Metamaterial Modeling Using Composite Cell MRTD Techniques

Nathan Bushyager* and Manos Tentzeris
School of ECE, Georgia Institute of Technology, Atlanta, GA 30332
nbushyager@ece.gatech.edu

Recently a new method has been presented that allows the modeling of complex PEC/dielectric structures within a single multiresolution time-domain (MRTD) cell (Bushyager and Tentzeris, Proc. 2003 EuMC, Munich, Germany, Oct. 2003). This technique uses wavelet decomposition to apply pointwise effects at the equivalent grid points in the MRTD grid. The equivalent grid points in an MRTD cell are the points inside the grid where distinct field values can be reconstructed (Sarris and Katehi, IEEE Trans. MTT, 50.7, 1752-1760, July 2002). Initially, this technique was presented as a method of modeling perfect electrical conductors (PECs) with an MRTD cell, but the technique has been further expanded to allow other localized effects to be modeled such as lumped elements. Using this technique it is possible to use the time and space adaptive grid that is inherent in the MRTD method for complex microwave structures. By using this grid coarse cells can be used in the majority of the grid and high resolution cells can be used only when needed. Furthermore, the resolution can be changed with time to account for the propagation of high frequency signals through the circuit. This decreases the simulation time and makes it possible to simulate larger and more complicated problems.

One class of structures that is particularly well suited for simulation with this technique is metamaterials. Metamaterials are characterized by a repeating array of finely detailed structures. Using the subcell MRTD technique, it is possible to place part or even an entire metamaterial unit cell within an MRTD cell. The space surrounding this complex structure can be treated with more coarse cells, leading to a very efficient simulation. In addition, like other time-domain full-wave simulators, the complete physics of Maxwell's equations are simulated, allowing these structure's complex electromagnetic interactions over a broad band to be fully modeled. Both electric and magnetic conductors can be modeled at the subcell level, as well as lumped elements. This allows the technique to be applied to printed elements in layered materials (Ziolkowski, IEEE Trans. Ant. Prop., 51.7, 1516-1529, July 2003) and to metamaterials that consist of periodically loaded lines (Siddiqui, Mojahedi, and Eleftheriades, IEEE Trans Ant. Prop., 51.10, 2619-1215, Oct. 2003).

Using this simulator a number of properties of metamaterials can be simulated. In addition to S-parameters of the devices, the fields inside the devices can be determined to examine their operation. Comparisions between the theory of operation of the device and the simulation of the fields inside the device can be made. The focusing properties of the device can be measured as well as near and far field radiation parameters. Finally, it should be noted that this technique is perfectly compatible with periodic structure simulation techniques that have been developed for the FDTD method.