Title: Innovative MIMO antenna for terahertz band 6G communications: Performance evaluation and machine learning integration

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Abstract: This paper presents a graphene-based multiband terahertz (THz) MIMO antenna developed to meet the stringent requirements of future high-speed wireless and biomedical systems. The antenna exhibits resonances at 2.7345, 3.2455, 3.739, and 4.243 THz, each offering a broad bandwidth greater than 0.21 THz. Graphene, chosen as the conducting element, and polyimide, selected as the substrate, provide an optimal material combination to ensure low losses and stable operation at terahertz frequencies. The antenna combines silicon decoupling structures with a low loss polyimide substrate, forming a composite material for improved isolation, stability and the terahertz performance. Performance evaluation demonstrates a radiation efficiency of 90.42%, a peak gain of 13.253 dB, and strong isolation of 33.026 dB between ports. Diversity performance is further validated through the calculation of envelope correlation coefficient (ECC), diversity gain (DG), total active reflection coefficient (TARC), channel capacity loss (CCL), and mean effective gain (MEG), all of which confirm excellent MIMO characteristics and robust transmission quality. The antenna design progresses from a single-element configuration to a MIMO structure, where silicon-based parasitic decoupling structures (PDS) and defective ground slots (DGS) are incorporated to suppress mutual coupling while maintaining stable radiation patterns. The resulting low-profile and high-performance antenna demonstrates wide frequency coverage, strong gain, and reliable isolation, making it a promising solution for diverse applications. These include non-invasive biomedical imaging and spectroscopy, high-resolution material characterization, environmental and security monitoring, and next-generation 6G communication scenarios requiring ultra-fast, low-latency, and high-capacity data transmission. To enhance design accuracy and efficiency, machine learning (ML) driven regression algorithms are employed for performance prediction, achieving high consistency with simulation results and reducing the need for repeated design iterations. The combination of multiband operation, advanced material utilization, and intelligent performance optimization positions this antenna as a strong candidate for integration into future terahertz-enabled systems.

Keywords: THz; MIMO antenna; Machine learning; 6G; Industrial and Innovation

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