Scattering Analysis of Periodic Structures Using Finite-Difference Time-Domain Method

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Scattering Analysis of Periodic Structures Using Finite-Difference Time-Domain Method

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ABSTRACT

Periodic structures are of great importance in electromagnetics due to their wide range of applications such as frequency selective surfaces (FSS), electromagnetic band gap (EBG) structures, periodic absorbers, meta-materials, and many others. The aim of this book is to develop efficient computational algorithms to analyze the scattering properties of various electromagnetic periodic structures using the finite-difference time-domain periodic boundary condition (FDTD/PBC) method. A new FDTD/PBC-based algorithm is introduced to analyze general skewed grid periodic structures while another algorithm is developed to analyze dispersive periodic structures. Moreover, the proposed algorithms are successfully integrated with the generalized scattering matrix (GSM) technique, identified as the hybrid FDTD-GSM algorithm, to efficiently analyze multilayer periodic structures. All the developed algorithms are easy to implement and are efficient in both computational time and memory usage. These algorithms are validated through several numerical test cases. The computational methods presented in this book will help scientists and engineers to investigate and design novel periodic structures and to explore other research frontiers in electromagnetics.

KEYWORDS

finite difference time domain (FDTD), periodic structures, periodic boundary conditions (PBC), generalized scattering matrix (GSM), frequency selective surfaces (FSS), multi-layer structures, auxiliary differential equation (ADE), dispersive material, general skewed grid

Khaled ElMahgoub: To my family and friends

Fan Yang: To my family and colleagues

Atef Elsherbeni: To my family

Contents

Preface

This book is intended to help students, researchers, and engineers who are using electromagnetics tools to investigate and design novel periodic structures and to explore related research frontiers in electromagnetics. Various electromagnetic periodic structures, such as dispersive materials, multi-layered structures, and arbitrary skewed grids, are studied using the finite-difference time-domain with periodic boundary condition (FDTD/PBC) method. The book starts with a description of the FDTD approach and the constant horizontal wavenumber PBC technique. The main advantages and limitations of the approach are discussed in Chapter 2. The FDTD updating equations are derived and numerical results are provided to verify the proposed approach. In Chapter 3, the constant horizontal wavenumber approach is extended to analyze periodic structures with an arbitrary skewed grid. The new approach is described and the FDTD updating equations are derived for both cases in which the skewed shift is coincident and non-coincident with the FDTD grid. In Chapter 4, a new dispersive periodic boundary condition (DPBC) for the FDTD technique is developed. The algorithm utilizes the auxiliary differential equation (ADE) technique with two-term Debye relaxation equation to simulate the general dispersive property in the medium. In addition, the constant horizontal wavenumber technique is modified accordingly to model the dispersive material on the periodic boundaries. In Chapter 5, a complete analysis of multi-layer periodic structures using the hybrid FDTD/GSM method is illustrated. Based on the FDTD simulation results on each layer, the generalized scattering matrix (GSM) cascading technique is used to analyze different kinds of multilayered periodic structures.

The algorithms developed in this book are implemented using MATLAB. These algorithms lead to comprehensive software tools that are capable of analyzing efficiently and accurately general electromagnetic periodic structures. These software tools can be used in many design applications involving different configurations and types of periodic structures with ordinary and dispersive-type material.

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