Substrate Integrated Waveguide Cavity-Backed Slot Antenna

Introduction

This application note represents the Substrate Integrated Waveguide (SIW) Cavity-Backed Slot Antenna modeled in WIPL-D Pro CAD. The antenna is simulated from 8 to 12 GHz (X-band), while results of interest are return loss and radiation pattern (RP).

WIPL-D Pro CAD is a modern and efficient full-wave 3D EM simulator based on the Method of Moments. With surface-based quadrilateral mesh and usage of the high-order basis functions, WIPL-D Pro CAD allows a single mesh element to span up to 2 λ. Therefore, WIPL-D Pro CAD is able to successfully solve electrically very large problems as well as electrically small ones.

Model Description

The model of the SIW Cavity-Backed Slot Antenna consists of a SIW cavity, a slot on the ground plane, and a microstrip port. Due to symmetry, only half of the antenna model is represented in Fig. 1-2. The antenna is modeled on the Rogers RT/duroid 5880 substrate (ε_r = 2.2) with the substrate thickness of 1.6 mm.

SIW is created by placing metallic rods in proximity to lateral walls. Diameter (d) and distance between two consecutive metallic rods (s) respect the following criteria: $d/s \geq 0.5$, $d/\lambda \leq 0.1$. Such criteria are set with a goal to disable energy leakage between the metallic rods. The slot (ls x ws) is placed on the ground plane. The position of the slot is optimized to meet both good antenna matching and satisfying gain criteria. The antenna is fed via microstrip port attached to the antenna by a 50 Ω microstrip line.

The total antenna dimensions are 29.15 mm x 22.9 mm. In terms of λ, this is an electrically small problem (less than 2 λ x 2 λ). This antenna model doesn't require an expensive machine, and can be simulated on a rather average-performance machine. The model dimensions are listed in Table 1 [1].

Table 1. Model dimensions

Parameter	*Value [mm]*
Hsub	1.6
Lsub	29.15
Wsub	22.9
ls	19
ws	1.4
d	1
s	1.5

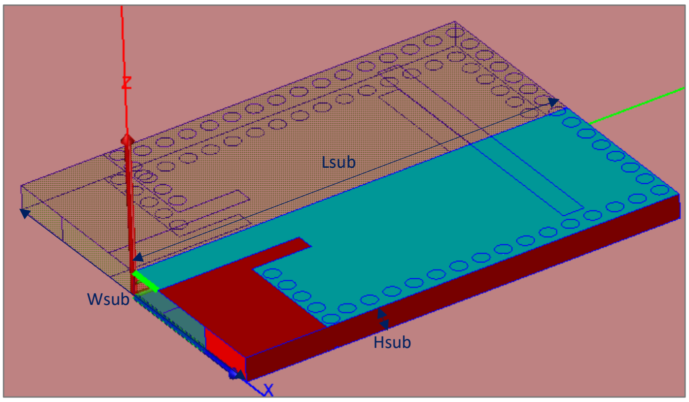

Figure 1. SIW Cavity-Backed Slot Antenna in WIPL-D Pro CAD (top view)

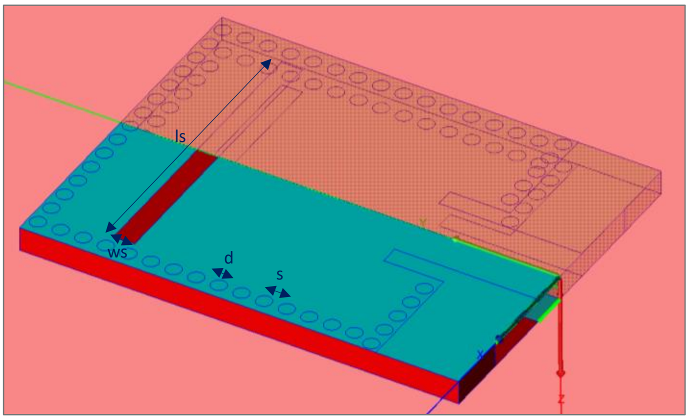

Figure 2. SIW Cavity-Backed Slot Antenna in WIPL-D Pro CAD (bottom view)

Simulation and results

The top and the bottom layer have the same contours ("imaging"), in order to speed up the meshing procedure and enable more accurate results. The return loss and RP are observed from 8 to 12 GHz, in 21 frequency points.

The proposed SIW Cavity-Backed Slot Antenna is well-matched from 9.52 GHz to 11 GHz (Fig. 3), with the maximum return loss of 13.64 dB at 10 GHz.

The antenna is radiating through the slot on the ground. The gain of the antenna is proportional to the slot area. For the chosen geometry of the slot, the proposed antenna's gain is between 1.8 dB and 3.9 dB in the frequency range where the antenna is well-matched. The maximum antenna gain is 3.9 dB at 10 GHz. The full RP is calculated in 37 x 19 directions (Phi x Theta). The 3D RP and gain over frequency plot are given in Fig. 4-5.

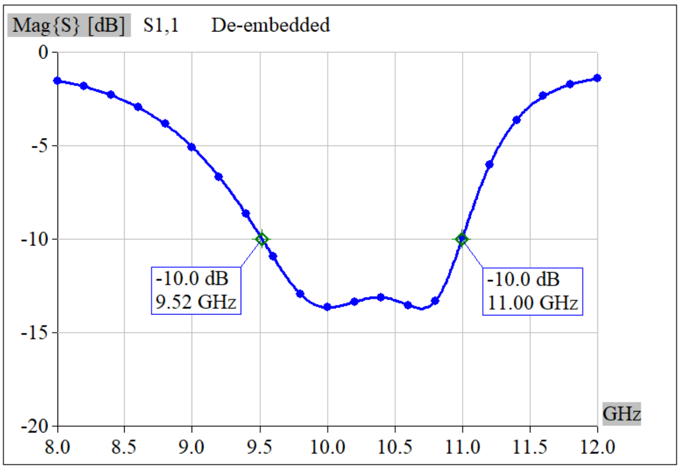

Figure 3. Return loss

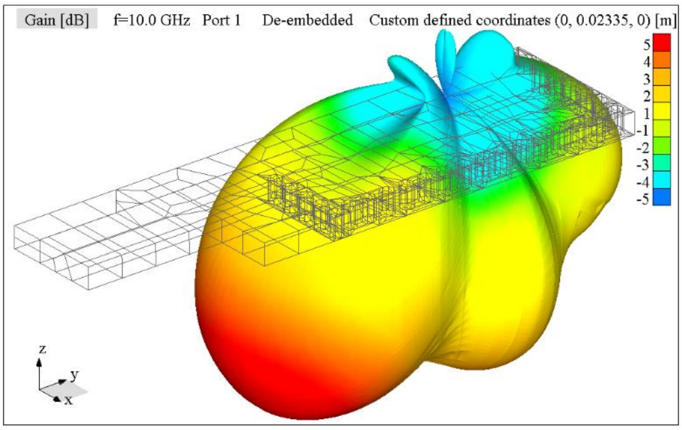

Figure 4. 3D Radiation pattern (RP origin set at slot center)

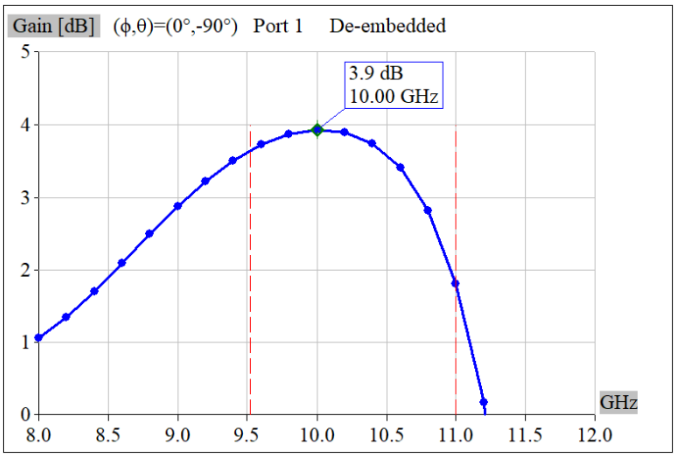

Figure 5. Gain over frequency

Additionally, near field (NF) is observed in order to verify that there's no energy leak between the two consecutive metallic rods. The NF is calculated in 50 x 50 x 1 points (Nx x Ny x Nz). Half the height of the substrate is chosen for the z-axis point. The electric field at 10 GHz is shown in Fig. 6. The position of metallic rods is represented with black circles.

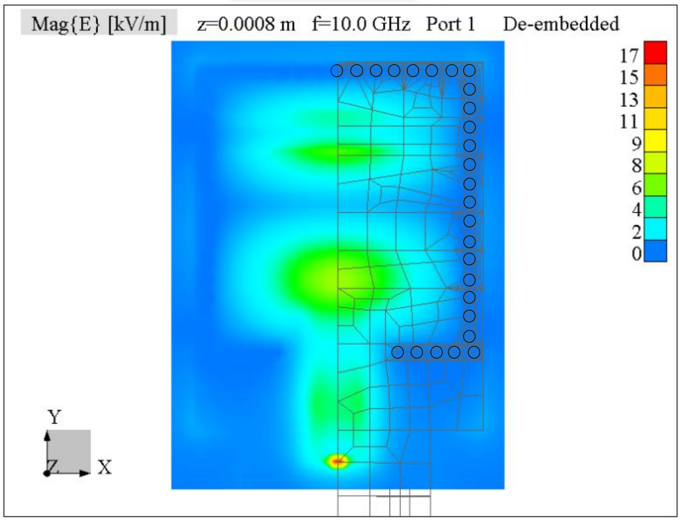

Figure 6. Electric field at 10 GHz

As previously stated, the antenna proposed in this application note is considered an electrically small problem. The total number of unknowns used for this model is 6,134. The desktop machine used for simulation has the following specifications: Intel(R) Core(TM) i7-7700 CPU @ 3.60GHz, while the GPU used for simulation is NVIDIA GeForce GTX 1080.

WIPL-D Pro CAD has a built-in CPU/GPU acceleration, allowing users to set calculations on CPU and/or GPU for the most time-consuming parts of simulation: matrix fill-in, matrix inversion, and near-field calculation. The simulation is performed in two ways. First, all parts of the simulation were carried out on the CPU. Later, all parts of simulations were carried on GPU. Simulation times for matrix fill-in, matrix inversion, and total simulation time, depending on the chosen CPU/GPU, are shown in Table 2.

Table 2. Measured simulation time

Number of unknowns	*CPU/GPU*	*Matrix fill-in [s]*	*Matrix inversion [s]*	*Total simulation time [s]*
6,134	CPU	264.35	48.32	375.63
6,134	GPU	152.20	21.85	207.21

Although GPU is usually preferred over CPU for solving electrically large problems, it can also be very helpful in shortening the simulation time even for smaller problems. Based on the simulation times given in Table 2, it can be seen that the speed of GPU outperforms the speed of CPU. Comparing the total simulation time, the simulation performed entirely on GPU is approximately 45% faster than the one performed entirely on CPU.

[1] B. Lokeshwar, D. Venkatasekhar, A. Sudhakar, **"**Bandwidth-Enhanced of Siw Cavity-Backed Slot Antenna By Perturbing Te210 Cavity Mode**",** BBRC Special Issue Vol. 13 No. 14, pp. 320-324, 2020.