Yagi-Uda Antenna

The Yagi-Uda (further Yagi) antenna is basically a dipole antenna, whose radiation is focused by a series of parallel dipoles and a reflector behind. It is mostly used in radio links for computer (Wi-Fi) networks, as well as a receiver for TV and FM radio signals.

Theoretical Characteristics

The main characteristics of Yagi antennas are increased gain (5-16 dBi) and narrow-band operation mode (relative bandwidth is approximately 10% of the central operating frequency).

Two models of Yagi antennas are simulated in WIPL-D. In the first, the radiating element, directors and reflector are modeled as wires, while in the second one they are made of plates (solid body). The wire model is shown in Fig. 1, plate antenna is shown in Fig. 2, while feeding area of the plate model is shown in Fig. 3. The dimensions of both models are identical. Each wire in the wire model is replaced by a body of rotation and terminated by using a circle object in the plate model.

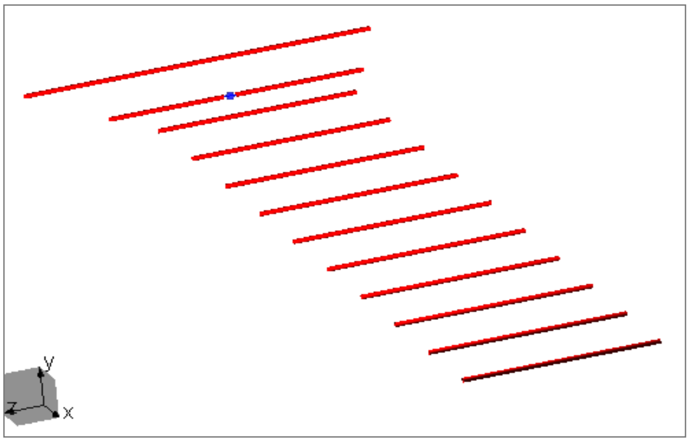

Figure 1. Yagi antenna made of wires

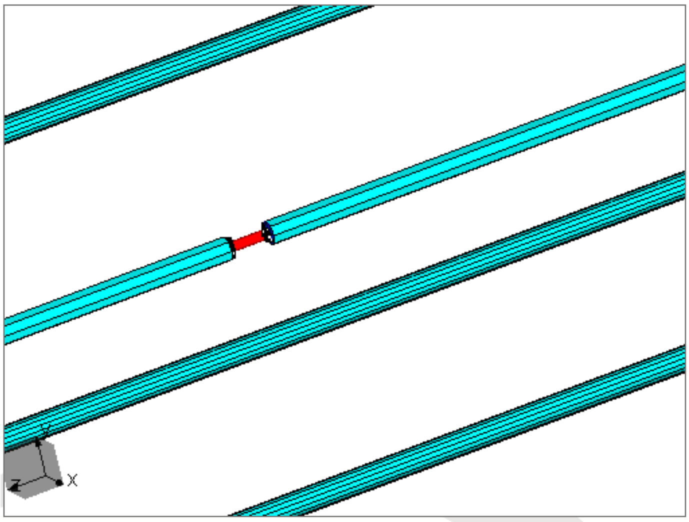

Figure 2. Yagi antenna made of plates

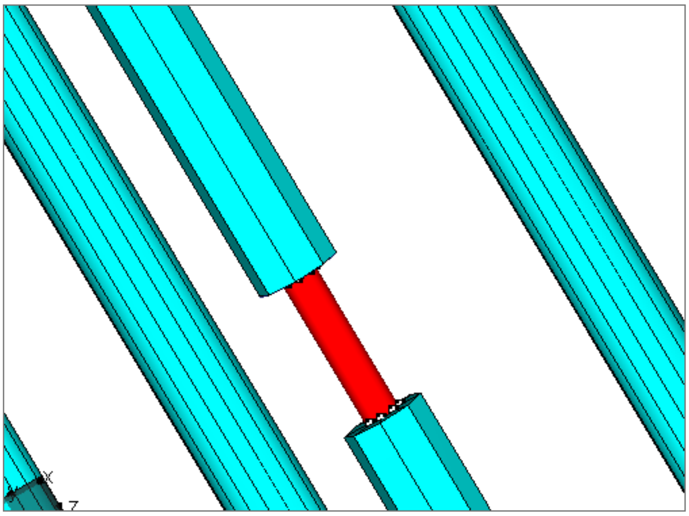

Figure 3. Yagi antenna made of plates – feeding area and plate modelling

The Yagi antenna simulated in this application note consists of single reflector, one fed dipole and ten directors.

Our aim is to compare simulation times for the wire and plate models, as well to establish if the approximation of the model by simple wire is justified. We will assume that the given antenna is used in B-band (NATO band classification).

WIPL-D Simulations

In the WIPL-D software, geometrically regular structures can be easily designed using built in features, in a few steps. Antennas shown in Figs 1-2 can be modeled in several ways. They are electrically small, so the simulation time and number of unknowns are rather low. One can use WIPL-D feature (Anti-) Symmetry and Object/Copy to build the antenna design quickly. Metallic parts are considered to be perfectly conducting, although that does not increase simulation requirements.

The operating frequency is 266 MHz (the B-band).

The results presented include calculated gain and near field. The computer used for these calculations is Intel® Core™ i7 CPU 7700@3.60 GHz. This is a standard desktop (quad core) PC, without any additional requirement.

Radiation pattern in 3D is shown in Fig. 4. Overlaid (for the wire and plate model) 2D radiation patterns for single theta cut are shown in Fig. 5. Near field of the wire model is given in Fig. 6. Number of unknowns and simulation time of the analysis are given in Tab. 1.

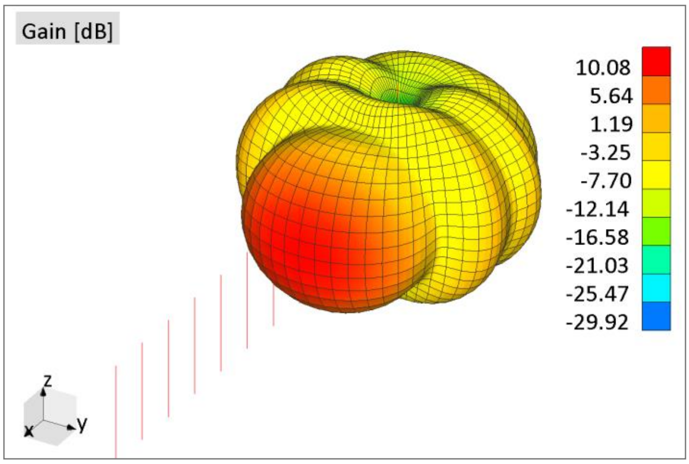

Figure 4. Radiation pattern of Yagi antenna made of wires

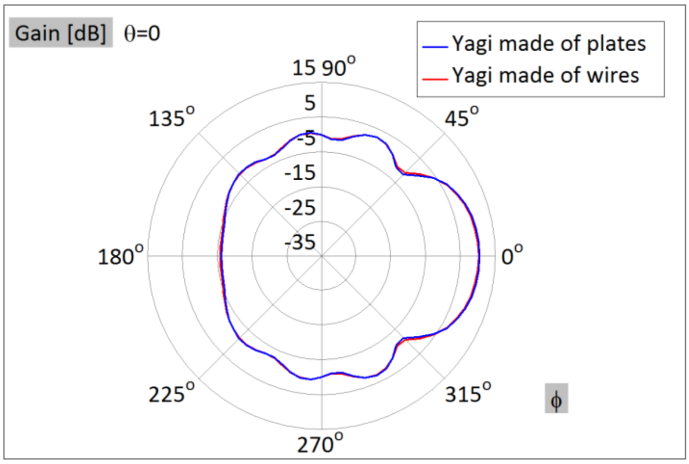

Figure 5. Overlaid 2D radiation patterns for theta cut

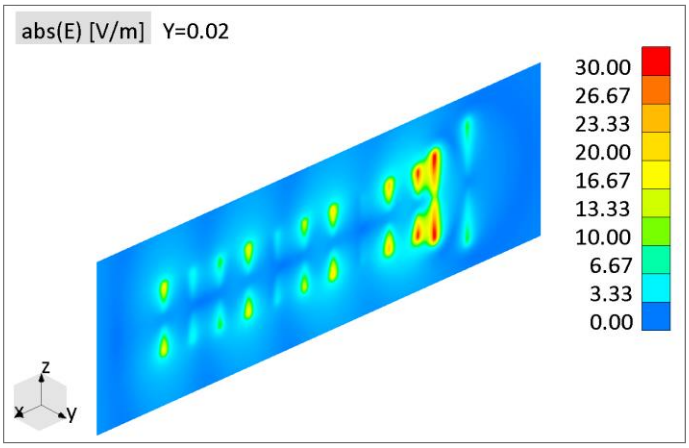

Figure 6. Near field of Yagi antenna made of wires

Table 1. Analysis characteristics

Model	Number of unknowns	Time @ 266 MHz [sec]
Wires	36	~0.001
Plates	1 560	~5

Applying Symmetry

Very often, the geometry involved in a specific EM simulation allows the usage of symmetry. This is not important for wire models due to their low number of unknowns and short simulation time. However, if the symmetry is applied to the plate model, the simulation requires less unknowns and has shorter simulation time. The quarter of the model used for simulation in case of two symmetry planes is shown in the following figure, while the simulation details are listen in Table 2.

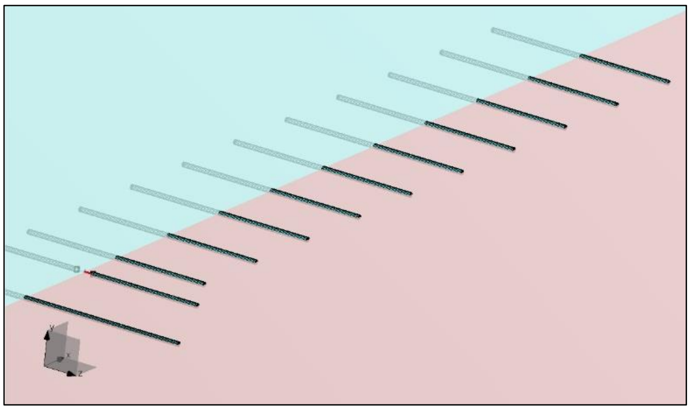

Figure 7. Applying symmetry to the plate Yagi

Table 2. Simulation details

Model	Number of unknowns	Time @ 266 MHz [sec]
Full	1,560	5
Symmetrical	592	2

Conclusion

This application note demonstrates the efficiency of the WIPL-D software suite for simulation of the Yagi antenna. The simulations are carried out almost instantly. The paper also shows the advantages of using the wire models. They are order of magnitude easier to develop and simulate.

This simple problem can lead us to the solution of very complex problems, involving thousands of wire elements. That means that numerous elongated structures can be approximated using wire models, without using the more precise and demanding plate models. We can, also, see that these two models have almost identical radiation pattern.

WIPL-D uses the thin wire approximation kernel. This means that the wire of the wire element is assumed to be changing only axially and not along the circumference. In practice, this leads to fully accurate solution for structures where the ratio of height and diameter is above 30. However, such model works approximately well even for much more "fat" wires (often even $0.1\cdot\lambda$).