Numerical analysis of metasurfaces by using the FDTD technique

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The study of metamaterials is not a new topic, but it is an exciting and prominent field for the current research and technology exploitation. The possibility to control the electromagnetic waves propagation, realize desired physical effects and field trasformation, whose can not be obtained in a natural manner due to the properties of materials, encourage the study on this fascinating field. In particular, a metamaterial modeled by a subwavelength thickness ($\Delta << \lambda$) is called metasurface, see Figure 1. Figure 1 represents a general metasurface where an incident wave is transformed into a reflected and transmitted wave. The synthesis procedure consists on determining the physical parameter of the metasurface in order to obtain the desired wave transformation. The analysis procedure is the opposite to the synthesis procedure. It consists on determining the field behavior based on given physical parameters of the metasurface [1]. The metasurfcace is characterized by the susceptibility tensors $\overline{\overline{\chi}}$, where their components allow us to create a metasurface that exhibits passive, lossless, reciprocal properties and desiderable wave behavior. In our study, the metasurface has been simulated by using the finite-difference time-domain (FDTD) method [2]. The metasurface can not be safely inserted within the FDTD grid where usual boundary conditions (BCs) are applied. In fact, the metasurface modeled as a surface with zero thickness represents a discontinuity in the space causing the inapplicability of those BCs. To correctly simulate the metasurface, the generalized sheet transition conditions (GSTCs) has been applied [3]. By implementing the GSTCs in our FDTD code, we evaluated the feature of the metasurface in terms of the electromagnetic field distribution over the whole domain. The metasurface has been placed along the $\hat{z}$-axis, as an example their susceptibility tensors components have been set considering a lossless, non reflecting and non absorbing behavior. According to the hypothesis, the metasurface does not alter the electromagnetic field, Figure 2. Simulations run on the Joliot-Curie KNL supercomputer based at GENCI@CEA, France. This work has been supported by the EU H2020 RISE-6G Project under Grant number 101017011.

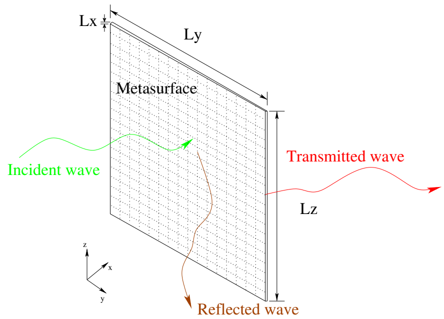

Figure 1. General metasurface where are depicted an incident, reflected and transmitted wave.

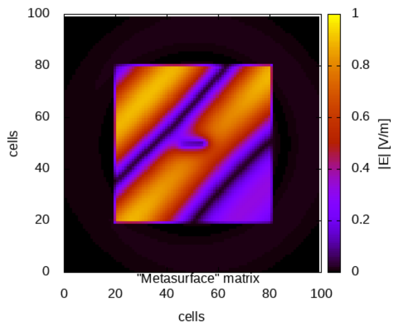

Figure 2. Field distribution of a 2D plane of the 3D simulation where the metasurface is placed in the centre of the domain. The whole domain consists of $100 \times 100 \times 100$ cubic cells.

References

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