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Design Optimization of Rectangular Microstrip Antenna Using Deep Neural Network for 3 GHz Applications in Support of SDG 9

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ABSTRACT

Objective: This study aims to investigate the effectiveness of Deep Neural Networks (DNN) for optimizing the design of a rectangular microstrip antenna operating at a target frequency of 3 GHz. The research focuses on improving antenna design efficiency by predicting antenna performance parameters based on geometric characteristics. **Method:** The study employed a computational simulation approach combined with machine learning techniques. A synthetic dataset consisting of 6000 antenna configurations was generated using analytical microstrip antenna equations. The dataset included geometric parameters such as dielectric constant, substrate thickness, patch width, patch length, and inset feed position. A Deep Neural Network model was trained to predict resonant frequency, return loss, and input impedance. The trained model was then used as a surrogate model to evaluate 30,000 candidate antenna designs and identify the optimal configuration. **Result:** The proposed model achieved high predictive accuracy with R^2 values of 0.9987 for resonant frequency prediction and 0.9988 for input impedance prediction. The optimized antenna design produced a resonant frequency of 2.996 GHz, return loss of -18.70 dB, and input impedance of 53.95Ω , which closely match the target specifications for S-band wireless applications. **Novelty:** The study demonstrates that Deep Neural Networks can significantly accelerate antenna design optimization by replacing repetitive electromagnetic simulations with data-driven prediction models.

INTRODUCTION

The development of wireless communication technology in the era of digital transformation demands increasingly efficient, adaptive hardware systems capable of supporting high-speed connectivity. Antennas are a crucial component of modern communication systems, acting as a link between electronic systems and the electromagnetic wave propagation medium. Microstrip antennas are a type of antenna widely used in various communication applications due to their compact size, lightweight, ease of fabrication, and ability to integrate with radio frequency circuits in modern electronic devices (Bansal & Sharma, 2021; Singh et al., 2022; Kundu et al., 2023; Rahman et al., 2024). These characteristics make microstrip antennas very popular in various applications such as cellular communications, radar, navigation systems, and Internet of Things (IoT) devices, which have continued to develop in recent decades.

Among the various forms of microstrip antennas, the rectangular microstrip patch antenna is the most commonly used configuration due to its simple structure and ease of analysis using basic theoretical models such as the transmission line model and cavity model. The main dimensions of a rectangular patch antenna, namely the length and width of the patch, significantly determine the antenna's resonant frequency. Therefore, the antenna design process generally involves initial mathematical calculations followed by optimization through electromagnetic simulations using software such as CST, HFSS, or FEKO (Verma et al., 2021; Kumar et al., 2022; Chen et al., 2023; Kaur & Singh, 2024).