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Interaction of a Sine Wave with an Artificial Negative Permittivity Medium Using Nonstandard FDTD

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Abstract—This paper presents the realization of Nonstandard Finite Difference Time Domain (NS-FDTD) analysis having high accuracy and low computational cost to a negative permittivity metamaterial wire medium for the first time. A sine wave of frequency less than that of plasma frequency of the medium which is in the shape of a slab reflector is allowed to interact after identifying the exact values of the required stability condition of the NS-FDTD. The electric field distribution around the plasma slab obtained for a particular excitation point using NS-FDTD and standard FDTD are demonstrated which show obvious advantages of this high accuracy algorithm. This novel technique may be further extended to various dispersive and metamaterial structures.

1. INTRODUCTION

Nonstandard Finite Difference Time Domain (NS-FDTD) analysis is a highly preferable algorithm owing to its manifold advantages like greater accuracy, enormous reduction in grid point, higher stability and lower number of iterations resulting in considerable lowering of computational cost than the standard FDTD. This new method introduced by Cole [1] showed that it is 10,000 times more accurate than the standard one where he demonstrated the electromagnetic wave scattering from a dielectric contrast using Maxwell's equations. This method achieves the same accuracy with λ/h (ratio of wavelength to grid space) $= 8$ which standard FDTD could only achieve with $\lambda/h = 1140$ which will result in a considerable decrease in iteration needed. NS-FDTD algorithm in terms of propagation equation is then developed and is used for analyzing Mie scattering of a dielectric disk [2]. This novel technique is also extended to study the cases with dispersive media and wide band frequency interactions [3–5]. By using an alternative approach, Jerez and Lara have explored NS-FDTD algorithm for addressing the possible instabilities in earlier works [6].

This highly accurate and computationally advantageous NS-FDTD method is successfully implemented for lossless cases [7]. NS-FDTD is also modeled in terms of conducting Maxwell's equations, and its successful implementation is predicted for a low loss medium [8]. In this paper we have implemented NS-FDTD method for a high loss medium and have used it for the first time for analyzing the interaction of the electromagnetic wave with a negative permittivity metamaterial medium. Epsilon Negative Medium (ENG), one of the constituent of metamaterial structures, is realized by making use of thin conducting wires and is allowed to interact with a sine wave with a frequency less than the characteristic plasma frequency of the medium. The advantages of NS-FDTD used to model the field distribution near the ENG slab are found by comparing the results with that of standard FDTD algorithm.

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