Parabolic Torus Reflector Antenna

Introduction: About WIPL-D

WIPL-D Pro is a well-established full wave 3D EM solver based on state-of-the-art implementation of Method of Moments (MoM). Inherently, MoM is very suitable for open region (radiating) problems and even for the simulation of electrically moderate and large structures. A typical example of such a problem would be simulation of reflector antennas, whose size can be measured in tens or hundreds of wavelengths.

A few unique features allow WIPL-D to be unbeatable tool for full wave simulation of electrically large models. The natural limitations of EM simulation are hardware resources and simulation time. Number of unknown coefficients needed to represent the current distribution at the certain frequency is used to determine problem size and software/hardware requirements in MoM. This number (N) scales as square with the simulation frequency. The first technique used to reduce this number is usage of quadrilateral mesh. It enables two times less unknowns than for tools based on triangular mesh. However, the market does not offer efficient quad meshes, so WIPL-D team developed its own in-house quad mesher, as well as numerous built-in primitives which are already meshed (such as reflectors). The second advantage is usage of higher order basis functions, which allow the usage of 2 wavelengths large mesh elements, compared to typical 0.1 lambda or less for the first order current coefficients. At the end, WIPL-D simulation is efficiently parallelized on multi-core CPU platforms, and also the simulation is available on inexpensive CUDA enabled GPU cards.

There are a few features specific to simulation of reflector antennas which offer additional simulation advantages for this specific application. Over the years, WIPL-D team has developed its own built-in primitive for meshed reflectors. The mesh is optimized for simulation of illuminated reflectors. Namely current coefficients are fixed so that Reflector object accounts 3 times less unknown coefficients than its electrical size requires. This is the minimum requirement which reduces simulation time and required resources, but preserves full accuracy. In addition, very often the symmetry can be applied to speed up simulations.

Torus Reflector Antennas

In most cases, parabolic reflector antennas are designed by rotation of parabolic curve along its axis. However, torus reflector antenna (TRA) is a quasi-parabolic antenna, where the defining parabola is not rotated around the main transmission axis, but around an axis which stands vertically to this axis. This is illustrated in Figure 1.

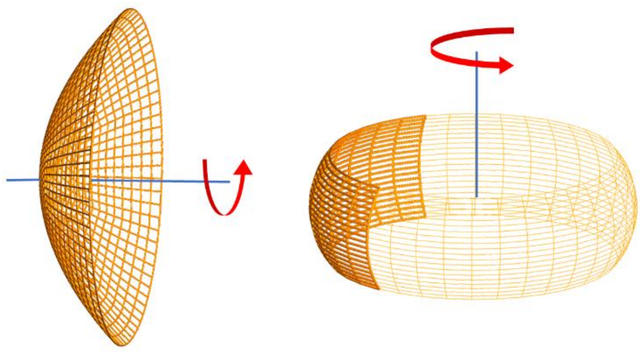


Figure 1 Parabolic reflector antenna (Left) and torus reflector antenna (Right)

Since this structure represents a Body of Rotation, in WIPL-D this structure is actually created via WIPL-D built-in BoR object. Such a structure does not offer excellent aperture efficiency as standard parabolic reflector, but if illuminated with several fixed antennas, it offers an efficient multibeam operation.

WIPL-D Model

WIPL-D modeling starts from design of the horn antenna. With its extensive multi-year experience in simulation of various antennas, WIPL-D support team has a large collection of models which can be re-used. In this case a dual mode choked conical horn antenna was used by simple adjusting the frequency (10 GHz) in a fully parametrized project which generates entire structure after user defines the frequency as project variable (WIPL-D term is *Symbol*). The dual mode choked conical horn antenna is shown in Figure 2, with illustration of the Symbols table shown in Figure 3.

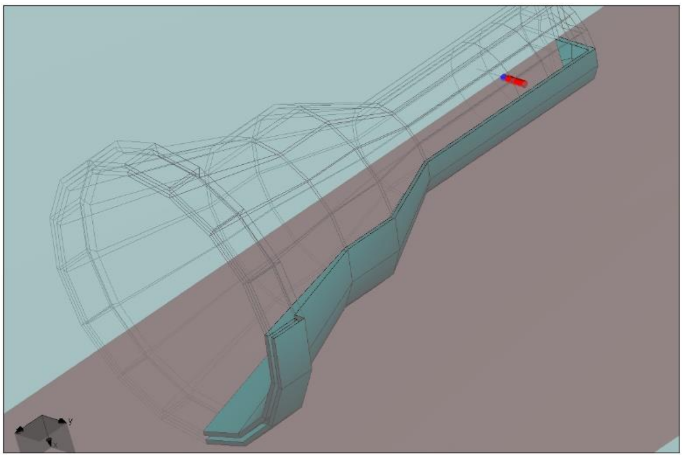
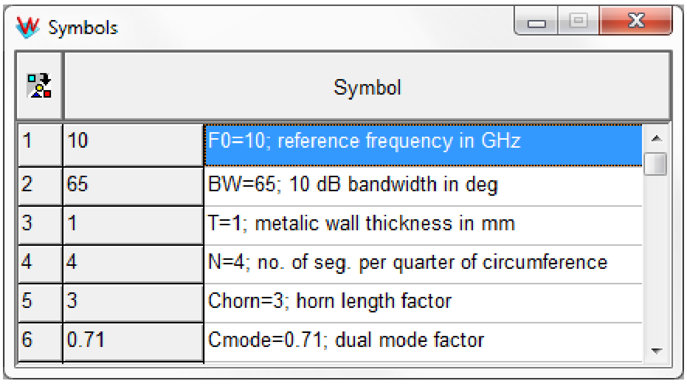


Figure 2 Conical horn antenna serving as illuminator



Symbols

	Symbol	
1	10	F0=10; reference frequency in GHz
2	65	BW=65; 10 dB bandwidth in deg
3	1	T=1; metalic wall thickness in mm
4	4	N=4; no. of seg. per quarter of circumference
5	3	Chorn=3; horn length factor
6	0.71	Cmode=0.71; dual mode factor

Figure 3 Symbols used to adjust the antenna

The torus reflector is next modeled as a single BoR object. The built in Reflector object cannot be used, so a series of symbols is defined for the parabolic curve. The parabolic curve is entered as one sweep path of the BoR, while the other sweep path is the segment of the circle with the required angle set by user. An array with 11 horns is used to illuminate the reflector, each horn being rotated for 10 degrees.

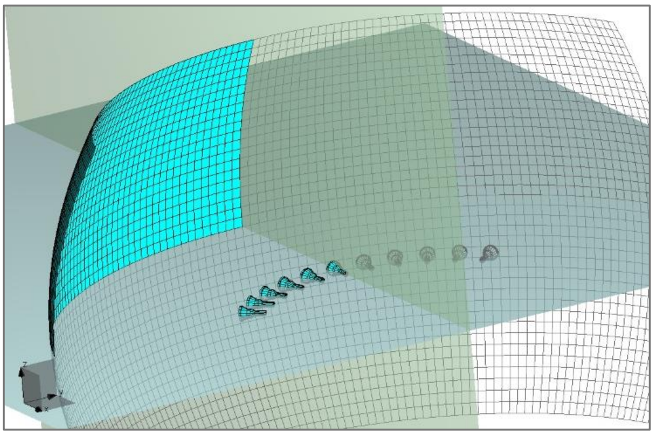


Figure 4 Torus reflector illuminated with 11 horn antennas

WIPL-D Simulations

The horn antenna was first simulated at 10 GHz to verify its proper radiation. Two symmetry planes were applied so the simulation requires only around 600 unknowns and can be carried out on any given PC in seconds. Figure 5 shows E and H plane radiation with 15 dB gain and approximately 35 degrees half beam width.

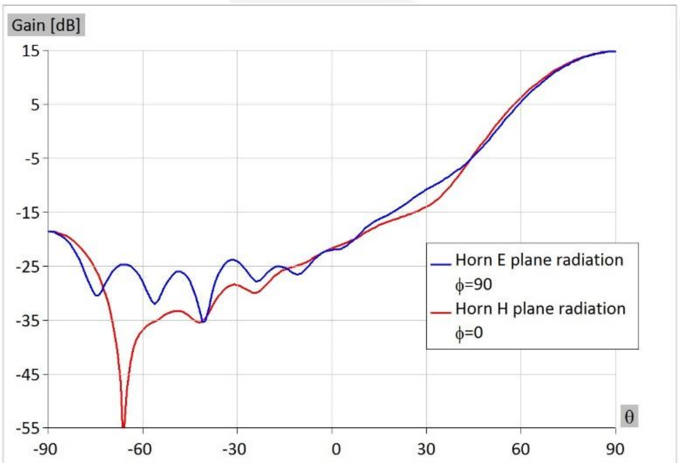


Figure 5 Horn radiation pattern

The final simulation step is to simulate the torus reflector with antennas. Horns are excited one by one and the radiation pattern is shown in Figure 6 for one half of horns (the remaining horns show the symmetrical pattern). Figure 7 shows the pattern of the horn illuminating the center of the reflector in horizontal plane.

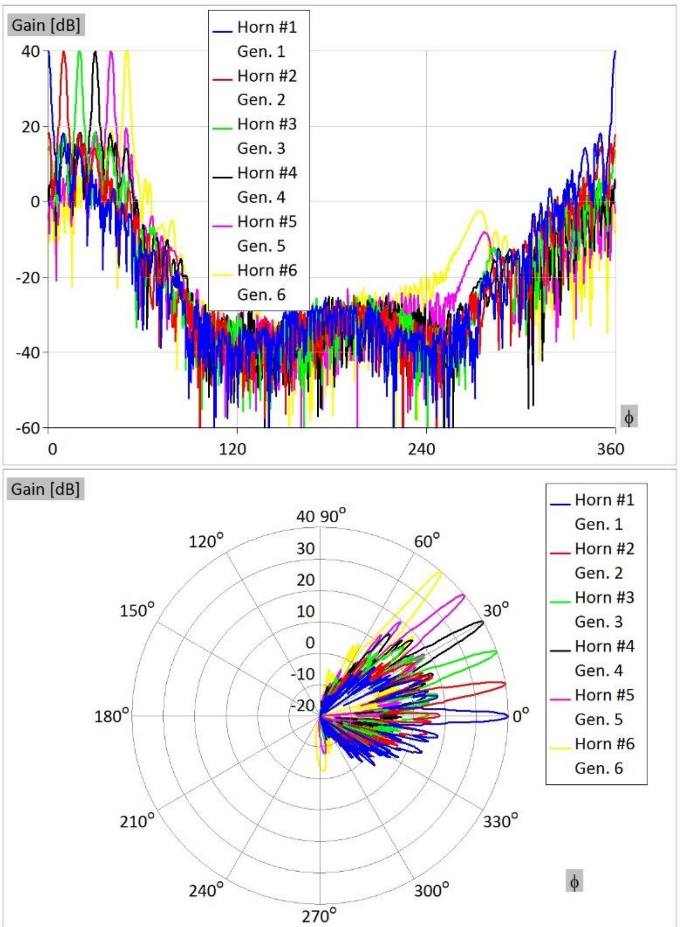


Figure 6 Radiation pattern for 6 horns

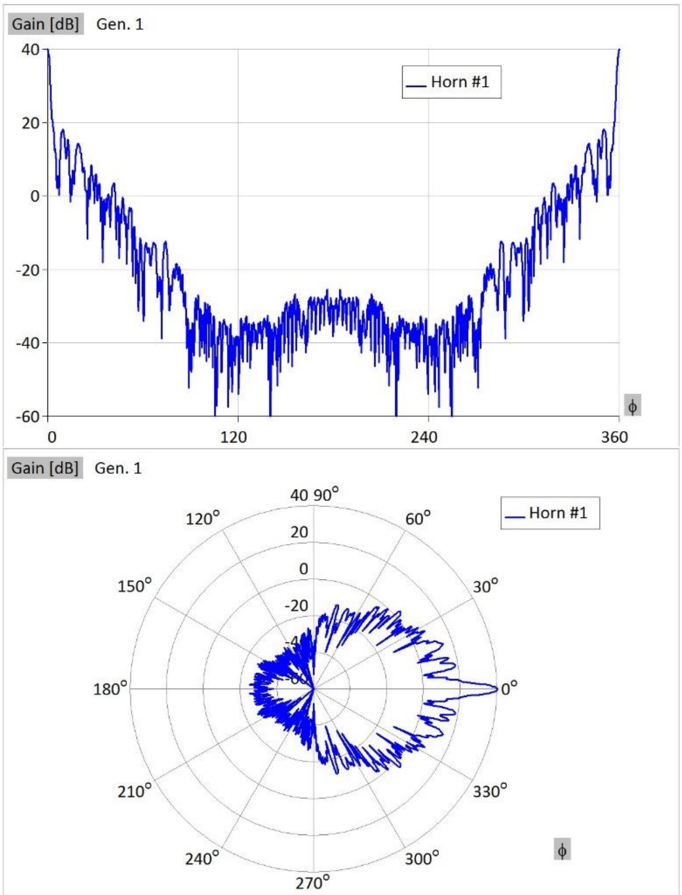


Figure 7 Radiation pattern of single horn in horizontal plane

The simulation is carried out by using anti-symmetry and asymmetry plane, which means that the MoM kernel is invoked twice but original number of unknowns is reduced 4 times. The entire simulation requires less than 25,000 unknowns. Reflector size (aperture) is approximately 1.8x3 m (corresponding to 60x100 wavelengths). Simulation can be carried out on regular desktop PC. Assuming that the CPU is quad-core and that PC has single inexpensive GPU card, the entre simulation (2 runs) lasts just a couple of minutes. If only a quad core CPU is used, simulation lasts a couple minutes longer. The PC used for simulation has Intel i7-7700@3.60 GHz quad core CPU and low-end Nvidia GeForce GTX1080 GPU card.

Table 1. Measured simulation times.

Matrix inversion	Number of unknowns	Time [sec]
GPU	22,674	235
CPU	22,674	380