

Preface

The metamaterial science and technology are emerging as a “next higher level” performance contributor, specifically in the electromagnetic community. After experimental verification of negative refractive index metamaterial in 2001, the research community is focusing on application side and an exponential growth has been observed in various metamaterial electromagnetic applications such as antennas, microwave devices, high NA lenses, and radar absorbers. Electromagnetic (EM) designs including metamaterial being complex and nonlinear in nature optimization play an important role. In this book, we focus on role of soft computing technique-based EM computational engines in design and optimization of a wide range of electromagnetic applications. Apart from the theoretical background of metamaterials and soft computing techniques, this contributed volume includes novel electromagnetic applications such as tensor analysis for invisibility cloaking, metamaterial structures for cloaking applications, broadband radar absorbers and antennas.

Chapter 1 gives an insight to background theory of metamaterial and soft computing techniques. The fundamental principle of metamaterial and their properties have been discussed. Toward optimization of these structures, various soft computing algorithms such as *genetic algorithm* (GA), *particle swarm optimization* (PSO), and *bacterial foraging optimization* (BFO) have been described. Various types of metamaterial unit cells and their design and optimization procedures using soft computing techniques have been detailed along with the development of soft computing-based electromagnetic computational engine.

Planar inverted F antennas (PIFA) have wide range of applications in wireless industry. These antennas are also used as wireless sensors in aircraft fuel tanks to check the fuel availability status. Chapter 2 explores the advancements in design optimization of PIFA systems. The literature reveals that the antenna size can significantly be reduced by introducing metamaterial structures. Hence, design optimization of a metamaterial-loaded compact planar inverted F antenna has been carried out and reported systematically. The optimized antenna shows a return loss of -51.57 dB, whereas the conventional PIFA is of -12.893 dB only.

Chapter 3 provides an insight into the scalars, vectors, and tensors in electromagnetics and the significance of their analysis in the aerospace domain. The fundamental mathematical concepts of scalars, vectors, and tensors are being explained, and a thorough investigation on the relevance of these parameters in electromagnetics, cloaking, and various other aerospace applications has been conducted. This chapter connects to the detail design of metamaterial cloaking and optimization of conformal unit cells in the subsequent chapters.

In recent years, the radar cross section (RCS) reduction characteristics of cloaking structures have been widely investigated as it found extensive applications in stealth platform. Chapter 4 deals with the design of ideal circular, cylindrical, and spherical cloaking structures in accordance with transformation optics theory. The simulations are performed by using finite element method (FEM)-based COMSOL Multiphysics software. The performance of the designed ideal spherical cloak is analyzed by comparing the RCS of PEC sphere without cloaking shells and with multilayer cloaking shells. It has been observed that multilayer spherical cloak shows reduced RCS in C band with respect to the PEC sphere. Further, the analysis of particle ray trajectories has been carried out by performing geometric ray tracing.

Conformal metamaterial multilayer analysis for design and simulation of invisibility cloak is a challenging task because of the curvature effects of the platform. Chapter 5 gives the analysis of material properties of various conformal metamaterial unit cell structures patterned on the cloaking layers. Design and simulation of planar and nonplanar metamaterial unit cells have been carried out and reported systematically. The extracted permittivity and permeability characteristics of the conformal metamaterial structures are compared with corresponding planar one. Further analysis of effect of radius of curvature of the platform has been studied and explained briefly.

The advances in artificial engineered materials such as metamaterials have created a wide interest in military aviation scientific community. The researches in modern military aviation are endowed with techniques based on low observable platforms. Design and development of metamaterial-based radar absorbers are one of the cutting edge technologies in this domain. Design and development of two metamaterial-based broadband microwave absorbers have been carried out and described in Chap. 6. Further, the proposed structures have been optimized for absorption in the entire X band, using soft computing-based computational engine. The proposed pentagon-shaped metamaterial structure and novel metamaterial structures have been fabricated, and backscattered signal power from the test samples is measured and compared with backscattered signal power from PEC of same footprint. The measurement result ensures the broadband absorption capability of proposed structures in the X band.

Metamaterial Inspired Electromagnetic Applications

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