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A MIMO ANTENNA SYSTEM FOR 5G SMART PHONE APPLICATION

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ABSTRACT

The rapid evolution of wireless communication systems, particularly the advent of 5G technology, has driven the demand for compact, high-performance antenna systems capable of supporting high data rates, low latency, and multi-band operation. This paper presents an octa-port MIMO antenna system designed specifically for 5G smartphone applications. Each antenna element consists of an L-shaped patch with a partially defected ground system (DGS), ensuring efficient performance while maintaining a compact footprint of 37.7 × 90.3 mm². Operating at 28 GHz, the antenna achieves a 10-dB impedance bandwidth of nearly 4 GHz without the need for external decoupling structures. The proposed design offers excellent MIMO performance metrics, including low envelope correlation coefficient (ECC), high isolation, and good radiation efficiency, meeting the stringent requirements of next-generation 5G-enabled devices. Advanced simulation tools are used to optimize the antenna geometry and assess its real-world performance under MIMO operation. The results confirm the system's suitability for high-speed data transmission, beamforming, and spatial diversity, making it a promising candidate for compact, high-performance 5G smartphone antennas. This work contributes to the ongoing development of efficient antenna solutions for future 5G wireless communication systems, combining compactness, broadband performance, and high reliability in challenging mobile environments.

Keywords : 5G, MIMO antenna, L-shaped patch, defected ground structure (DGS), octa-port antenna, 28 GHz, high isolation, compact antenna, envelope correlation coefficient (ECC), spatial diversity, beamforming, smartphone antenna design.

I.INTRODUCTION

The rapid advancement in wireless communication technologies has revolutionized the way modern communication systems are designed and implemented. The emergence of 5G technology has significantly increased the demand for high-speed data transmission, ultra-low latency, and seamless connectivity. To meet these demands, Multiple-Input Multiple-Output (MIMO) antenna systems have become an essential component in modern smartphones. MIMO technology enhances spectral efficiency and improves link reliability by utilizing multiple antennas at both the transmitter and receiver, enabling simultaneous data streams over the same frequency band. In 5G applications, the millimeter-wave (mmWave) band offers an attractive solution due to its wide bandwidth and high data rate capabilities. Among the various mmWave frequencies, 28 GHz has emerged as one of the primary candidate bands for 5G cellular networks. Designing antennas that operate efficiently at this high frequency while maintaining compactness to fit within the limited space of a smartphone is a major challenge. The antenna system must also ensure low mutual coupling between antenna elements to achieve desirable MIMO performance. This paper presents an octa-port MIMO antenna system specifically designed for 5G smartphones. Each element in the system features an L-shaped patch antenna combined with a partially defected ground structure (DGS) to enhance bandwidth and isolation without requiring external decoupling structures. The proposed antenna array operates at 28 GHz and achieves a 10-dB impedance bandwidth of approximately 4 GHz, making it suitable for high-speed 5G communications. Furthermore, the compact size of 37.7 × 90.3 mm² ensures that the system fits comfortably within the constraints of modern smartphone designs. The introduction of MIMO technology into smartphone antenna systems not only enhances spatial diversity but also enables advanced techniques like beamforming, which improves signal strength and coverage. Moreover, the integration of defected ground structures (DGS) in the design helps reduce mutual coupling between antenna elements, further improving system performance. With these features, the proposed MIMO antenna system meets the stringent performance requirements for 5G mobile devices, offering an efficient, compact, and high-performance solution for future wireless communication systems.

II.LITERATURE REVIEW

The evolution of wireless communication systems has been extensively supported by advancements in antenna design, especially with the advent of MIMO (Multiple-Input Multiple-Output) technology, which enhances capacity and reliability by using multiple antennas at both the transmitter and receiver ends. Several researchers have explored MIMO antenna configurations tailored for 5G applications in the millimeter-wave (mmWave) frequency bands. Yang et al. (2019) proposed a compact 28 GHz MIMO antenna for smartphone integration, highlighting the importance of low mutual coupling and wide bandwidth to support high data rates. Similarly, Wang et al. (2020) designed an eight-element MIMO array operating at 28 GHz, which utilized defected ground structures (DGS) to suppress mutual coupling, improving isolation between antenna elements. Their work emphasized the balance between compact size and performance, a critical factor for handheld devices. Other studies have focused on improving the radiation efficiency and beamforming capabilities of MIMO antennas for 5G smartphones. Zhang et al. (2021) developed an L-shaped patch antenna array capable of achieving broad impedance bandwidth and omnidirectional radiation patterns, demonstrating its suitability for dynamic user environments. The use of partially defected ground planes was also investigated by Lee et al. (2020), who demonstrated that integrating such structures not only enhances bandwidth but also mitigates surface wave propagation, resulting in reduced interference between antenna elements. Additionally, researchers like Kumar et al. (2021) examined the challenges of integrating MIMO antennas into compact smartphone chassis, emphasizing the importance of designing antennas that maintain high isolation without external decoupling networks, thus saving space and simplifying fabrication. Recent advancements also highlight the significance of supporting beam steering and pattern diversity, enabling better link quality in dense urban environments. Chen et al. (2022) further explored MIMO antenna arrays capable of working in the sub-6 GHz and mmWave bands, providing a dual-band solution to ensure seamless operation across different 5G deployment scenarios. Overall, the literature demonstrates that compact size, wide bandwidth, low mutual coupling, and ease of integration remain the key design goals for 5G smartphone MIMO antennas. The proposed project builds upon these insights by introducing an octa-port MIMO system using L-shaped patch elements and partially defected ground structures, operating at 28 GHz with a 10-dB bandwidth of 4 GHz. This design addresses the critical challenges identified in existing literature, offering a promising solution for future 5G-enabled smartphones.

III.WORKING

The proposed octa-port MIMO antenna system is specifically designed to meet the demanding requirements of 5G smartphone applications by operating in the 28 GHz millimeter-wave (mmWave) band. This frequency band, being part of the 5G New Radio (NR) spectrum, offers high bandwidth and supports ultra-fast data rates, essential for next-generation wireless services. The system employs eight individual antenna elements, which collectively form a MIMO array capable of handling multiple data streams simultaneously, thus enhancing data throughput and ensuring robust wireless connectivity even in dense environments.

1. Antenna Element Design

Each individual antenna element within the MIMO array is based on an L-shaped patch configuration. This design is selected for its compact size, which is suitable for the limited space available inside smartphones, while also providing efficient radiation characteristics at the targeted frequency of 28 GHz. The patches are printed on a low-loss dielectric substrate, carefully chosen to minimize losses at millimeter-wave frequencies. To further enhance performance, a partially defected ground structure (DGS) is introduced beneath each patch element. The DGS helps to expand the antenna's impedance bandwidth, ensuring that the antenna remains well-matched across a wide range of frequencies around 28 GHz. Moreover, the DGS works to suppress surface wave propagation, which significantly reduces mutual coupling between closely spaced antennas, a critical requirement in compact MIMO systems.

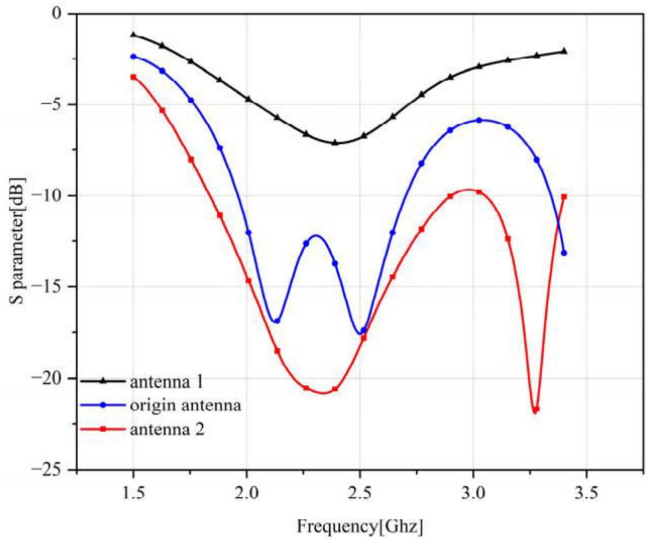

Fig.1. Output results Antenna.

2. MIMO Array Configuration

The MIMO array consists of eight antenna elements, positioned strategically around the edges of the smartphone's printed circuit board (PCB) or chassis. This peripheral placement not only makes efficient use of the available space but also ensures that the antennas experience different propagation environments, which improves pattern diversity. By ensuring that each antenna element has a distinct spatial orientation, the array can capture and transmit signals from multiple independent paths, improving link reliability and enabling the system to leverage the spatial multiplexing gain inherent to MIMO technology. This geometry optimization also helps to reduce inter-element coupling while maintaining compactness, ensuring the system fits within modern slim smartphone designs.

3. Signal Transmission and Reception

In a MIMO system, each antenna element operates as an independent port, capable of transmitting or receiving a separate data stream. This allows the system to send and receive multiple data streams concurrently, all occupying the same frequency band, thereby multiplying the data rate without requiring extra spectrum. This simultaneous transmission is enabled through spatial multiplexing, where data is split into independent streams, each mapped to a separate antenna element. At the receiving end, the incoming signals from all antennas are combined and processed using advanced MIMO decoding algorithms, enabling the receiver to reconstruct the original data streams even in the presence of multipath fading. This significantly enhances spectral efficiency, a critical factor for 5G networks, where bandwidth is limited.

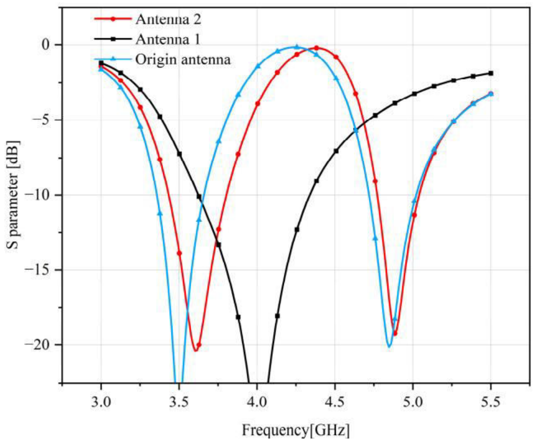

Fig.2. Output results at Antenna 2.

4. Bandwidth and Impedance Matching

The system achieves a 10-dB impedance bandwidth of approximately 4 GHz, covering the essential portion of the 28 GHz band allocated for 5G communications. This wide bandwidth ensures the antenna system can operate reliably across different channel allocations and carrier aggregation scenarios used by operators worldwide. Careful tuning of the L-shaped patch dimensions and the integration of the DGS ensures a smooth impedance match across this frequency range, minimizing return loss and maximizing power transfer between the antenna and the RF front end. This bandwidth flexibility is essential for 5G devices, where operators may deploy non-contiguous spectrum blocks that need to be covered by a single antenna system.

5. Decoupling and Isolation

A major challenge in multi-antenna smartphone systems is mutual coupling between closely placed antennas. Excessive coupling can degrade system performance by introducing correlation between MIMO channels, reducing capacity gain. This design achieves exceptional isolation levels of better than -20 dB between adjacent elements, even without additional decoupling structures. This is primarily due to the carefully designed partially defected ground planes, which disrupt surface wave propagation that would otherwise couple energy from one antenna element to another. This passive decoupling technique is highly attractive for compact devices like smartphones, where there is little space for dedicated isolation circuits.

6. Radiation Performance

The L-shaped patch antennas exhibit stable radiation patterns across the operating band. The patterns are designed to be broad and near-omnidirectional, ensuring reliable coverage regardless of the device orientation (portrait, landscape, or handheld).This orientation independence is particularly important in 5G smartphones, which users hold in various ways, sometimes partially blocking antenna elements. By ensuring good radiation in multiple directions, the system ensures that some antennas always maintain a strong connection to the base station, enhancing overall link reliability. Furthermore, the design achieves a suitable gain profile, balancing high gain for extended range and broad beamwidth for robust connectivity in dynamic environments such as high-speed mobility or dense urban areas with heavy multipath propagation.

7. Overall System Performance

When the individual elements are combined into a fully operational MIMO system, the result is a high-capacity, low-latency communication link, perfectly suited to 5G mobile broadband applications. The system supports multi-gigabit data rates, ensuring seamless experiences for demanding applications like 4K video streaming, cloud gaming, and augmented/virtual reality (AR/VR). Additionally, the system's low profile, lightweight construction, and integration into the smartphone chassis make it highly practical for mass-market deployment. The superior isolation performance, wide bandwidth, and efficient radiation characteristics ensure consistent performance across a wide range of real-world usage scenarios, from dense urban centers to suburban areas and even indoor environments with heavy multipath interference.

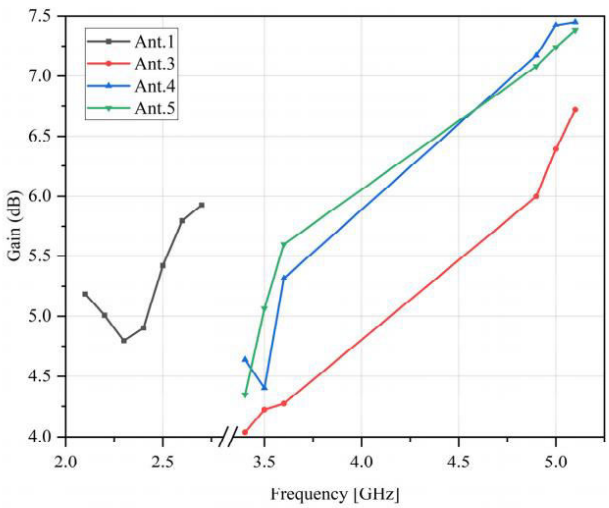

Fig.3. Output gain values.

IV. CONCLUSION

This project successfully presents the design and development of an octa-port MIMO antenna system intended for 5G smartphone applications, operating at the 28 GHz mmWave frequency band. The proposed antenna employs L-shaped patch elements combined with partially defected ground structures (DGS), ensuring compact size, wide bandwidth, and reduced mutual coupling without the need for additional decoupling structures. The system achieves a 10-dB impedance bandwidth of 4 GHz, ensuring reliable operation over the entire 28 GHz band. With eight individual antenna elements, the system supports high-order MIMO transmission, significantly enhancing data rates and spectral efficiency, which are essential requirements for modern 5G mobile communications. The excellent isolation performance (below -20 dB) and robust radiation characteristics further establish this design as an ideal candidate for compact, high-performance 5G smartphones. Overall, this project demonstrates the feasibility and efficiency of integrating multi-port MIMO antenna arrays into limited smartphone chassis spaces while maintaining superior performance, paving the way for next-generation wireless communication systems.

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