Using FDTD To Illustrate the Behavior of Double Negative Materials

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There is strong interest in the behavior of metamaterials which have negative real parts for both permittivity and permeability. These are called by various names, including Negative Index Materials (NIM) and Double Negative Materials (DNG). It has been conjectured that these materials may have significant practical applications. Fully understanding their behavior is important to these potential applications. This understanding is initially challenging, since they behave in ways that appear to be contrary to intuition. For example, due to the negative index of refraction, the electromagnetic waves in DNG media may appear to defy causality and propagate toward the source. The ability to include these materials in full wave three dimensional solvers will be an important aid in using these materials in actual three dimensional designs.

The Finite Difference Time Domain (FDTD) method can be applied to these DNG materials ®. W. Ziolkowski and R. Heyman, Phys Rev E, Vol 64, 056625, October 2001) with good success. While several techniques for this exist, in this paper the recursive convolution method has been applied to both the permittivity and permeability. Both are modeled with Drude behavior, thus satisfying causality and allowing stable FDTD results to be obtained. Since calculations are made in the time domain, the results are determined by straightforward numerical methods. The ability of the time domain results to show the transient interaction of the electromagnetic fields with the DNG materials provides important insights into their characteristics, including the physical impact of negative phase velocities that can be superluminal. Results which seem to defy causality are readily observed. Investigation of these results is an important consideration of this paper.