

This application note compares the radiation patterns of an electrically large Cassegrain reflector antenna calculated using WIPL-D Pro and DDS.

### WIPL-D and DDS Models of Reflector Antenna with 420 Wavelengths Diameter

The Cassegrain reflector antenna is modeled **easily with WIPL-D Pro built-in objects.** Very suitable built-in objects for modelling this class of antennas are *Reflector*, *Body-of-Rotation*, and *Circle*. The built-in objects not only allow for fast and easy creation of various reflectors but also include predefined optimal meshing parameters providing **highly efficient simulations.** The particular antenna model presented in this application note represents an element from a WIPL-D Pro models library. Dimensions of the model are parameterized by applying symbolic variables. Therefore, any change in antenna performance associated with the changes in dimensions can be easily investigated.

The WIPL-D Pro preview of simulated reflector antenna is shown in Figure 1. The feeding zone is also shown as inset in the same figure. Number of patches (bilinear surfaces) per quarter of reflector circumference originally set for simulations of the reflector have been reduced from 210 to 40 to increase the clarity of the picture. The model has two symmetry planes which are used to decrease the problem size accordingly saving computational resources.

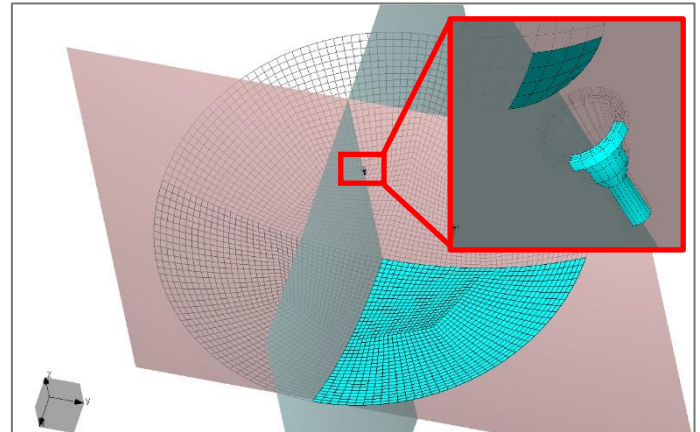


Figure 1. Cassegrain reflector antenna in WIPL-D Pro with magnified feeding horn antenna and secondary reflector

The WIPL-D Pro model shown in Figure 1 can be easily converted to Domain Decomposition Solver (DDS). The process of full conversion from WIPL-D Pro project to DDS project and invoking the DDS project run takes a couple of steps. The initial preview of the model converted to DDS is shown in Figure 2. The figure also explains some particularities of the DDS model.

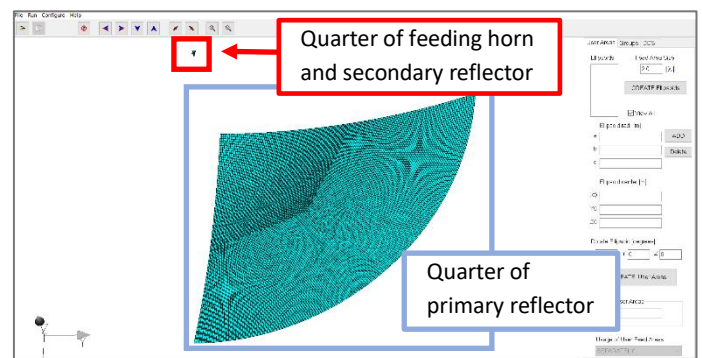
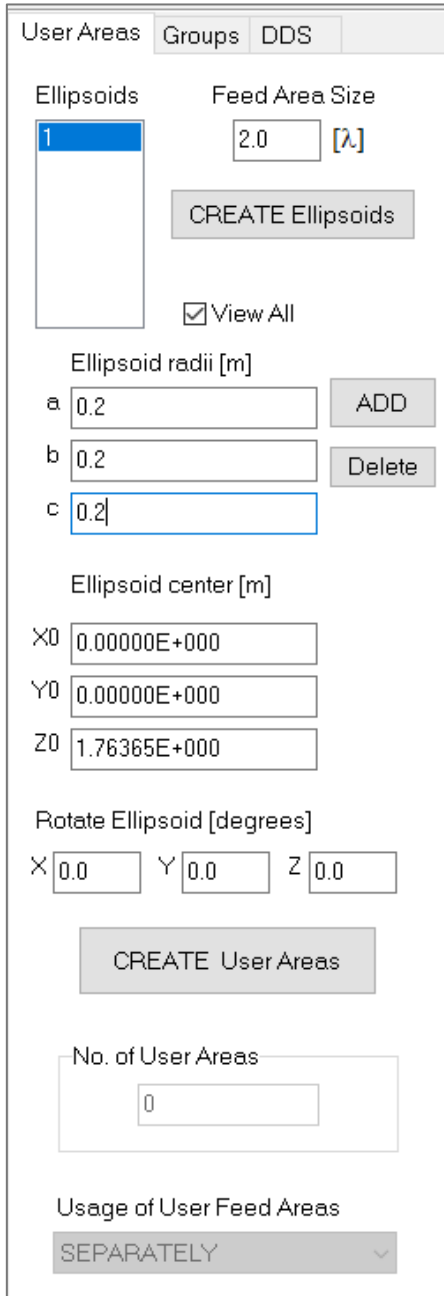


Figure 2. Initial preview of the reflector antenna converted to DDS

Three steps should be applied before simulating the model in DDS. The following steps should be applied to fully converted model.

The Cassegrain antenna simulation within DDS requires a **feeding zone to be defined within DDS, which is the first of the three steps.** The feeding zone parameters are set under the first tab from the left - the *User Areas* tab. The initial shape and the location of feeding zone is **automatically determined within DDS.** In this case, the DDS feeding zone should be extended by increasing size of the feeding zone ellipsoid so that the horn antenna with secondary reflector become encompassed with feeding zone area. The *User Areas* tab setting is shown in Figure 3, while the preview of the feeding zone after completing the first step of conversion and clicking on *CREATE User Areas*

button is shown in Figure 4. To increase the clarity of the picture, the original DDS feeding zone preview is postprocessed. Figure 4 actually displays spherical feeding zone area with quarter of horn antenna and the secondary reflector immersed within.



The screenshot shows the 'User Areas' tab with the following settings:

- Ellipsoids:** A list containing '1'. Below it is a 'CREATE Ellipsoids' button and a checked 'View All' checkbox.
- Feed Area Size:** A text box containing '2.0' with a unit selector '[λ]'.
- Ellipsoid radii [m]:** Three text boxes labeled 'a', 'b', and 'c', each containing '0.2'. There are 'ADD' and 'Delete' buttons.
- Ellipsoid center [m]:** Three text boxes labeled 'X0', 'Y0', and 'Z0' containing '0.00000E+000', '0.00000E+000', and '1.76365E+000' respectively.
- Rotate Ellipsoid [degrees]:** Three text boxes labeled 'X', 'Y', and 'Z', each containing '0.0'.
- Buttons:** 'CREATE User Areas' and 'CREATE Ellipsoids'.
- No. of User Areas:** A text box containing '0'.
- Usage of User Feed Areas:** A dropdown menu set to 'SEPARATELY'.

Figure 3. User Areas tab

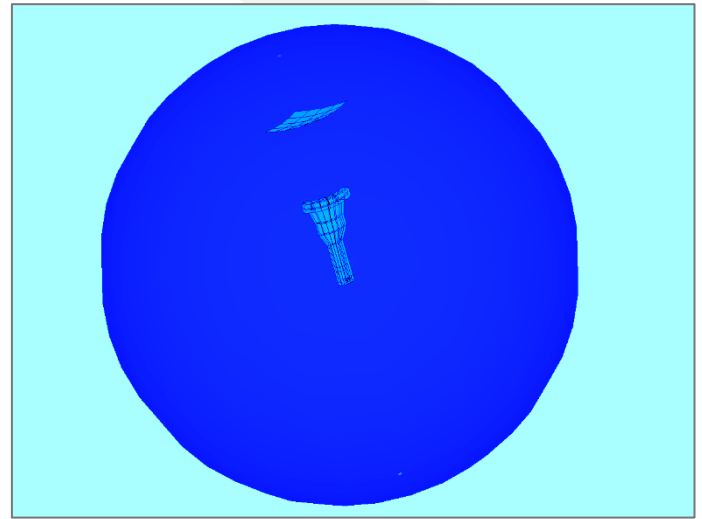
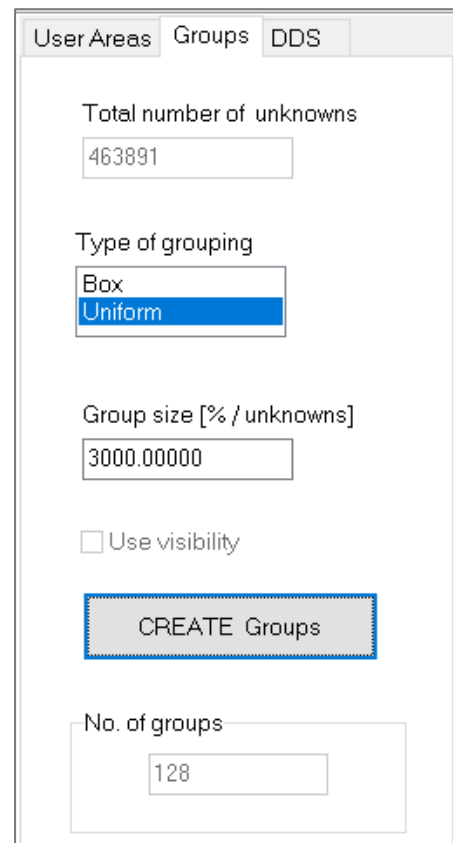


Figure 4. DDS feeding zone encompassing the horn and secondary reflector

The next step is to define DDS groups. The groups are set using the second tab named *Groups* (Figure 5). In this case, parameter *Group size* which is used in the simulations is set to 3,000. The *Group Size* parameter defines desired number of unknowns per group. The process of defining groups representing a second step is finished after clicking on *Create Groups* button (Figure 5). The groups over the reflector surface are created as shown in the preview in Figure 6.



The screenshot shows the 'Groups' tab with the following settings:

- Total number of unknowns:** A text box containing '463891'.
- Type of grouping:** A dropdown menu with 'Box' and 'Uniform' options, where 'Uniform' is selected.
- Group size [% / unknowns]:** A text box containing '3000.00000'.
- Use visibility:** An unchecked checkbox.
- Buttons:** 'CREATE Groups'.
- No. of groups:** A text box containing '128'.

Figure 5. Groups tab

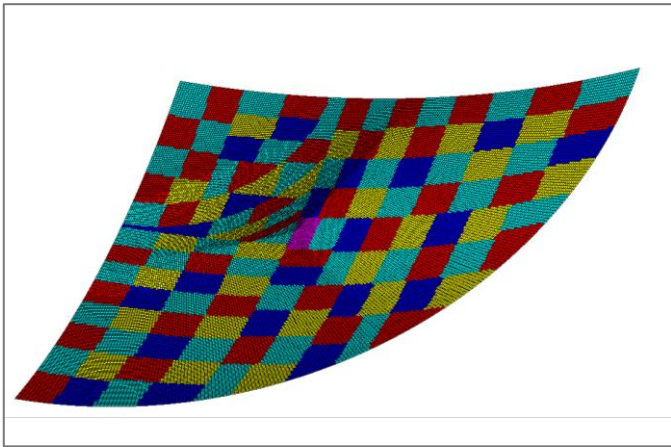


Figure 6. DDS groups over the reflector surface

The final step assumes invoking DDS run. The run is invoked after performing settings within DDS tab (Figure 7). The explanation of DDS tab settings are as follows. The workstation used for simulations contains GPU cards. The GPU cards will be used for matrix inversion. That's why, *Use GPU for partial projects* field is checked. The recommended value for defining a number of unknowns above which GPU inversion is activated is 5,000. The default value for *Error*, which is used as a threshold for accepting the solution as accurate, has been left unchanged. The total of 3 iterations will be performed. **The field *Residual* has been changed from default 60% to 100%, which is required for reflector antenna simulations.**

The DDS tab and *Residua* window are shown in Figure 7. After applying all required settings, the DDS run is invoked by clicking on *START DDS* button.

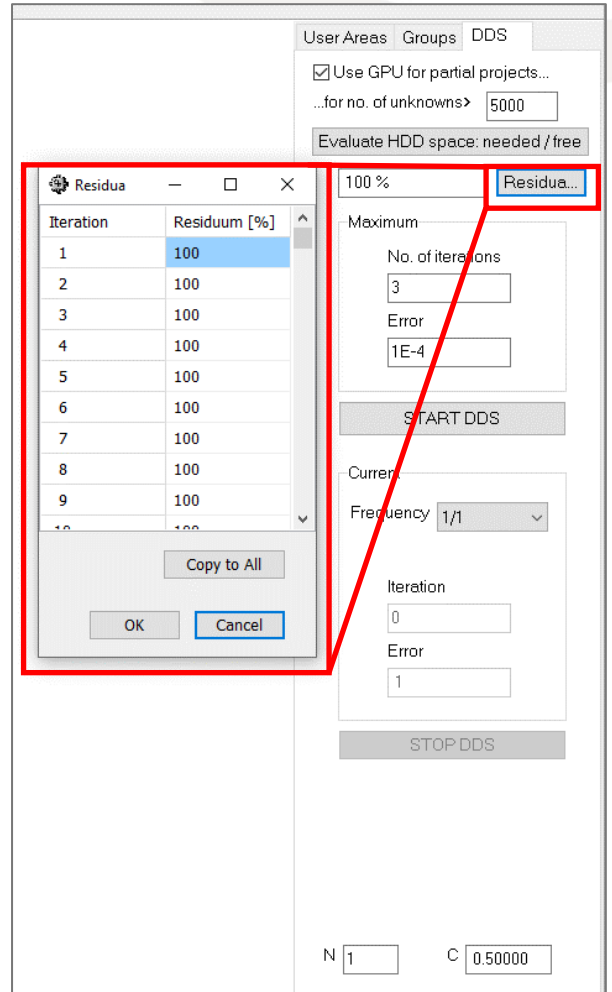


Figure 7. DDS tab

## WIPL-D and DDS Simulations and Results for Reflector Antenna with 420 Wavelengths Diameter

The antenna was simulated at 25.5 GHz calculating the radiation pattern in  $\phi=90$  degrees plane at 3601 equidistant directions along theta angle.

The WIPL-D Pro and DDS antenna simulations were performed using a workstation with the hardware specification as presented in Table 1. The number of elements, number of unknowns, and total simulation time required for WIPL-D Pro simulation are given in Table 2. Simulation times when using DDS iterations are presented in Table 3.

Table 1. Workstation used for the simulations

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

Table 2. Number of elements, number of unknowns, and total simulation time required for WIPL-D Pro simulation

Model	Number of elements	Number of unknowns	Total simulation time
420 wavelengths diameter reflector antenna	132,846	463,891	6 hours 25 minutes

Table 3. DDS iterations and simulation times

Iterations	Simulation time [minutes]
0 <sup>th</sup> +1 <sup>st</sup>	36.3
0 <sup>th</sup> +1 <sup>st</sup> +2 <sup>nd</sup>	64.9
0 <sup>th</sup> +1 <sup>st</sup> +2 <sup>nd</sup> +3 <sup>rd</sup>	99.0

Radiation pattern obtained using WIPL-D Pro is shown in Figure 8. Radiation patterns obtained after DDS iterations are shown in Figure 9.



According to the radiation patterns presented in Figures 8-9, it can be recognized that the results presented in these figures are very similar. Especially, the result of the 3<sup>rd</sup> iteration obtained using Domain Decomposition Solver is in excellent agreement with the full 3D EM MoM result obtained using WIPL-D Pro Software. It can be confirmed directly in Figure 10 where DDS result obtained after three (0<sup>th</sup>+1<sup>st</sup>+2<sup>nd</sup>+3<sup>rd</sup>) iterations is compared with WIPL-D Pro result.

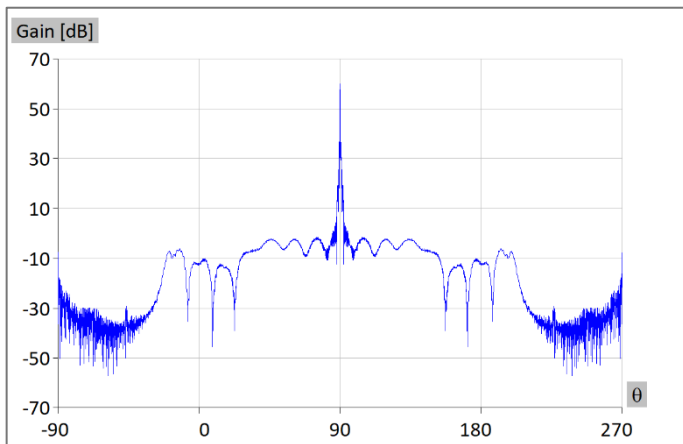


Figure 8. WIPL-D Pro radiation pattern result

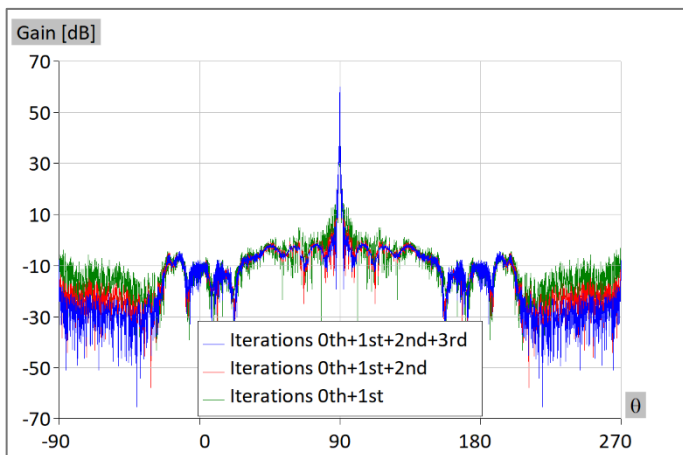


Figure 9. Radiation pattern results after DDS iterations

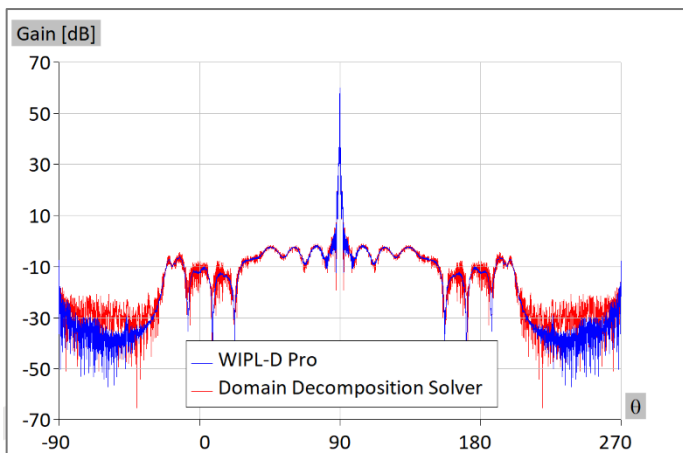


Figure 10. DDS result compared with WIPL-D Pro result

## Conclusion

An electrically large reflector antenna was modeled using WIPL-D Pro and simulated using WIPL-D Pro and Domain Decomposition Solver (DDS). In particular, radiation patterns of an electrically large Cassegrain reflector antenna have been calculated and compared.

The simulations were carried out using **WIPL-D Pro, a full wave 3D electromagnetic Method-of-Moments based software** which applies **Surface Integral Equations** on one hand and iterative **Domain Decomposition Solver** on the other side. DDS method of operation is shortly explained in the introductory part of this document.

Having in mind an electrical size of the structure, one can conclude that all the results were calculated in relatively short amount of time. In addition, the workstation on which the calculations were performed is by no means a cutting edge or highly sophisticated but an affordable desktop PC empowered with GPU cards.

Convergence of the results is very good leading to high efficiency. With respect to the results of the first DDS iteration, the accuracy improves after the 2<sup>nd</sup> iteration and even more after the 3<sup>rd</sup> iteration. On the other hand, the result of the 3<sup>rd</sup> iteration is in excellent agreement with the full 3D EM MoM result. Considering that all iterations are completed in less than 100 minutes, a conclusion can be drawn that with WIPL-D DDS, **very high numerical efficiency can be achieved** even for electrically large and demanding structure such as reflector antenna with 420 wavelengths diameter.