GA-FDTD Based Design of Metamaterials

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Metamaterials have been widely explored in recent years [1]. They exhibit unique electromagnetic features that cannot be achieved from ordinary materials in nature, such as in-phase reflection of electromagnetic waves, negative effective dielectric permittivity and permeability, etc.. Metamaterials are normally composed of periodic structures. Due to the computational complexity, the analysis and design of antennas and microwave components based on metamaterials poses a significant challenge to the electromagnetic society.

As a versatile approach, the finite-difference time-domain (FDTD) method has been widely used in the electromagnetics field. Direct analysis of periodic-structure-based metamaterials using the FDTD method would consume significant time and computer resources, such as large computing time, internal memory and disk space. To accurately and efficiently characterise these structures, we combine the FDTD method with periodic conditions of the structure so that the problem domain can be truncated to one element [2]. For structures with a ground plane, the element is surrounded by periodic boundary conditions on four sides, the ground plane on the bottom and a perfectly matched layer (PML) on the top. For cases without a ground, another PML is placed on the bottom. Therefore, the analysis of the periodic structure has been reduced to that of a single element, making the calculation very efficient.

Genetic algorithms (GAs) [3] fall under a special category of optimisation schemes that are robust and stochastic. Based on the principle of natural selection, they are particularly effective in searching for global maxima in a multidimensional and multimodal functional domain. For electromagnetic problems, GAs have been successfully applied to the design of broadband or multi-band antennas, spatial filters, and microwave absorber synthesis [3].

In this paper, we combine GAs with the FDTD method to design metamaterials. In the past GAs have been applied to the design of metamaterials by combining with the method of moments (MoM) [4]. Howver, due to the complexity of the MoM, this combination can only be applied to planar structures at present, namely uniplanar compact photonic-bandgap (UC-PBG) structures and their derivatives. With the application of the FDTD method, many other configurations of metamaterial structures can be designed and optimised, such as mushroom-like structures. As an example of FDTD application, artificial magnetic conductor (AMC) ground planes are first designed and optimised by the GA-FDTD method. Details of the results will be given in the presentation.

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