Cassegrain Antenna

Cassegrain antennas are the subcategory of reflector antennas. Reflector antennas have been used from the discovery of the electromagnetic wave propagation. The most important application of reflector antennas was in radars manufacturing, as well as in space communications and radio astronomy.

Reflector Antennas in WIPL-D Software Suite

WIPL-D Pro is a Method of Moments (MoM) based code which enables very accurate EM simulation of arbitrary 3D structures. Among them are antennas in various technologies: wire antennas, horn and aperture antennas, reflector antennas, microstrip antennas, phased array antennas, helical antennas etc. For parabolic reflector antennas, a special type of aperture antennas, MoM based simulation gives more accurate results than approximate techniques based on physical optics PO and/or uniform/geometrical theory of diffraction (UTD/GTD) which are widely used for simulation of dishes.

WIPL-D kernel implements MoM in the advanced way by using higher order basis functions. They are implemented in the most efficient but yet very accurate and stable manner. Expansion order of currents are supported up to the 8th order which is reserved for 2 lambda by 2 lambda mesh elements. This offers order of magnitude more efficient simulation than the traditional low order MoM implementation with highly dense mesh. The mesh elements are quadrilateral rather than usual triangular mesh elements which reduces required number of unknowns two times.

There are several distinct features allowing WIPL-D suite to be extremely efficient in simulation of reflector antennas. Besides the usage of the default MoM kernel, WIPL-D offers specialized built-in Reflector object, applying symmetry and highly efficient CPU/GPU in the modern hardware configuration.

Typically, a model of the reflector is built in WIPL-D Pro using predefined Reflector object editor, shown in Fig. 1. Automatic geometry and mesh generation enable creation of parabolic reflector of circular, elliptic or rectangular shape (with or without rounded corners), with central or offset feed. Two types of meshing are available: Classic and Advanced. Advanced meshing is customized for reflectors of circular and elliptical shape and simulation of such reflector requires less unknowns than with classic meshing.

Alternatively, a model of the reflector can be imported from a CAD file, or custom-defined by the user, through a script file.

The advantages of using built-in reflector objects are numerous. The primary is the straight-forward definition of the reflector geometry. But more important ones are: fast and easy control of the simulation accuracy, and reduced number of unknowns. Namely the default mesh of reflectors is the Advanced mesh technique. It assumes that the central part of the reflector surface is meshed with more quadrilateral plates then the reflector rim. Also, the current expansion orders are fixed throughout the mesh. The simulation accuracy is controlled solely by the number of segments used to define the reflector.

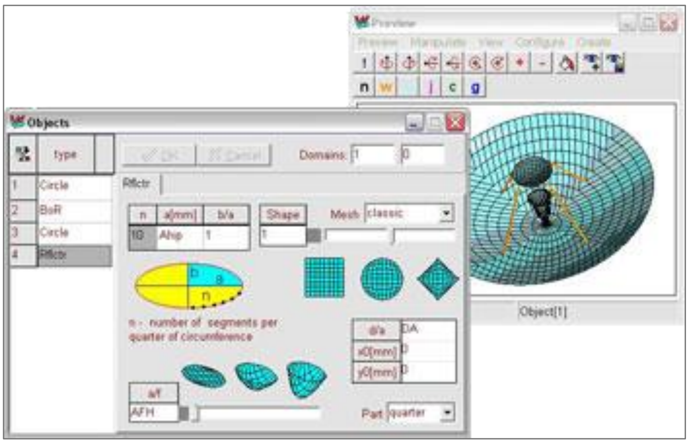

Figure 1. Defining reflector objects in WIPL-D Pro

Number of segments for the reflector should be chosen in start so that the size of mesh elements on the rim is approximately 1.5 lambda. Such mesh elements would require the 5th expansion order and around 50 unknowns per mesh element in general simulations. However, since they are a part of the reflector object, their order is reduced to the 3rd and they require only 18 unknowns per quad, approximately three times less.

The user is advised to increase the Integral Accuracy parameter to Enhanced 2 for the simulation of the reflector antennas. The testing convergence procedure is simple. The number of reflector segments should be increased (thus decreasing the reflector patch size), until the desired accuracy is obtained. This is usually measured as accuracy of the side lobes calculation compared to the level of main lobe. 1.5 lambda patches ensure this accuracy at the -40 dB level. Once the required accuracy is achieved, user can test if Integral Accuracy = Enhanced 1 or Normal will yield the identical results with slightly reduced simulation time.

This way, the simulation time for large reflectors is decreased significantly. However, very large reflectors (it is possible to simulate the dishes whose diameter is measured in dozens and even hundreds of wavelengths) require very large number of unknowns. User is advised to apply symmetry whenever that is possible. Finally, the simulation is extremely efficient in modern multicore CPUs. When the size of MoM matrix is very large, user is advanced to perform simulations (MoM matrix inversion) by using CUDA enabled modern GPU cards, where WIPL-D solution is tremendously fast with inexpensive hardware requirements.

Theoretical Performances

Main characteristic of reflector antennas is high directivity. In certain applications they can substitute antenna arrays. The maximum achievable gain of any reflector antenna is proportional to the aperture surface (diameter).

An example of the Cassegrain antenna is simulated in WIPL-D Pro 3D EM solver (Fig. 2). The simulation is performed in the Ka band (used for satellite communications).

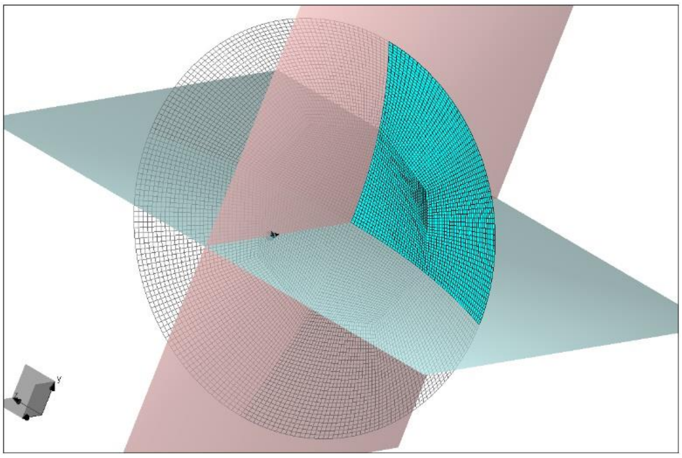

Figure 2. Cassegrain antenna

Cassegrain antenna consists of two reflectors (primary and secondary), as well as the illuminator (feeder). The primary reflector is curved and serves as illuminator of the secondary reflector (Fig. 3).

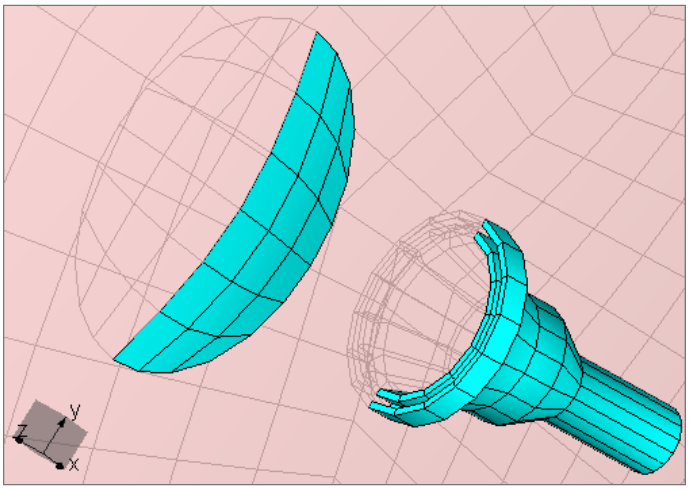

Figure 3. Cassegrain primary reflector. Half antenna model

In the reflector antenna system, the function of the feeder is usually done by horn antenna (Fig. 4). In this project, the feeder is particularly designed to suppress backward radiation. This was achieved by adding a choke to the horn aperture edge. The length of the choke is equal to quarter of free-space wavelength (the parameter Lam/4 in Fig. 4). Axial two-level design enables dual mode electromagnetic wave propagation.

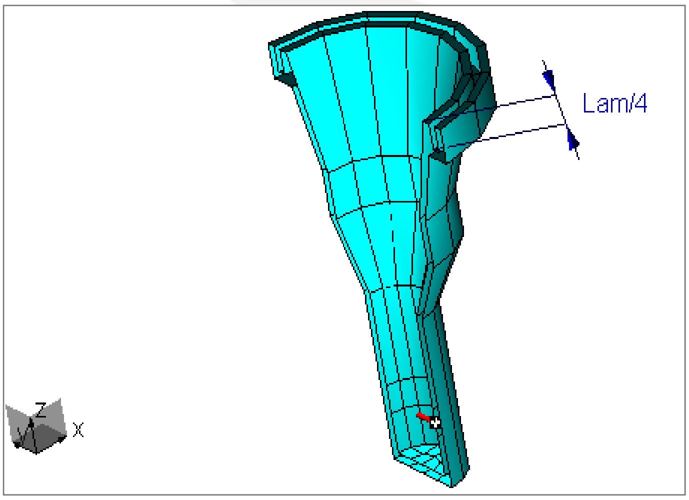

Figure 4. Feeder. Half antenna model

Assuming that the feeding system is optimized, the most critical design parameter is secondary reflector radius (R).

WIPL-D Simulation

The most efficient way to perform simulation of the Cassegrain reflector system is to apply two symmetry planes and to use the built-in Reflector object. In this case, metallic parts are considered to be perfectly conducting while the realistic losses can be added as distributed loadings (not increasing number of unknowns or the simulation time).

The operating frequency is 26.5 GHz (Ka-band). For the given operation frequency, the secondary reflector radius has been chosen as 1132 mm (approximately 100 wavelengths). This makes the diameter of the simulated dish around 200 lambdas. The data is enlisted in Table 1.

Table 1. Parameter of analysis

Parameter	Value [mm]	Value [lambda]
R	1132	100

For the parameters given in Table 1, the gain of the antenna is shown in Figure 5 (2D Phi-cut, Phi=0 degrees). The simulation is performed by using inexpensive desktop PC: Intel® Core(TM) i7 CPU 7700 @3.60 GHz, 32GB RAM, one low end GPU card Nvidia GeForce GTX 1080. Simulation was performed using GPU card for MoM matrix inversion to achieve the best performances. The PC is basically a standard quad core desktop PC, with slightly increased amount of RAM and improved by adding a low end CUDA enabled GPU card. The GPU card is optimum solution for matrix inversion for electrically larger problems, while the matrix fill in and matrix inversion for electrically smaller problems are performed by using CPU.

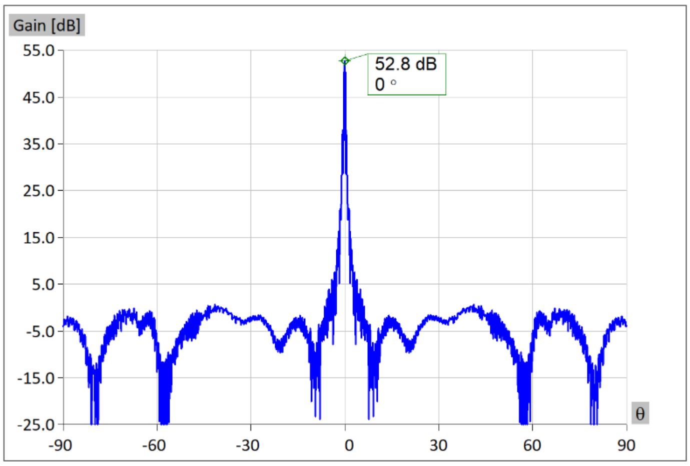

Figure 5. Radiation pattern, phi-cut

The number of unknowns and the simulation time of analysis are given in Table 2. This very large (200 wavelengths) reflector antenna has been simulated at regular desktop PC in several minutes. If such a configuration is expanded with even the low-end GPU card, the matrix inversion time (the dominant part of the simulation) is reduced several times. However, since the significant part of the simulation time is matrix fill-in, the overall speed up is two times.

Table 2. Simulation details

Model	Number of unknowns	CPU time @26.5 GHz [min]	GPU time @26.5 GHz [min]
quarter	38,525	13.3	7

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Conclusion

The results shown in this application note demonstrate that it is possible to simulate very large reflector antennas in WIPL-D software by using regular desktop PC. Typically, 200 lambda dish would be solved by using approximate high frequency techniques. Cassegrain antenna of this size is a challenging simulation task and this sort of antenna is usually analyzed using the geometrical optics methods.

WIPL-D Pro offers specialized geometrical objects to be used as building blocks for complex antenna system models. Reflector shapes can also be imported from a CAD file, or they can be customized according to a user-defined shape (script file). Hence, practically any type of a reflector antenna can be easily modeled. WIPL-D implements MoM by using quadrilateral elements of 2 lambda by 2 lambda size (the 8^{th} expansion order). Furthermore, the simulation is efficiently parallelized on modern CPUs.

These unique WIPL-D features allow accurate simulation in acceptable simulation time in inexpensive hardware configurations. Simulations can be significantly faster if low-end GPU cards are used for matrix inversion phase.

In this particular application note, WIPL-D Pro successfully analyses 200 lambda Cassegrain reflector antenna by using higher order MoM, without any need for the approximations (such as GO or PO). Simulation time and hardware requirements are minimum (CPU or GPU based platform). The simulation time is dramatically reduced when the GPU solution is introduced. The simulation accuracy has been chosen in such a way that it yields the acceptable engineering accuracy for the main lobe and major side lobes. The size of patches is approximately 2.5 wavelengths while the most accurate results are obtained for 1.5 lambda.