Modeling of 2D and 3D Metamaterials Using Higher Order General Impedance Boundary Conditions (GIBCs)

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Metamaterial and coated surfaces are known for their unique properties enabling novel antenna designs. As these surfaces are complex, in this paper we present a simple higher order generalized impedance boundary condition (GIBC) demonstrated to represent the reflection properties of such surfaces in the real and imaginary angular spectrum. In past, GIBCs have been applied for canonical problems, such as metal backed dielectric slab and thin multilayer structure. In the developed approach, we use GIBCs as an extrapolation scheme for angle dependent characterization in real and complex space. Our new approach allows characterization of 2D and 3D metamaterial structures as well as thick multilayer substrates.

To derive the angle-independent GIBC expression, we must determine the unknown coefficients of the higher order boundary condition. To do so, we first use full-wave simulations to calculate the reflection coefficients at a few incidence angles (typically one to three or more). The choice of angles depends on the order and the desired GIBC representing the metasurface. The GIBC-derived reflection coefficient is then equated to the numerically obtained reflectivities at each angle. As expected, the number of equalities between numerical and GIBC-derived reflection coefficients is proportional to the order of the GIBC.

Once the GIBC is derived, analytical expression for the reflection coefficient can be generated for all angles. Of course, using GIBCs, the reflection coefficient of the impedance surfaces is predicted at a tiny computational cost.

In the presentation, the theory and implementation of the proposed GIBC generation method will be shown for a variety of impedance surfaces and engineering periodic structures. The examined surfaces include corrugated surfaces, mushroom structures and woodpile 3D EBG periodic surfaces. We will also employ the proposed GIBC-based reflection coefficients to predict surface waves in these surfaces.