



Chapter 11

Metamaterials and Metasurfaces for Radio-Frequency Energy Harvesting Applications

Man Seng Sim

 <https://orcid.org/0000-0001-7776-2239>
Universiti Teknologi Malaysia,
Malaysia

Kok Yeow You

 <https://orcid.org/0000-0001-5214-7571>
Universiti Teknologi Malaysia,
Malaysia

Fahmiruddin Esa

Universiti Tun Hussein Onn Malaysia,
Malaysia

Fandi Hamid

Universiti Teknologi Malaysia,
Malaysia

ABSTRACT

In ambient energy harvesting applications, metamaterials and metasurfaces are useful in localizing and absorbing energy from the surroundings. This chapter reviews past achievements, recent developments and future trends in metamaterial-based radio-frequency (RF) energy harvesters. The chapter begins by introducing metamaterial energy harvesters from a general perspective, covering mechanical, acoustic, and electromagnetic metamaterial energy harvesters. The subsequent section focuses specifically on the working principle of electromagnetic metamaterial energy harvesters in the RF regime. To enhance understanding of the absorption mechanism and performance evaluation, a simulation of an Omega-ring-shaped metamaterial harvester operating at a frequency of 5.8 GHz is demonstrated. The absorption efficiency, harvesting efficiency, and conversion efficiency of the metamaterial harvester are determined and discussed. Furthermore, the state-of-the-art design of metamaterial RF harvesters and their respective performance are reviewed.

DOI: 10.4018/978-1-6684-8287-2.ch011

INTRODUCTION

The Internet of Things (IoT) refers to a network of wirelessly connected devices that can communicate and act on the information they receive from each other. The recent advancements in IoT technology have led to an increase in the number of wireless remote devices. Many of these low-power electronic devices require only a small amount of electrical energy to power them up. However, relying on conventional batteries for powering such devices would lead to environmental issues and high maintenance costs, as batteries are non-renewable and only yields for a limited amount of time. Therefore, there is a need for alternative energy sources.

A simple energy harvesting system can be integrated to collect the energy from the surroundings and convert the energy into useful electrical energy. This has the potential to provide a renewable source of energy, reduce the reliance on batteries, and enhance the sustainability of electronic systems. Furthermore, energy harvesting enables the expansion of applications for various wireless devices by eliminating the need for wired connections to a power source (Dinh et al., 2021). For instance, energy harvesting systems can be applied in unmanned aerial vehicles (UAVs), micro-robots, wireless sensors networks, radio-frequency identification (RFID) tags, wearable or implanted medical devices, portable charging devices, and smart switches.

One of the ambient energy sources that can be utilized is radio-frequency (RF) energy, which are radiated by various sources including Wi-Fi networks, broadcast towers, mobile devices, RFID systems, and Bluetooth devices. RF energy harvesting encounters two primary challenges. Firstly, the ambient sources from which RF energy is derived typically yield only low-power energy (about $-40\sim-50$ dBm in urban areas) (Piñuela et al., 2013). Secondly, the efficiency of the harvesting system itself in converting RF energy into direct current (DC) is relatively low (Huang et al., 2022). Metamaterials and metasurfaces can be introduced into the wireless RF energy harvesting system to enhance the RF absorption and harvesting efficiency (Eteng et al., 2021).

This book chapter aims to review the application of metamaterials and metasurfaces in energy harvesting, with a specific focus on RF energy harvesting. The chapter is organized as follows. Firstly, the utilization of metamaterials for harvesting various types of ambient energy is discussed. Next, the working principle, simulation and experimental testing, and efficiency evaluation of metamaterial RF energy harvesters are provided. Subsequently, a simulation of an Omega-ring shaped metamaterial RF energy harvester operating at a frequency of 5.8 GHz is presented. Finally, recent developments and future trends in metamaterial RF energy harvesters are discussed.

25 more pages are available in the full version of this document, which may be purchased using the "Add to Cart" button on the publisher's webpage: www.igi-global.com/chapter/metamaterials-and-metasurfaces-for-radio-frequency-energy-harvesting-applications/328951

Related Content

Security Issues on IoT Environment In Wireless Network Communications

Gowthami K. (2019). *International Journal of Wireless Networks and Broadband Technologies* (pp. 31-46).

www.irma-international.org/article/security-issues-on-iot-environment-in-wireless-network-communications/243660

Power-Aware and QoS Provisioned Real Time Multimedia Transmission in Small Cell Networks

Christos Bouras, Anastasios Bikos, Dimitrios Biliou and Antonios Alexiou (2016). *International Journal of Wireless Networks and Broadband Technologies* (pp. 24-45).

www.irma-international.org/article/power-aware-and-qos-provisioned-real-time-multimedia-transmission-in-small-cell-networks/170427

An MPEG-DASH Methodology for QoE-Aware Web3D Streaming

Kostas Kapetanakis, Markos Zampoglou, Athanasios G. Malamos, Spyros Panagiotakis and Emmanuel Maravelakis (2014). *International Journal of Wireless Networks and Broadband Technologies* (pp. 1-20).

www.irma-international.org/article/an-mpeg-dash-methodology-for-qoe-aware-web3d-streaming/125873

An Investigation into the Use of Pervasive Wireless Technologies to Support Diabetes Self-Care

Nilmini Wickramasinghe, Indrit Troshani and Steve Goldberg (2012). *Wireless Technologies: Concepts, Methodologies, Tools and Applications* (pp. 1211-1226).

www.irma-international.org/chapter/investigation-into-use-pervasive-wireless/58839

Survey and Evaluation of Advanced Mobility Management Schemes in the Host Identity Layer

László Bokor, Zoltán Faigland and Sándor Imre (2014). *International Journal of Wireless Networks and Broadband Technologies* (pp. 34-59).

www.irma-international.org/article/survey-and-evaluation-of-advanced-mobility-management-schemes-in-the-host-identity-layer/104629