Simulation of Zero Thickness Metasurface Using Frequency Domain Methods

Summary

In this project we will propose a new method for analyzing zero thickness structures and especially for metasurfaces. In our proposed method FDFD – finite Difference Frequency Domain – [1] equations will be used for all the nodes in space except for some nodes around metasurface. For those nodes around the metasurface the resultant equations of GSTC – Generalized Sheet Transition Condition - method can be employed.

Trigger

Following GSTC method, in [2] a general method is presented for the extraction of the metasurface susceptibility tensor parameters. In that paper, given the required functionality, metasurface susceptibility parameters are extracted. While, in this project having metasurface susceptibility tensors, we will analyze the metasurface. It is not an easy job to find the corresponding metasurface unit cell for a given susceptibility. Thus, it is very time consuming to study the behavior of the metasurface for any other angles and frequencies than proposed by the problem. While, using the result of this project, without attempting to find appropriate unit cell, the behavior of the metasurface can be studied for any incident angle or operating frequencies. Apart from this, none of the commercial softwares are able to simulate these types of structures.

Frontier of knowledge

Metasurfaces are dimensionally reduced type of Metamaterials and are used for the design of many different structures such as Lens, absorber and polarization rotation. Recently, it has gained significant attention due to its lighter, low loss and easy to fabricate properties. Compared to wavelength, they are very thin structure. Thus, they are considered as a discontinuity in space and the design equation can be found by GSTC method [3].

The problem of zero thickness can be analyzed by conventional methods by approximating the zero thickness with a thickness too small compared to the wavelength. But for the case of metasurfaces this is not true at all since the susceptibility of the metasurface is found by the GSTC method in which a discontinuity is represented by the delta Kronecker function; and when the metasurface is considered as a nonzero thickness, due to the imaginary part of the susceptibility tensor which cause losses in that thickness, the resulted reflected and transmitted waves will be attenuated significantly. Moreover, this simulation will cause undesired reflected and transmitted waves. From Floquet theorem for periodic structures, the transmitted wave from a periodic structure will have many diffraction orders in different directions.

Question / Hypothesis / Objectives:

The objective of the project is to innovate a new method or modifying available methods to simulate zero thickness structures. In reality, thickness of the metasurface is not zero. However, due to the methods that are used for the extraction of the susceptibility tensors of the metasurfaces, simulation result of a nonzero thickness metasurface will not be correct.

Expected results

We will test our method for some special examples. The first example will be a normally propagating TE/TM wave that impinges on the metasruface and refracted at an angle of θ. Moreover, it should work fine for the case of complete electric and magnetic conductor and free space case. If the result for these cases be correct, we can expect that for all the problems it will work fine.

Originality

Previously, methods are proposed for the analysis of the zero thickness electron gas and graphene [4, 5], which are made up of exactly one layer of electron and atom, respectively. However, in both of these problems, one of the electric or magnetic components of the field are continuous. While, for the metasurface both of the field components are discontinuous and the previously proposed methods are not applicable here. Thus, this work is original have great contribution.

Anticipated impact

In my opinion, it will have a high impact; and the result can be published at IEEE Antenna and Propagation Transaction which has an impact of about 4.

Anticipated risks and approach to manage/mitigate them

The first problem maybe is writing FDFD code and benchmarking the code. The second problem is that we don't know which numerical methods is the best choice. The third problem is the possibility of analyzing a zero thickness structure with discontinuity in both components of the field.

Required resources (the main ones)

The most important resources can be found at the references section.

Proposed timeline

I don't have any Timeline for this project.

References:

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3. Idemen, M.M., *Discontinuities in the Electromagnetic Field.* Wiley, 2011.
4. Nayyeri, V., M. Soleimani, and O.M. Ramahi, *Modeling Graphene in the Finite-Difference Time-Domain Method Using a Surface Boundary Condition.* Antennas and Propagation, IEEE Transactions on, 2013. **61**(8): p. 4176-4182.
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