Waves in Random and Complex Media, 2013
http://dx.doi.org/10.1080/17455030.2013.791409

Zero reflection from layered anisotropic metamaterial structures

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(*Received 30 May 2012; final version received 22 March 2013*)

Mathematical formulation for analysis of electromagnetic wave scattering from multilayer anisotropic homogeneous metamaterial structures with general tensors is presented. The result is reflection and transmission matrices formulas. Then, closed form formulas are extracted for structures with diagonal tensors. We try to find structures with exact zero reflection for general incident waves. New cases with zero and low reflection are introduced.

Introduction

Metamaterials are artificial electromagnetic materials with negative values of epsilon or/ and mu which may have properties like negative refraction index that do not appear in common materials.[1,2] In this paper, our goal is to show the application of metamaterials in reducing the reflection of electromagnetic waves scattered by layered structures. We will introduce some novel flat layered structures consisting of common materials and metamaterials which are perfectly matched to the air (or any other isotropic media).

The idea of zero reflection or perfectly matched layers was developed by Veselago, Pendry, Berenger, Gedney, Alù, Engheta, and others. Veselago [1] and, some years later, Pendry [3,4] considered a flat slab of metamaterials with epsilon and mu equal to -1. They showed that this structure is perfectly matched to the free space and can be used to make a perfect lens. Another structure with zero reflection when opposed to the air is introduced by Berenger called perfectly matched layer (PML).[5] Berenger's PML is a lossy flat layer which is used in finite difference time domain method (FDTD) to absorb wave at the boundaries. Berenger's idea was developed by Gedney to anisotropic case in 1996.[6] Other notable researches are done by Alù and Engheta to find bilayer structures with zero reflection. Their main contribution is discovering matched paired layers of different metamaterial types.[7–9]

We first present a mathematical analysis of electromagnetic scattering for a layered anisotropic metamaterial structure.[10–16] Anisotropic media give us a larger variety of zero reflection structures with respect to isotropic states (for example in [17–19]). It is assumed that all the layers of the structure are homogeneous. Of course, in some cases of inhomogeneous layers, we can decompose each layer to many homogeneous layers and make the problem homogeneous. Despite works which are done on the anisotropic media, in our research, the tensors of the constitutive parameters of the layers are in

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