ELECTROMAGNETIC WAVES PIER 9

Progress In Electromagnetics Research

This publication is printed on acid-free paper.

ISSN 1070-4698

Manufactured in the United States of America

ELECTROMAGNETIC WAVES PIER 9

Progress
In
Electromagnetics
Research

Chief Editor: J. A. Kong

Bianisotropic and Bi-isotropic Media and Applications

Editor: A. Priou

EMW Publishing
Cambridge, Massachusetts, USA

PREFACE

The bi-isotropic and bianisotropic media are opening a new field in electromagnetics research and becoming a challenging topic covering many aspects of electromagnetic theory and applications. The first manifestation of the bi-isotropic media was revealed by the chiral media with possible applications in the microwave range. In various countries in the world many works started and various meetings and conferences were organized where results have been presented. This includes fields related to mathematics, physics, optics, chemistry, biology, and life sciences. The number of papers per year in the field is increasing very rapidly. The objective of this special issue is to present a state-of-the-art report and future trends in bianisotropic and bi-isotropic media and their applications. An attempt is made to collect theoretical and applied researches carried out in the world in the last years including works from China, Finland, France, Italy, Russia, Sweden, UK, and USA.

In Chapter 1, I. Lindell and A. Viitanen considered the problem of a plane wave propagation in the most general uniaxial bianisotropic medium, with symmetric parameter dyadics. The dispersion relations and eigenvector expressions are derived.

The formalisms of the bi-isotropic media are quite numerous and different in appearence. In Chapter 2, S. Ougier, I. Chenerie, A. Sihvola, and A. Priou classified the various constitutive relations that have been employed and established the links between them. In Chapter 3, F. Guerin examined three different formalisms commonly used for describing wave propagation in reciprocal bi-isotropic media and make comparisions with respect to the question of energy dissipation. The author presented the influence of the chirality parameter on the reflection coefficient and the possibility of obtaining absorbing material with new properties.

The contribution of A. Sihvola in Chapter 4 deals with the electromagnetic modeling of bi-isotropic media. All the mixture equations for spherical and ellipsoidal inclusions were presented. This chapter includes, also, an important part on temporal dispersion effect in bi-isotropic media.

In the two following chapters the polarizabilities of a layered chiral sphere or a layered dielectric bi-isotropic ellipsoids are derived. In Chapter 5, M. Ermutlu and A. Sihvola solved the dipole moments that are induced by electromagnetic fields in a layered chiral sphere consisting of a spherical core and a spherical shell. The result is the low-frequency polarizability matrix of the sphere used for calculating the Rayleigh scattering of the object. In Chapter 6, Wei Ren derived the polarizabilities of a general layered bi-isotropic ellipsoids using a chain-matrix algorithm. The results are used in the analysis of layered bi-isotropic mixtures.

In Chapter 7, W. Yin, P. Li, and W. Wang derived the eigenfunction expansions of dyadic Green's function in unbounded and multilayered bi-isotropic media in terms of normalized cylindrical and elliptical cylinder vector wave functions. They were able to calculate the radiation characteristics of sources in stratifled bi-isotropic media.

The contribution of S. He, M. Norgren, and S. Strom in Chapter 8 deals with the problem of a time-harmonic electromagnetic plane wave obliquely incident on a stratified chiral slab with multiple discontinuities in the materials parameters. Up and down-going eigenmodes are identifled together with their dispersion equations. The solution for the reflection coefflcient matrix is given for both a multilayered structure and a general stratifled slab.

In Chapter 9, S. Tretyakov and A. A. Sochava addressed the issue of electromagnetic properties of plane layers of microstrutures comprising two arrays of small metal wire elements embedded in an isotropic matrix constituting a novel uniaxial bianisotropic material. This novel structure offers possibilities for increasing shielding efflciency of screens in wide ranges of frequencies and incidence angles having applications in radar and antenna technology.

Chapter 10 by A. Toscano and L. Vegni deals with a formulation for the solution of the electromagnetic flelds in vertically stratified structures with a general bianisotropic grounded slab under planar electric excitation conditions. As an application of the theory, the authors present the transmission-line representation for an unbounded pseudo chiral W medium.

In Chapter 11, Guerin presented, after a brief review of experimental studies carried out so far, a wave propagation theory in a chiral medium and the interaction of plane waves with a chiral slab. The main focus of this article is on experimental chiral media research works. The author presented on-going works related to measurements and modeling.

The three following papers are related to applications:
In Chapter 12, P. Pelet and N. Engheta, using the dyadic Green's functions and method of moments, presented theoretically the radiation properties of a center fed finite length thin-wire chirostrip antenna which can be thought of as a thin cylindrical wire antenna on a grounded substrate of lossless chiral material.

In Chapter 13, C. R. Brewitt-Taylor presented a model of a helix-loaded chiral material by computing the polarizabilities of an helix and using these elements to obtain electromagnetic constants for a homogeneous equivalent composite medium. These are in turn used to compute the reflection from a chiral radar absorbing coating.

In Chapter 14, F. Mariotte, P. Pelet, and N. Engheta presented a review of analytical and experimental studies of guided-wave structures utilizing chiral and, in general, bianisotropic materials that have been the subject of research interest for many researchers and engineers. The waveguiding elements constitute an important part of most devices and as a result the functional characteristics of these devices depend, among many factors, on guldance condition and propagation properties of guided modes in these waveguides.

In Chapter 15, M. M. I. Saadoun and N. Engheta presented in some detail theoretical study of electromagnetic properties of non-local Ω medium which they recently introduced as a generalization to the idea of speudo-chiral Ω medium. Conceptually it consists of a composite medium with an isotropic host materials within which a large number of " stretched " Ω shaped conducting planar microstructures are embedded.

It is our hope that this special issue will provide the inspiration for developing many possible applications of these materials and participate in the terms of new devices, circuits, or systems.

As guest editor, I wish to thank Professor J. A. Kong for his guidance and constant encouragment throughout this endeavor. I would also like to express my sincere gratitude and appreciation to the authors, whose contributions are the foundations upon which this special issue is formed. Finally I would adress all my thanks to all reviewers who gave their time and expertise so generously to undertake the important task of reviewing the various papers.

Alain Priou

Paris, France
September 1994

CONTENTS

Chapter 1 EIGENWAVES IN THE GENERAL BI-ANISOTROPIC UNIAXIAL MEDIUM WITH SYMMETRIC PARAMETER DYADICS 1
I. V. Lindell and A. J. Viitanen

1. Introduction 1
2. Theory 3
3. Polarization properties 9
4. Conclusion 17
References 17

Chapter 2 PROPAGATION IN BI-ISOTROPIC MEDIA: EFFECT OF DIFFERENT FORMALISMS ON THE PROPAGATION ANALYSIS 19
S. Ougier, I. Chenerie, A. Sihvola, and A. Priou

1. Introduction 19
2. Constitutive equations for bi-isotropic media 20
3. Propagation in bi-isotropic media 24
4. Definition of the pair (ε, μ) in a bi-isotropic medium 28
5. Conclusion 29
References 29

Chapter 3 ENERGY DISSIPATION AND ABSORPTION IN RECIPROCAL BI-ISOTROPIC MEDIA DESCRIBED BY DIFFERENT FORMALISMS 31
F. Guerin

1. Introduction 31
2. Connections between the different sets of constitutive parameters 33

3. Requirements for passive reciprocal bi-isotropic media 36
4. Reflection coefficients of reciprocal bi-isotropic media and comments on their use for reducing microwave reflection 40
5. Conclusion 43
References 43

Chapter 4 ELECTROMAGNETIC MODELING OF BI-ISOTROPIC MEDIA 45
A. H. Sihvola

1. Introduction 45
2. Constitutive Parameters 47
3. Polarizabilities of bi-isotropic inclusions 49
4. Effective parameters of bi-isotropic mixtures 58
5. Temporal dispersion effects in bi-isotropic mecia 70
6. Analogies of bi-isotropic media with anisotropic dielectrics and ferrites 77
7. Conclusion 81
References 82

Chapter 5 POLARIZABILITY MATRIX OF LAYERED CHIRAL SPHERE 87
M. E. Eremutlu and A. H. Sihvola

1. Introduction 87
2. Theory 89
3. Discussion of the result 97
References 101

Chapter 6 BI-ISOTROPIC LAYERED MIXTURES 103
Wei Ren

1. Introduction 103
2. Polarizability of bi-isotropic layered ellipsoids 104

3. Macroscopic parameters of ordered layered ellipsoid mixtures 111
4. Conclusion 114
Appendix 115
References 116

Chapter 7 THE THEORY OF DYADIC GREEN'S FUNCTION AND THE RADIATION CHARACTERISTICS OF SOURCES IN STRATIFIED BI-ISOTROPIC MEDIA 117
W. Yin, P. Li, and W. Wang

1. Introduction 117
2. The extended eigenfunction expansions of DGF in unbounded bi-isotropic media 118
3. The formulations of DGF for the stratified bi-isotropic media 112
4. The radiation patterns of a dipole antenna in stratified bi-isotropic media 128
5. Conclusion 132
Appendix 133
References 135

Chapter 8 WAVE PROPAGATION IN A STRATIFIED CHIRAL SLAB WITH MULTIPLE DIS-CONTINUITIES: OBLIQUE INCIDENCE 137
S. He, M. Norgren and S. Strom

1. Introduction 137
2. Formulation 138
3. Up- and down-going modes in a homogeneous chiral medium 141
4. Multilayered chiral slab 144
5. General stratification 148
6. Discussion and numerical results 149
References 155

Chapter 9 NOVEL UNIAXIAL BIANISOTROPIC MATERIALS: REFLECTION AND TRANSMISSION IN PLANAR STRUCTURES 157
S. A. Tretyakov and A. A. Sochava

1. Introduction 157
2. Eigenwaves in uniaxial omega media 159
3. Reflection and transmission in slabs 164
4. Analysis and numerical results 167
5. Conclusion 176
References 177

Chapter 10 ELECTROMAGNETIC WAVES IN PLANAR INTEGRATED PSEUDOCHIRAL Ω STRUCTURES 181
A. Toscano and L. Vegni

1. Introduction 181
2. Full wave analysis 184
3. Pseudochiral slab embedded in an isotropic half-space 199
4. Discussion 208
5. Conclusion 212
Appendix 213
References 217

Chapter 11 MICROWAVE CHIRAL MATERIALS: A REVIEW OF EXPERIMENTAL STUDIES AND SOME RESULTS ON COMPOSITES WITH FERROELECTRIC CERAMIC INCLUSIONS 219
F. Guerin

1. Introduction 220
2. Interaction between an EM wave and a chiral medium 224
3. Processing and characterization of ceramic helices 233

4. Experimental results and discussion 240
5. Future experimental and theoretical studies 256
6. Conclusion 260
References 260

Chapter 12 THEORETICAL STUDY OF RADIATION PROPERTIES OF A FINITE-LENGTH THIN-WIRE CHIROSTRIP ANTENNA USING DYADIC GREEN'S FUNCTIONS AND METHOD OF MOMENTS 265
P. Pelet and N. Engheta

1. Introduction 265
2. Current distribution along a center-fed finite length this-wire chirostrip antenna (over a thick grounded chiral slab) 267
3. Radiation patterns of finite-length thin-wire chrostrip antenna 272
4. Summary 278
Appendix 279
References 286

Chapter 13 MODELLING OF HELIX-LOADED CHIRAL RADAR-ABSORBING LAYERS 289
C. R. Brewitt - Taylor

1. Introduction 289
2. Elementary theory 290
3. Microscopic analysis of chiral media 293
4. Properties of single helices 299
5. Absorber optimizations 305
6. Conclusion 308
References 309

Chapter 14 A REVIEW OF RECENT STUDY OF GUIDED WAVES IN CHIRAL MEDIA 311
F. Mariotte, P. Pelet, and N. Engheta

1. Introduction 311
2. Review of basic formulation 312
3. Metallic parallel-plate chirowaveguides: a review 315
4. Metallic rectangular chirowaveguides 326
5. Metallic circular chirowaveguides: a review 329
6. Dielectric slab chirowaveguides 330
7. Mode orthogonality and mode coupling in chirowaveguides 334
8. Partially filled chirowaveguides: a review 337
9. Potential applications 342
10. Summary 343
References 344

Chapter 15 THEORETICAL STUDY OF ELECTROMAGNETIC PROPERTIES OF NON-LOCAL Ω MEDIA 351
M. M. I. Saadoun and N. Engheta

1. Introduction 351
2. Non-local Ω medium 354
3. Constitutive relations of non-local Ω medium 360
4. Electric-field wave equation in non-local Ω medium 363
5. Circuit model analysis for frequency characteristics of Ω medium 366
6. Plane wave propagation in unbounded non-local Ω medium 379
7. Summary 395
References 396