

Abstract No: PO-15

Design and characterization of a tunable metamaterial absorber for efficient RF energy harvesting in the Wi-Fi frequency band

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The pursuit of miniaturization and connectivity in semiconductor technology has led to the development of compact, interconnected devices. However, the reliance on batteries for power presents limitations. Ambient energy harvesting, particularly from radio frequency (RF) waves, offers a promising solution. This study explores the feasibility of wireless energy harvesting, especially in the context of the saturated frequency spectrum due to wireless communications. Building upon recent advancements in metamaterial technology, this study focuses on the design, fabrication, and characterization of a tunable metamaterial absorber unit cell for efficient RF energy harvesting. The aim is to exploit metamaterials, specifically tunable metamaterial absorbers (MMA), to harvest RF energy, particularly in the widely utilized Wi-Fi frequency band. To design a novel unit cell structure, simulations were conducted using the commercially available EM simulation tool CST Microwave Studio software. A novel MMA unit cell consisting of E-shaped split ring resonators, copper reflector, and FR-4 substrate layer in the middle was designed and simulated. Results demonstrated its RF energy harnessing ability, achieving peak absorptivity of 98% of incident RF energy at 2.4 GHz. The designed unit cell was fabricated using the standard PCB fabrication method. Experimental results were obtained using a network analyzer through non-contact measurement method. Results closely mirrored the simulation results, confirming a high absorptivity of 99% at 1.44 GHz. To achieve frequency tunability, an external capacitor switching circuit was integrated into the MMA unit cell. Simulation and experimental results were obtained confirming its frequency tunability. The proposed tunable metamaterial absorber unit cell offers advantages over conventional RF energy harvesting systems, including ease of implementation, a wider range of RF energy absorption, and cost-effectiveness paving the way for integration into various applications. In conclusion, this study contributes to the development of energy harvesting technologies by leveraging tunable MMA to harness ambient RF energy.

Keywords: Capacitor switching network, RF energy, Tunable metamaterial absorber, Wi-Fi frequency band, Wireless energy harnessing

Acknowledgment

This work was partially supported by the University of Kelaniya Internal Research Grant under the research grant no. RP/03/02/05/02/2023.