MODELING FREQUENCY SELECTIVE SURFACES IN COMSOL MULTIPHYSICS

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ABSTRACT

Finite Element Method (FEM) implemented in COMSOL Multiphysics is used to analyze free-standing frequency selective surfaces (FSS) in a 3-dimensional (3D) space. Practical procedures for using periodic boundary conditions were developed and tested. A case study concerning a mesh grid density (number of degrees of freedom - DOF) vs. results accuracy in a tight relationship with the calculation time needed was worked out. Outcomes were compared with results published in [1].

1. INTRODUCTION

FEM is a general method used to solve partial differential equations (PDE). Since Maxwell equations can be expressed in the PDE form, FEM can be exploited to solve them.

FSS are periodic structures consisting of electrically conductive elements of various shapes placed on a dielectric substrate. The structure is called the free-standing one if no dielectric substrate is used. Complementary, FSS can consist of non-conducting slots placed on an electrically conductive plane.

An ideal FSS is of an infinitely large size, which helps to simplify the numerical analysis (spectral domain moment method or periodic boundary conditions can be used). The FSS is illuminated by a harmonic plane wave. All the electric conductors are assumed to be perfectly electrically conducting (PEC).

When using periodic boundary conditions (PBC), just one element is numerically analyzed. If such an element is enclosed with edges, which mirror the element in extent to infinity, an ideal FSS is obtained.

2. FREE-STANDING SURFACE ANALYSIS

A rectangular patch element with conductive area dimensions a = 13 mm, b = 1.5 mm and surrounding (air) cell dimensions A = 15 mm, B = 7.5 mm was chosen to allow the designer to compare simulation outcomes with dependencies published in [1].

2.1. DRAWING THE STRUCTURE

Since the conductive area thickness is required to be lower than 1/1000 of an expected resonance wavelength $\lambda_\in$ (a threshold value to assume a free-standing structure), a 2D geometry has to be added [2]. The rectangular conductive patch is then transformed from 2D into a 3D geometry by its etching. The work plane position is then leveled to $\pm\lambda_\in/2$ z-coordinate and the surrounding cell is created by its extruding in the total $\lambda_\in$ height.

2.2. BOUNDARY SETTINGS

FSS is analyzed for a linear E polarization with a zero incidence angle (a normal incidence). The conductive patch boundary and both left and right wall has to be set to PEC (Fig. 1). The front wall and the back one are assumed to be perfect magnetic conductors (PMC). The cell is fed from the top boundary, which is assumed to be a port generating TE mode with the incident field given by $E_{0x} = 1$ V/m. The S-parameters output is chosen to magnitude and phase. In the bottom, the scattering boundary condition is used and does not produce any reflections from a propagating wave.

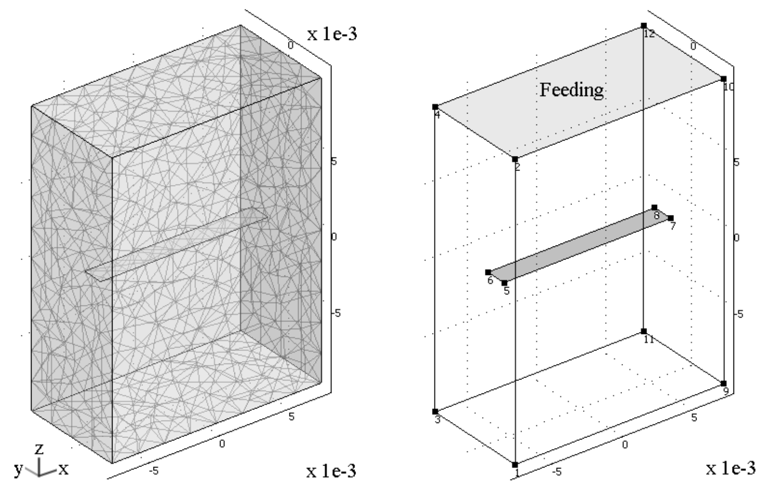

Fig. 1: Left: used mesh structure. Right: vertex labels.

2.3. PERIODIC BOUNDARY CONDITIONS SETUP

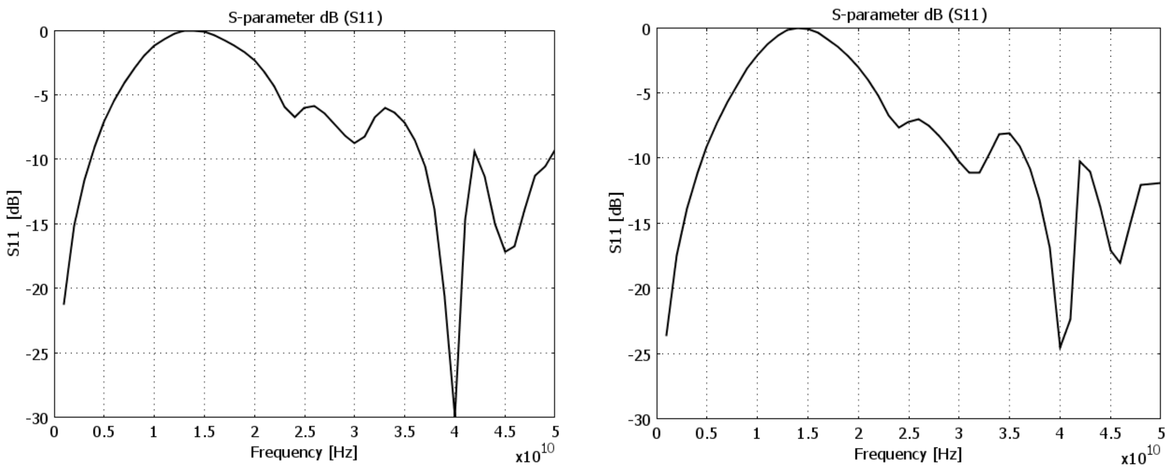

Fig. 2: Frequency response of reflection coefficient in range from 1 to 50 GHz. Left: $\lambda_\in/2$, normal mesh (6 708 DOF, 164 s). Right: $\lambda_\in/2$, finer mesh (36 789 DOF, 3 437 s).

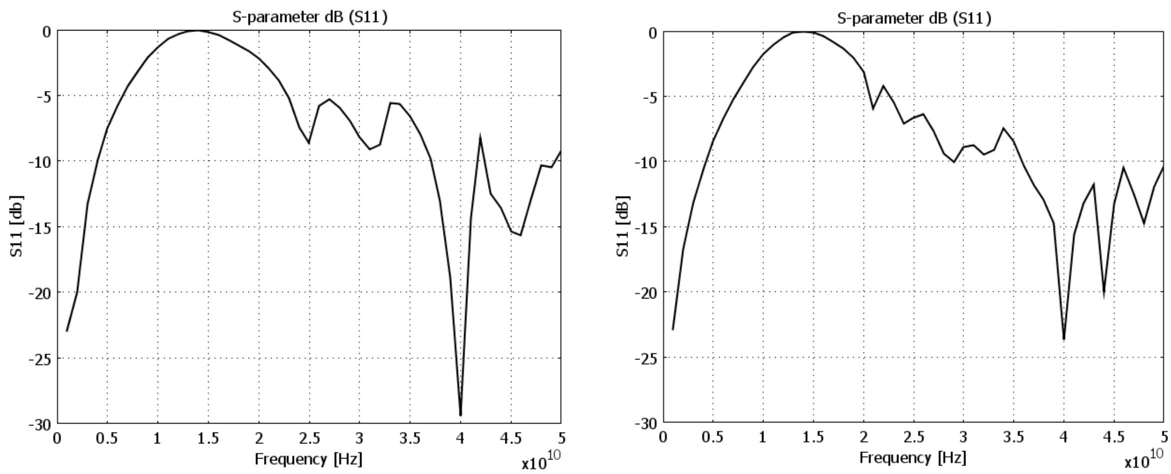

Fig. 3: Frequency response of reflection coefficient in range from 1 to 50 GHz if PBC are used. Left: $\lambda_{\in}/2$, normal mesh (7 481 DOF, 295 s). Right: $\lambda_{\in}$ (25 401 DOF, 2 427 s).

In order to create an infinite surface using PBC, electric field tangential components in all the coordinates (*tEx*, *tEy*, *tEz*) must be equal on two pairs of boundaries – on the left wall and the right wall, and on the back wall and the front wall. Moreover, an extra equation to explicitly set the divergence of the **B** field to zero must be implemented [3]. Practically, a new periodic variable *psi* (can have this name only, otherwise the calculation fails) is used on two pairs of boundaries. When using PBC, denser meshes should be created on the left, right, back and front wall, while keeping a sparse mesh inside the domain.

3. CONCLUSION

In order to determine the number of degrees of freedom, which ensure smooth and accurate dependencies, Fig. 2 should be discussed. Obviously, a slight accuracy improvement (the right figure) is conditioned by an enormous CPU-time requirements increase.

The position of the feeding edge in the model is a key factor of the FSS analysis. The minimum allowed distance between the feeding edge and the FSS is $\lambda_{\in}/2$. Moving the feeding edge to the longer distance does not cause fatal numerical errors (see Fig. 3 comparing two feeding edges distances), but a higher number of discretization elements needed to keep satisfying accuracy leads to the increase of the solution time up to 2 427 s.

REFERENCES

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