Coplanar Waveguide Elliptical Slot Antenna

Introduction

This application note represents a Coplanar Waveguide (CPW) Elliptical Slot Antenna in printed technology, modeled and simulated in WIPL-D Pro CAD. The simulations were performed between 2 GHz and 15 GHz, with the results of interest being the reflection coefficient (s_{11}) and radiation pattern (RP). The proposed antenna is suitable for applications in lower C-band long-distance radio telecommunications as well as in X-band.

WIPL-D Pro CAD is fast and user-friendly full-wave 3D EM simulation software based on the Method of Moments (MoM). The goal of this application note is to demonstrate the advantages of the Symmetry feature for simulation time, as well as to explore how to optimize simulation time based on the available workstation hardware.

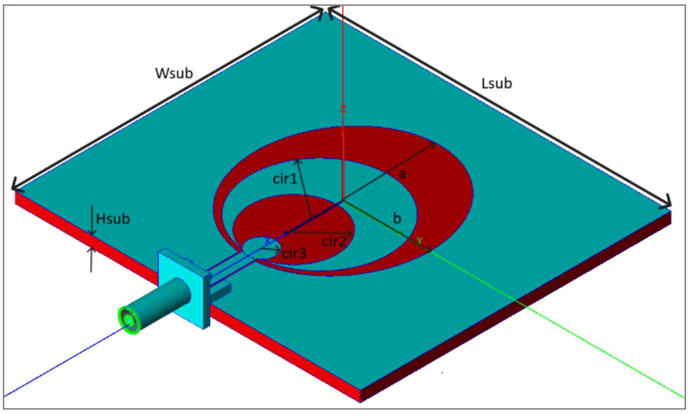

Figure 1. CPW Elliptical Slot Antenna in WIPL-D Pro CAD.

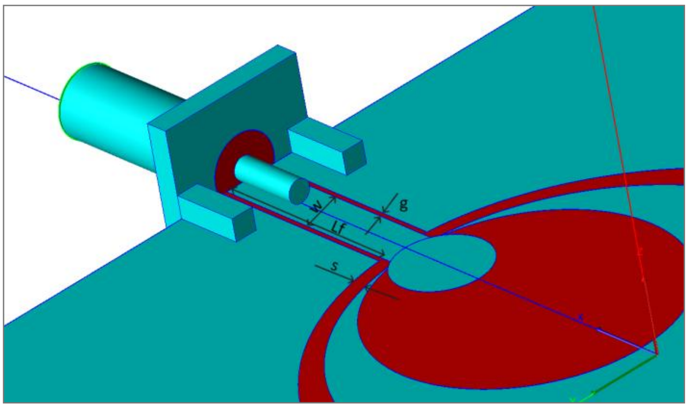

Figure 2. SMA connector as a feeder.

Model Description

The model consists of two radiating patches, a CPW and an SMA connector, excited by a coaxial port. The antenna is printed on the FR-4 substrate, with $\varepsilon_r = 4.4$ and a height of 1.6 mm. The total antenna dimensions are 45 x 50 mm, excluding the SMA connector. The antenna model is shown in Fig. 1-2.

The radiating patch is composed of a full circle (radius cir_3) and a carved-out circle (radius cir_1), placed inside a carved elliptical area (major axis a, minor axis b). This radiating patch is connected to the CPW signal line (width w, length L_f). The signal line is separated from the ground by a distance g. The CPW and SMA connector both have characteristic impedances of 50 Ω. The antenna dimensions are listed in Table 1 [1].

Table 1. Model dimensions

Parameter	*Value [mm]*
L_{sub}	50
W_{sub}	45
cir_1	10
cir_2	6.25
cir_3	2
a	28
b	25.2
w	2
L_f	9.1
g	0.2

Simulation and results

The antenna is symmetrical in the xOz plane, enabling the WIPL-D Pro CAD Symmetry feature. To verify the impact of the Symmetry feature on result accuracy, two antenna models were simulated and compared. The first model is the full antenna model, without symmetry (presented in Fig. 1). The second antenna model is the half model, with symmetry (presented in Fig. 3).

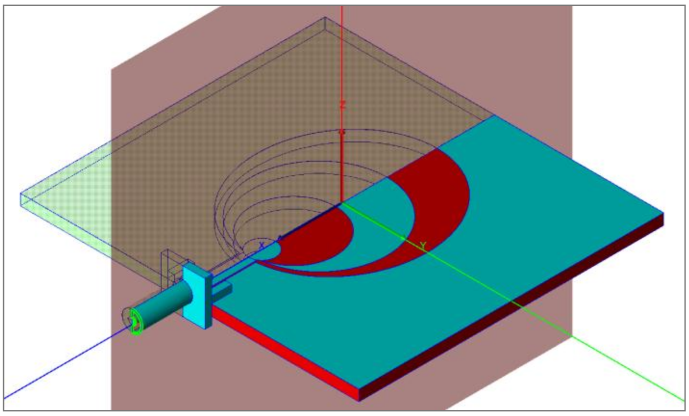

Figure 3. Half model of the antenna.

The reflection coefficient and RP are observed between 2 GHz and 15 GHz at 27 frequency points. The antenna is well-matched from 4.2 GHz to 5 GHz and from 7 GHz to 13.1 GHz (Fig. 4).

The Symmetry feature enables shortening simulation time by simulating only half of the model. The results obtained from the model without symmetry (full model) and the model with symmetry (half model) are almost identical, while the half model has approximately 50% fewer Number of Unknowns (NoU) than the full model. This verifies that the Symmetry feature does not affect the accuracy of the results.

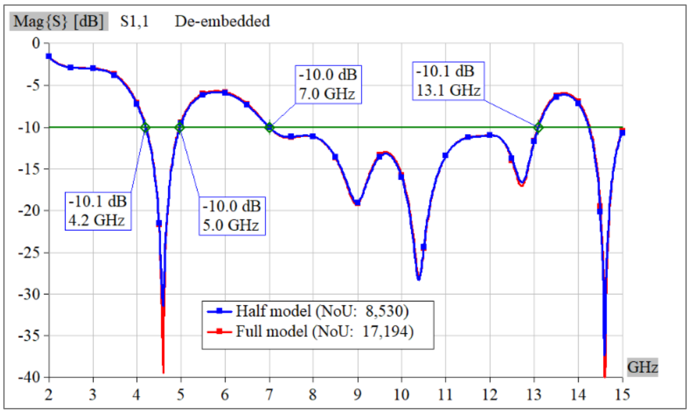

Figure 4. Reflection coefficient.

RP is obtained in 2 x 181 directions (ϕ x θ) and shown for the half model (Fig. 6-7). The normalized RP is observed for θ cut, for two values of ϕ: ϕ = 0 and ϕ = 90°.

The simulations were performed on a laptop, with the following specifications: Intel(R) Core(TM) i7-10870H CPU @ 2.20GHz, while the GPU card used for simulations was NVIDIA GeForce GTX 1650 Ti with Max-Q Design (4 GB). The WIPL-D Pro CAD simulation consists of several phases, such as meshing, matrix fill-in, matrix inversion (solution), etc. In general, matrix fill-in and matrix inversion (solution) are the most demanding phases of the simulation. Consequently, WIPL-D Pro CAD enables users to assign matrix fill-in and/or matrix inversion to CPU or GPU, with a goal to optimize the simulation time according to available workstation hardware.

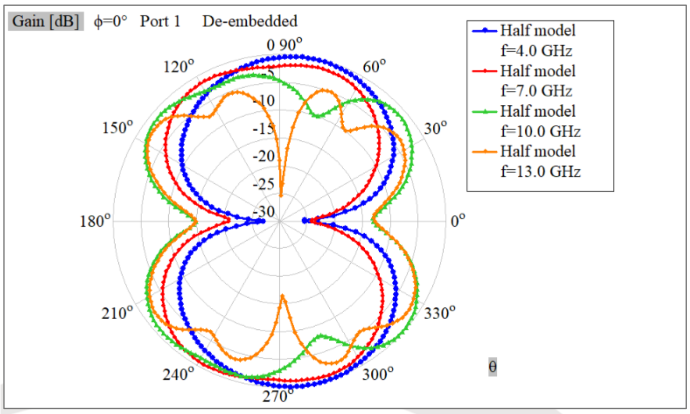

Figure 6. RP (θ cut, ϕ = 0)

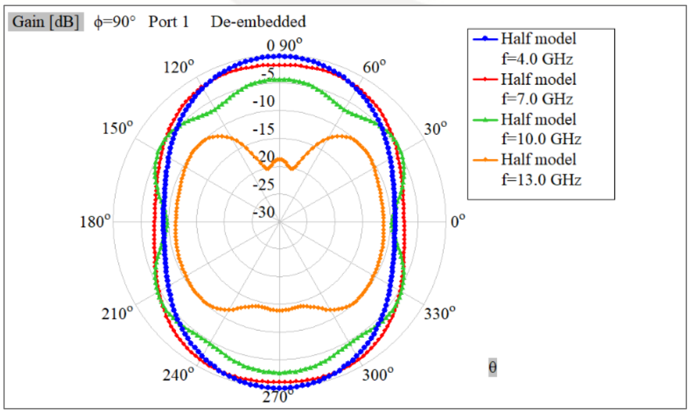

Figure 7. RP (θ cut, ϕ = 90°)

Each of the models is simulated in two scenarios, with total simulation times listed in Table 2. In the first scenario, both matrix fill-in as well as matrix inversion (solution) were performed on the CPU; in the second scenario, matrix fill-in was performed on the CPU, while matrix inversion (solution) was performed on the GPU. The simulation times for the first scenario are given in the column "CPU", and simulation times for the second scenario are given in the column "GPU".

Table 2. Measured simulation time

Model	***NoU***	***t [s]***	
		CPU	***GPU***
Full model	17,194	1,759.43	1,345.75
Half model	8,530	637.74	626.00

By comparing the simulation times given in Table 2, it is noticeable that for the smaller NoU (half model), matrix inversion (solution) is performed relatively same on CPU and GPU. However, with increased NoU (full model), matrix inversion (solution) is performed more efficiently on GPU. Based on the simulation times for a full model in Table 2, simulation is performed 23.51 % faster on the GPU.

[1] D. Konhar, A. Kumar Behera, S. Narayan Mishra, D. Mishra, "A High Gain Elliptical Slot Antenna for Lower C-band and X-band Application", Journal of King Saud University – Engineering Sciences 34 (2022) 108–115