Electromagnetic Band Gap Structures in Antenna Engineering

This comprehensive, applications-oriented survey of the state of the art in Electromagnetic Band Gap (EBG) engineering explains the theory, analysis, and design of EBG structures. It helps you to understand EBG applications in antenna engineering through an abundance of novel antenna concepts, a wealth of practical examples, and complete design details. You discover a customized finite difference time domain (FDTD) method of EBG analysis, for which accurate and efficient electromagnetic software is supplied (www.cambridge.org/yang) to provide a powerful computational engine for your EBG desgins. The first book covering EBG structures and their antenna applications, this provides a dynamic resource for engineers, and researchers and graduate students working in antennas, electromagnetics and microwaves.

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Preface

In recent years, electromagnetic band gap (EBG) structures have attracted increasing interests because of their desirable electromagnetic properties that cannot be observed in natural materials. In this respect, EBG structures are a subset of metamaterials. Diverse research activities on EBG structures are on the rise in the electromagnetics and antenna community, and a wide range of applications have been reported, such as low profile antennas, active phased arrays, TEM waveguides, and microwave filters. We believe that the time is right for a focused book reviewing the state of the art on electromagnetic band gap (EBG) structures and their important applications in antenna engineering.

The goal of this book is to provide scientists and engineers with an up-to-date knowledge on the theories, analyses, and applications of EBG structures. Specifically, this book will cover the following topics:

- a detailed overview of the EBG research history and important results;
- an advanced presentation on the unique features of EBG structures;
- an accurate and efficient numerical algorithm for EBG analysis and an evolutionary optimization technique for EBG design;
- a wealth of examples illustrating potential applications of EBG structures in antenna engineering.

The book is organized into seven chapters and one appendix. Chapter 1 introduces the background and basic properties of EBG structures. The EBG analysis methods and antenna applications are also summarized.

In Chapter 2, the finite difference time domain (FDTD) method is presented with a focus on periodic boundary conditions (PBC), which is used as an efficient computation engine for the analysis of periodic structures. The fundamentals of the FDTD method are reviewed and a constant k_x (spectral) method is discussed to model the PBC. A hybrid FDTD/ARMA scheme is introduced to unify the guided wave and plane wave analysis and improve the simulation efficiency.

Chapter 3 illustrates some interesting properties of EBG structures. The band gap features are clearly visualized from the near field distributions. The dispersion diagram and reflection phase for both normal and oblique incidences are presented. The soft and hard properties of the EBG ground plane are also discussed. A classification of various EBG structures is provided at the end of the chapter.

Chapter 4 presents how to achieve the desired characteristics by properly designing the EBG structures. A parametric study on the mushroom-like EBG structure is performed first, followed by a comparison between two popularly used planar EBG structures, mushroom-like EBG surface and uni-planar EBG surface. Novel EBG designs such as polarization-dependent EBG (PDEBG), compact spiral EBG, and stacked EBG structures are also studied. Furthermore, utilizations of the particle swarm optimization (PSO) technique are demonstrated in EBG synthesis.

The applications of EBG structures in antenna engineering are presented in Chapters 5, 6 and 7. In Chapter 5, the EBG structures are integrated into microstrip patch antenna designs. The surface wave band gap property of EBG helps to increase the antenna gain, minimize the back lobe, and reduce mutual coupling. Some applications of EBG patch antenna designs in high precision GPS receivers, wearable electronics, and phased array systems are highlighted at the end of the chapter.

Chapter 6 introduces a novel type of antennas: low profile wire antennas on an EBG ground plane. Using the in-phase reflection feature of the EBG structure, the radiation efficiency of wire antennas near a ground plane can be greatly improved. A series of design examples are illustrated, including dipole, monopole, and curl. Various functionalities have been realized, such as dual band operation, circular polarization, and pattern diversity.

Chapter 7 presents a grounded slab loaded with periodic patches that can enhance the surface waves along a thin ground plane. Using this property, a low profile surface wave antenna (SWA) is designed, which achieves a monopole-like radiation pattern with a null in the broadside direction. Different feed techniques are explored and a dual band SWA is developed.

In the Appendix, a comprehensive literature review is presented based on nearly 300 references. This is to help both the seasoned and new comers in this research arena to establish a clear picture of the EBG developments and identify published work related to their own research interests. We regret if we have missed some of the publications as it has been very hard to identify all the research and development works that have been conducted in various international organizations.

We hope that the readers find this book useful and we welcome all their constructive suggestions.

F. Yang and Y. Rahmat-Samii

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Abbreviations

ABC	Absorbing Boundary Condition
ANN	Artificial Neural Network
AMC	Artificial Magnetic Conductor
AR	Axial Ratio
ARMA	Auto-Regressive Moving Average
CP	Circular Polarization
DNG	Double NeGative
DBSWA	Dual Band Surface Wave Antenna
EBG	Electromagnetic Band Gap
EMI	ElectroMagnetic Interference
FDTD	Finite Difference Time Domain
FEM	Finite Element Method
FSS	Frequency Selective Surface
GA	Genetic Algorithm
GPS	Global Positioning System
GUI	Graphic User Interface
HIS	High Impedance Surface
LH	Left Handed
LHCP	Left Hand Circular Polarization
LTCC	Low Temperature Co-fired Ceramic
MEMS	Micro-Electro-Mechanical System
MMIC	Monolithic Microwave Integrated Circuit
MoM	Method of Moment
NRI	Negative Refractive Index
PBC	Periodic Boundary Condition
PBG	Photonic Band Gap
PCB	Printed Circuit Board
PDEBG	Polarization-Dependent Electromagnetic Band Gap
PEC	Perfect Electric Conductor
PMC	Perfect Magnetic Conductor
PFSWA	Patch-Fed Surface Wave Antenna
PML	Perfectly Matched Layers
PSO	Particle Swarm Optimization
RCS	Radar Cross Section

RHCP	Right Hand Circular Polarization
RFID	Radio Frequency IDentification
SFDTD	Spectral Finite Difference Time Domain
SWA	Surface Wave Antenna
TE	Transverse Electric
TEM	Transverse ElectroMagnetic
TM	Transverse Magnetic
WLAN	Wireless Local Area Network