CHARACTERIZATION OF NEGATIVE-REFRACTIVE-INDEX MATERIALS WITH MRTD

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The Multiresolution Time Domain (MRTD) technique (M. Krumpholz and L. P. B. Katehi, *IEEE Trans. Microwave Theory Tech.*, **44**, 555-561, 1996) has been presented as an advanced technique that is advantageous when compared to other time-domain techniques because of its inherent time-and-space adaptive grid. This grid allows complex structures to be simulated in high resolution while surrounding and connecting areas are simulated in low resolution. Through the use of wavelet thresholding, the resolution can be varied automatically during simulation, in response to the transient field propagation. Recently, a composite-cell technique has been presented for Haar wavelets that allows the modeling of complex structures within a cell, including lumped elements (N. Bushyager and M. Tentzeris, *Proc. 2004 IEEE MTT-S*, June, 2004). This technique can be directly applied to the characterization of negative-refractive-index (NRI) materials.

NRI materials have recently been fabricated using lumped elements embedded in transmission lines (O. Siddiqui, M. Mojahedi, G. Eleftheriades, *IEEE Trans. On Antennas and Prop.*,51.3, 2619-2625, 2003). These materials can have unique properties such as simultaneous negative magnetic permeability and electric permittivity. Waves propagating in these materials also feature unique properties, such as negative phase and/or group velocity.

These materials can be efficiently modeled in MRTD using the composite cell MRTD technique. When compared to the FDTD technique, Haar-cells contain the equivalent of several FDTD cells, with resolution (the number of embedded cells) varying as a function of time and space. It is possible to represent the NRI unit cell (the transmission line with embedded lumped elements) as a single MRTD cell. This high resolution cell can be combined with low resolution connecting cells, as well as adaptive cells, to efficiently simulate the NRI structure over a wide band. The presentation will focus on the modeling of NRI materials in an adaptively gridded MRTD simulation, as well as the analysis of the output. Due to the time-domain nature of the simulation technique, properties of NRI materials such as negative group and phase velocity can be observed directly in the time domain output.

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