**Title: Machine learning validation in performance evaluation to optimize 6G terahertz MIMO antenna designs for future wireless networks**

**Author names:** Md Ashraful Haque, Mahafujul Haq Riad , Mehidy Hasan , Jun-Jiat Tiang, Maruf Billah, Liton Chandra Paul and Narinderjit Singh Sawaran Singh

**Abstract:** This research introduces a graphene-based 2×2 MIMO microstrip antenna designed for 6G terahertz (THz) wireless communication. The antenna features a hybrid slot-elliptical patch configuration on a polyimide substrate, operating within the 2.4673–6.185 THz frequency spectrum. It showcases excellent electromagnetic performance, with three notable resonances at 3.0162, 4.942, and 5.8301 THz. The antenna boasts a bandwidth of 3.7177 THz, a peak gain of 11.19 dB, and a radiation efficiency of 88.06%. Furthermore, it achieves a minimal envelope correlation coefficient (ECC=0.0002577) and an almost perfect diversity gain (DG=9.9987 dB), making it well-suited for MIMO applications in high-capacity 6G systems. A key contribution of this study is the integration of a circuit-level RLC model that aligns closely with the results of full-wave simulations. This RLC model simplifies the design process by providing quick insights into the antenna's performance while ensuring accuracy. It employs resistive (R), inductive (L), and capacitive (C) components to enhance understanding of the antenna's resonant characteristics and optimization. Additionally, machine learning optimization techniques are used to refine the antenna design. Various machine learning algorithms, including Decision Tree, Random Forest, and Extra Trees Regressor, were evaluated for their effectiveness in predicting performance metrics and optimizing design parameters. These machine learning models significantly reduce computational load, improve predictive accuracy, and surpass traditional optimization methods. A regression-based machine learning approach accelerates the antenna design process, ensuring an ideal balance of bandwidth, gain, and isolation, which is crucial for the emerging 6G THz communication systems. Overall, this study combines RLC circuit modeling with machine learning optimization to create a stable and efficient method for developing high-performance THz MIMO antennas. This approach facilitates the advancement of sophisticated, low-interference, high-capacity wireless networks for 6G.

**Keywords**: 6G, THz, MIMO antenna, Machine learning, industrial and innovation

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