Apertures in PEC Applied to an FSS Simulations

Introduction

The aim of this application note is to present an efficient simulation using WIPL-D software where a feature called "apertures in PEC/PMC plane" is used with a frequency selective surface (FSS) simulation. The report describes EM model, simulation details, and some considerations related to simulation of a typical FSS structure.

FSS Model

This EM simulation targets simulation of classical FSS described in the thesis by Dr. Sievenpiper (the subject of PhD thesis are EM surfaces with high impedances). The mushroom type FSS cells of interest for this particular application note are presented Fig. 1.

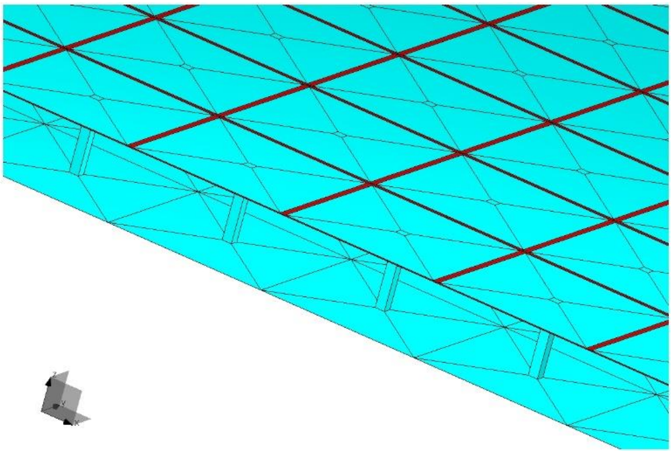

Figure 1. FSS cross section

The picture above indicates all the details about the FSS structure. It consists of a given number of unit cells (repeated periodically). Each cell is a microstrip patch, separated by a gap from the neighboring patches. The size of a patch is 2.85 mm by 2.85 mm, while the gap between the patches is 0.1 mm. The FSS is placed on a top side of a grounded dielectric substrate with a thickness of 1.33 mm and relative dielectric constant of Er=2.2. Each unit cell is connected to the ground by a square via (or post). The side of a square is 0.177 mm. The post with a square cross section of that size corresponds to the equivalent round via with a radius of 0.1 mm.

The available literature does not reveal all the relevant details about this simulation. The location of a transmitting probe at one end of FSS and the location of another probe used to measure coupling at the other end have not been specified. In addition, the geometry of the probes, details on surrounding environment possibly including absorbers to reduce the parasitic coupling and reflections have not been provided. Furthermore, the actual number of cells used in the particular FSS is not given, which introduces large uncertainty in the simulations as it could severely affect the performance and having in mind that in reality the FSS structure must be of finite size.

In that sense, we have made the simulation setup to replicate the measurement conditions we would create in our own laboratory. This is the test model that we expect to yield a good match between measurement and simulation.

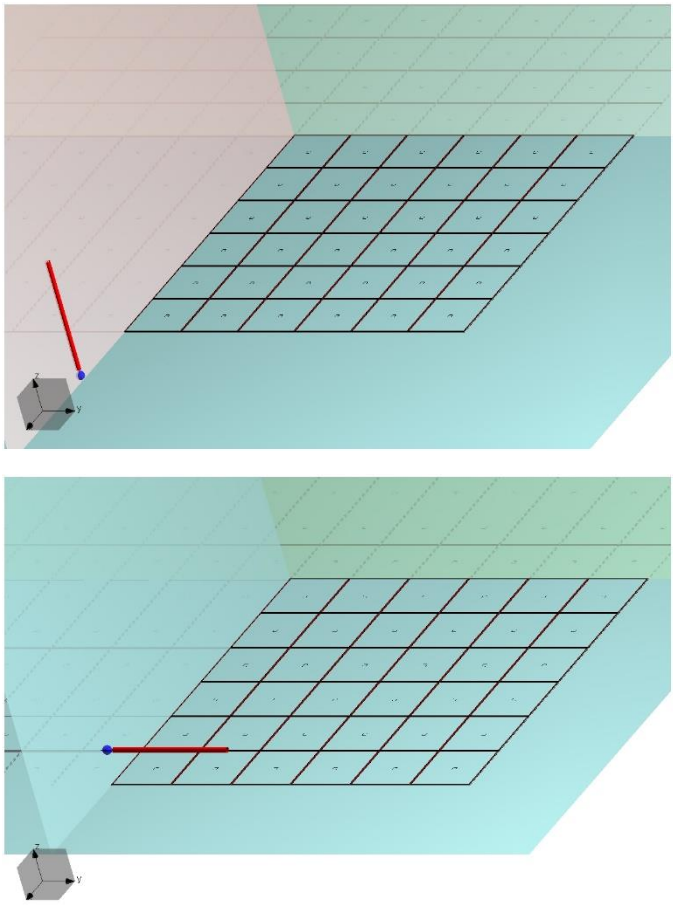

Figure 2. FSS simulation model for TM and TE polarization (quarter of the model, 6x6 cells per quarter as illustration)

Instead using absorbers to prevent coupling between antennas in any other way other than over FSS, we placed a PEC plane below antenna. Then we added FSS as aperture in such a PEC plane (special feature of WIPL-D Software). We used a very simple wire dipole to model the probe. The model is depicted in Figure 2. The feature is based on introducing different domains on opposite sides of the PEC/PMC plane, where the EM waves solely propagate through apertures defined in such planes.

We have tested various sizes of FSS and observed the EM gap in transmission which is reported in the paper. At the end, we chose a maximum size of FSS which enables clear effect of band gap, but allows having a very reasonable and affordable simulation time. To illustrate how effective WIPL-D software is, this FSS has 32x32 cells and requires only 33,000 unknowns (8.1 GB of RAM for in-core simulation). We have reduced the EM size of the problem to simulation of 16x16 cells by using symmetry of the problem. The simulation is carried out on regular desktop or laptop PC in just a couple of minutes per frequency point.

FSS results

The simulation confirms the band gap which has been reported in the literature. The existence of the gap is best illustrated when results obtained from FSS simulation are compared to the result obtained for the coupling between Tx and Rx antenna over infinite PEC. The comparison is presented in Fig. 3.

The presence of the gap is obvious in the area between 10 and 13 GHz. The larger the FSS, the better pronounced the gap is. However, the rest of the response, below and above the gap frequency, heavily depends on the size of the FSS. Position of the probe also influences results.

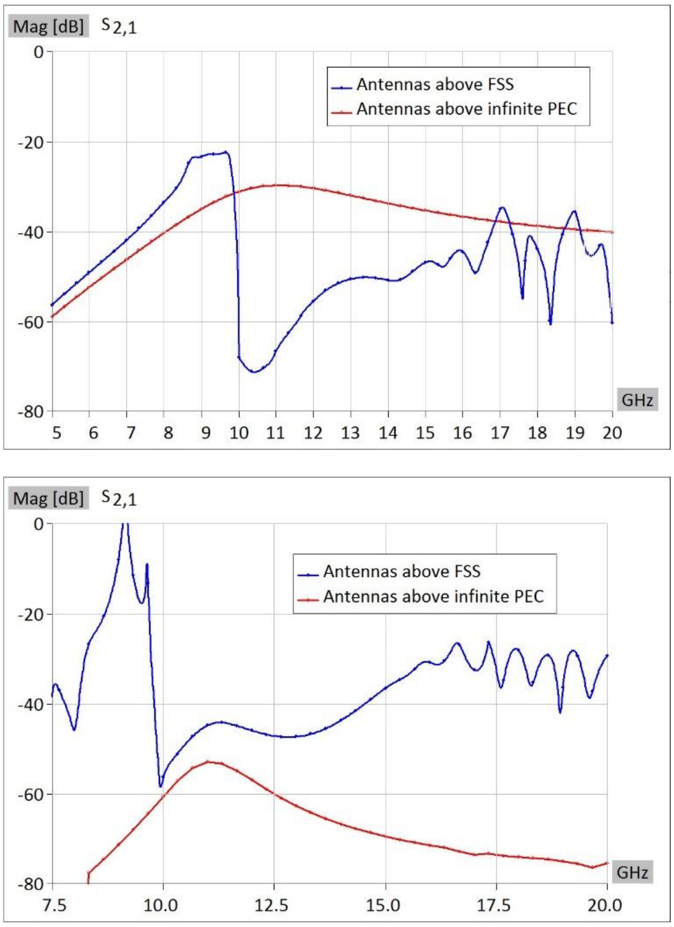

Figure 3. FSS simulation results (TM and TE polarization)

It can be seen on the Fig. 3 that the interpolation in the low frequency range is not sufficiently accurate. To have more accurate interpolation and more detailed response we have repeated the simulation using additional frequency points. As an illustration, we have presented in Fig. 4 simulation results obtained using 100 frequency points within 0.5 GHz band between 8.5 and 9 GH as response was clearly not smooth in that area. Even that was not enough to capture all the details of the FSS complex response.

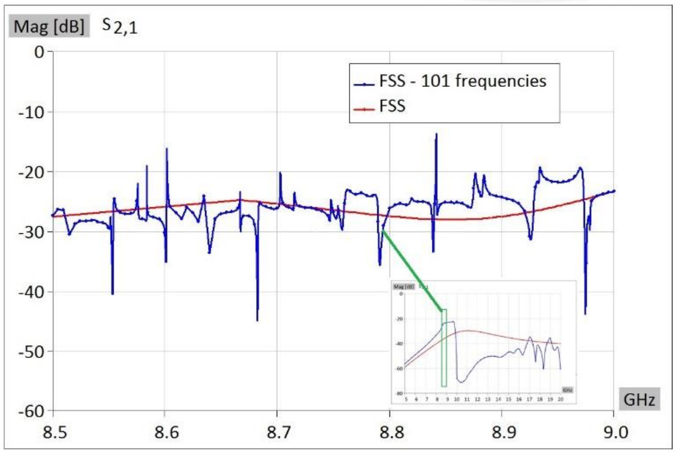

Figure 4. FSS in narrow frequency band

Conclusion

This application note focuses on the simulation of a classical FSS structure by applying the feature “apertures in PEC/PMC plane”. The FFS comprises of large periodical array of mushroom type printed patches, spaced by a narrow gap. In order to emulate reasonable measurement scenario, two antennas are placed a large 32x32 array and excited using TE or TM polarization. The simulation is simplified by applying two symmetry planes reducing the problem to 16x16 array, requiring approximately one quarter of the original number of unknowns.

A rather complicated realistic scenario can be simulated on a standard laptop or desktop PC in a couple of minutes per frequency point. Considering the fact that the simulation requires around 33,000 unknowns, the required time can be decreased if a single inexpensive CUDA enabled GPU card is added to configuration and utilized via the GPU solver.

The simulation verifies the measured results showing the gap in the frequency band between 10 and 13 GHz. The problem of interest is rather wideband. If the simulation band is narrowed to a 0.5 GHz and simulations performed at 100 frequency points, numerous local resonances and glitches can be observed in the results.