Chapter 7
Advanced Engineering Design of the Metamaterial Absorbers

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ABSTRACT

In this chapter, the authors introduce the concept of MMA through reviewing the development of conventional absorbers. To illustrate the important operating mechanism, design process, and functionalization of the metamaterial absorber, they show the absorption relation of the absorber, impedance matching condition, equivalent circuit model, the evaluation of thickness, and oblique incidence condition in the first part. Then, they show the basic design method of the absorber, including parameter sweep method, equivalent circuit method, and deep learning method. Next, the planar integration strategy, vertical stacking strategy, and dispersive material strategy for broadband absorption bandwidth are discussed. In addition, they illustrate the tunable design of absorber, involving lumped element design method, thermal tunable design method, electrical tunable design method, mechanical tunable method, and reconfigurable tunable method. Finally, they talk about the basic engineering application of the metamaterial absorber in practical engineering application.

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1. INTRODUCTION

The advance of modern electronic science and technology comes with a dramatic increase in the number of electronic devices, such as communication equipment, mobile phones and base stations. However, in order to achieve higher transmission efficiency, communication equipment needs to cover a wider range of electromagnetic wave spectra, which consequently results in a higher amount of electromagnetic radiation energy (Jeong, Nguyen, & Lim, 2018). Excessive electromagnetic radiation has negative effects in everyday life, industrial production and military defence. When the energy exceeds a certain range, the biological level interferes with the body's DNA and brain waves, which may cause fetal malformation or miscarriage in pregnant women, and may have adverse effects such as headaches in normal individuals. In industrial production, strong electromagnetic radiation energy may interfere with electronic equipment and prevent it from functioning properly, thus affecting normal industrial production activities. Besides, some electronic functional devices that require precise measurements cannot be measured accurately in environments with high levels of electromagnetic radiation interference due to the presence of large interference (Shen, Zhai, & Zheng, 2014). For example, the complex electromagnetic radiation environment that prevails requires artificial "electromagnetic clear zones" by means of electromagnetic absorbing materials. The locations with "electromagnetic clear zones" are often found in remote and mountainous areas, which is inconvenient for experimental functional tests. On the defence and military front, military radars emit spatial electromagnetic waves at certain frequencies and then analyze the echoes by measuring them to construct a radar reflection target. Radar detection stealth by absorbing space electromagnetic waves emitted by radar is an effective method to keep military targets out of detection and surveillance (Z. Li, Li, Zhao, & Zhou, 2020). In summary, realizing electromagnetic energy absorption in the microwave regime is of great importance in everyday life, industrial production and defence and military areas. Therefore, we mainly discuss the MMA in the microwave regime in this chapter to the scope of practical engineering application for wireless systems.

In order to address absorption issues in engineering, traditional absorption materials are limited by the preparation conditions and parameter characteristics of the materials themselves, making it difficult to achieve perfect absorption. Therefore, achieving perfect impedance matching conditions usually requires exploring improvements in materials composition, making it difficult to achieve effective perfect absorption design (Jones & Wooding, 1964). Compared to traditional absorption materials, MMA can accurately control the equivalent dielectric constant and magnetic permeability of the material surface, achieve perfect impedance matching with free space, reduce surface reflectivity, and combine with loss media in the structure to achieve perfect