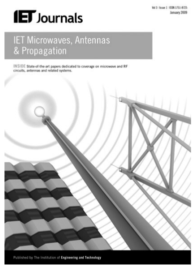
www.ietdl.org

Published in IET Microwaves, Antennas & Propagation
Received on 14th August 2013
Revised on 16th November 2013
Accepted on 9th January 2014
doi: 10.1049/iet-map.2013.0438



ISSN 1751-8725

Robust technique based on transition matrix method to electromagnetic characterisation of anisotropic material

Davoud Zarifi[1,2], Mohammad Soleimani[1], Ali Abdolali[1], Homayoon Oraizi[1]

[1]Department of Electrical Engineering, Iran University of Science and Technology, Tehran, Iran
[2]Department of Electrical and Computer Engineerng, Azad University, Kashan Branch, Kashan, Iran
E-mail: zarifi@iust.ac.ir

Abstract: This study presents a parameter retrieval technique based on the state space approach for the electromagnetic characterisation of biaxial anisotropic structures. First, the formulation of a 4 × 4 transition matrix method for the analysis of forward scattering problems is reviewed; then a procedure for the extraction of the constitutive tensor parameters of a biaxial anisotropic medium from the knowledge of reflection and transmission coefficients is implemented. In the proposed retrieval method, scattering parameters are employed for a plane wave incident normally and obliquely on a biaxial anisotropic slab. This characterisation algorithm is based on the state transition matrix and its properties in the biaxial anisotropic layers are presented as two theorems. In this method, it is not necessary to solve directly the wave equation in complex media and then apply the boundary conditions. To demonstrate the validity of the proposed method, the constitutive parameters of two non-dispersive and dispersive biaxial anisotropic slabs at microwave frequencies are retrieved. From the numerical results, one can find out that when the scattering parameters are combined with the properties of a state transition matrix, a robust technique is provided for the parameter retrieval of the anisotropic structures.

1 Introduction

Complex artificial electromagnetic structures with interesting electromagnetic properties have generated an enormous research interest over the years. Many natural or artificial electromagnetic materials exhibit unusual properties that would be beneficial to engineers if they were artificially designed to suit our needs. Therefore the study and the electromagnetic characterisation of such complex structures are recognised subjects which date back to the last decade.

Recently, with the increased interest in electromagnetic metamaterials (MTMs) and their wide applications in different microwave devices [1–5], various methods have been proposed for retrieving the effective electromagnetic parameters of such artificial structures. Some of these methods have been based on the electromagnetic fields inside the MTM structures, and so they are not practical for application in the experimental setups measurements [6–8]. In another well-known method, parameter extraction of the electromagnetic MTM structures is achieved by using analytical dispersion models [9, 10]. As a manifest disadvantage, the application of this method for complex structures is difficult. A more commonly used scattering parameter method is generally based on the inversion of the reflection and the transmission parameters of a plane wave incident on the MTM structure to give effective electromagnetic parameters [11–13]. Many papers have discussed the application of this method in different media and situations [14–19]. Most attempts at measuring the MTMs electromagnetic parameters at an oblique incidence or accounting for anisotropy or bianisotropy have relied on fully numerical optimisation and curve fitting techniques [20, 21].

The objective of the present paper is to characterise the biaxial anisotropic media using the state space approach. Although the application of the state transition matrix method in the forward scattering problems has been well studied over the years [22–27], its application in the formulation for the inverse scattering problems of the biaxial anisotropic mediums has not been reported. In the present paper, an electromagnetic characterisation procedure is presented for retrieving the constitutive tensor parameters of a biaxial anisotropic slab by using the scattering parameters based on the state transition matrix and its characteristics expressed as two theorems. The proposed technique allows for a characterisation at oblique incidences.

This paper is organised as follows. In Section 2, the analysis of the forward problem through the state space approach is reviewed. Two interesting properties of the state transition matrix of the biaxial anisotropic layers are presented in Section 3. Section 4 deals with the formulation of the inverse scattering of a biaxial anisotropic medium based on the 4 × 4 state transition matrix method. In Section 5, some numerical results are provided to validate the proposed formulation, from which it is found that the proposed scheme works well.