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Design of Triple-Band Dielectric Resonator Antenna for WLAN Application

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Abstract: This study describes the design and implementation of a compact triple-band Dielectric Resonator Antenna (DRA) for Wireless Local Area Network (WLAN) applications. The suggested antenna features a new hybrid dielectric structure consisting of two overlapping hemispherical resonators with radii and separated by a distance. This study introduces a new triple band DRA architecture that is fed by a microstrip line. On a FR-4 substrate, two cut cylindrical dielectric resonators make up the suggested configuration. The microstrip feed line's precise length and positioning are crucial for accomplishing multi-band functioning because they efficiently stimulate three different resonant modes. Triple band operation with severe resonances at roughly 6.57 GHz, 8.01 GHz, and 9.2 GHz is confirmed by the simulated return loss (S11) response, which was acquired via HFSS. Because these frequency bands span a large spectrum, the antenna can be used in a number of high-frequency applications. Its potential for incorporation into future wireless local area network (WLAN) systems and other microwave communication systems is suggested by its small size, effective design, and good performance metrics.
Keywords: Dielectric resonator antenna, HFSS Soft, Triple-band antenna, WLAN application.

I. INTRODUCTION

The growing demand for compact, high-performance antennas in modern wireless communication systems has led to significant advancements in antenna design, particularly in multi-band and wideband technologies. Dielectric Resonator Antennas (DRAs) have emerged as a promising solution due to their high radiation efficiency, low loss, and design flexibility. Wang et al [1]. introduced a novel triple-band cylindrical DRA aimed at WLAN applications, providing efficient performance across multiple frequency bands. In parallel, the development of Multiple-Input Multiple-Output (MIMO) antenna systems has become crucial in enhancing data throughput and reliability. Li et al [2]. proposed a compact wideband MIMO antenna with innovative bent slits that improve isolation and broaden bandwidth. Addressing the need for portable solutions, Liu et al. designed a compact MIMO antenna optimized for Ultra-Wideband (UWB) applications, offering high performance in space-constrained environments.

Additionally, Antonino-Daviu et al [4]. developed an ultra-wideband slot ring antenna specifically for diversity applications, further enhancing signal robustness across broad frequency ranges. These innovative designs build upon the foundational principles outlined in Petosa’s Dielectric Resonator Antenna Handbook, which provides comprehensive guidance on the theory and practical implementation of DRAs. Collectively, these works represent significant progress in antenna technology, catering to the evolving needs of next-generation wireless communication systems [5].

II. LITERATURE REVIEW

The increasing demand for compact, multi-band antennas to support modern wireless communication standards such as WLAN, WiMAX, Bluetooth, LTE, and Zigbee has accelerated the evolution of dielectric resonator antenna (DRA) technology. DRAs are known for their low loss, high radiation efficiency, and suitability for integration into compact wireless devices. Numerous researchers have proposed novel DRA designs to address the challenges of achieving triple-band performance, polarization diversity, and miniaturization.

Sharma et al. (2018) proposed a tri-band, dual-port hybrid DRA designed for WLAN and WiMAX applications. The antenna combined a dielectric resonator with a monopole, offering improved isolation between ports and enhanced impedance bandwidth. Their design demonstrated the potential of hybrid structures in achieving multiple resonant modes within a compact form factor, making it suitable for integrated communication systems [6].

Similarly, Rao (2014) developed a cylindrical DRA tailored for Wireless Body Area Networks (WBANs). This design emphasized human-body-friendly configurations with compact size and low specific absorption rate (SAR), underscoring the relevance of DRAs in wearable and biomedical communications [7].

Rao et al. (2021) extended this concept by introducing a tri-band hybrid DRA using both dielectric and conducting elements. Their work demonstrated high gain and enhanced radiation efficiency, particularly for WLAN and WiMAX bands. The hybrid structure efficiently combined multiple resonant paths to achieve tri-band operation, aligning with the trend toward spectrum reuse and compact device integration [8].

Mitra et al. (2018) presented a triple-band circularly polarized DRA that supports WLAN, WiMAX, Bluetooth, Zigbee, and LTE applications. Using a single dielectric block with a carefully designed feed structure, the antenna provided polarization agility and multiple resonant bands, crucial for modern devices requiring multi-standard support and robust signal transmission under various orientations [9].

Further advancements in circular polarization are evident in the work of Lu et al. (2016), who introduced a stair-shaped dielectric resonator antenna with an open-ended slot ground plane. Their wideband circularly polarized design addressed the need for enhanced axial ratio bandwidth, which is vital for applications involving dynamic device orientations and mobility [10].

Bemani et al. (2011) contributed a compact rectangular DRA capable of triple-band performance for WLAN and WiMAX. By exploiting multiple resonant modes of a single dielectric resonator, their design achieved significant size reduction without compromising radiation characteristics. This work highlighted the importance of structural optimization and material selection in achieving performance goals within strict space constraints [11].

Collectively, these studies illustrate a clear progression in DRA research, moving from basic single-mode structures toward complex, hybrid, and multi-resonant designs capable of supporting diverse wireless standards. Common themes include enhancing bandwidth, improving isolation in multi-port systems, achieving circular polarization, and reducing physical size—all while maintaining high efficiency and gain. As wireless systems continue to demand higher data rates and compact multi-functionality, dielectric resonator antennas are poised to play a crucial role in next-generation wireless device architectures.

III. PROPOSED ANTENNA DESIGN

This paper presents a new design for a cylindrical dra with a triple operating band. figures 1 and 2 illustrate the antenna layout. the dielectric resonator, feeding line, and fr-4 substrate make up the majority of the antenna's simple composition, which is visible in rough form from the 3d image. the grounding plane and fr-4 substrate are located at the base of the entire structure. It is 1.6mm thick. the microstrip lines, which are generally made up of three thinner and one thicker feed, are located above the fr 4 substrate. Two unfinished cylindrical dielectric resonators, each composed of Rogers RT/duroid 6010 material with a dielectric constant of 10.2 and a loss tangent of 0.0023, are located above the entire structure. The antenna's general design is straightforward, its dimensions are perfect, and its outstanding performance is achieved. The form and arrangement of the microstrip lines, as well as the position of the dielectric resonator, are readily visible from two top views of the feed and the suggested antenna. The letter L is formed by the three narrower microstrip lines, which vary in width and length. Although the two unfinished cylinders' centres are at the same location, their heights and radiuses differ. It is important to note that the two cylinders' cut faces are near to one another and rectangular. The two cylindrical dielectric resonators have their cutting positions optimized. The two dielectric resonators above hold down the portion of the microstrip line. Table I provides an illustration of the planned antenna's dimensions.

Table 1: Dimensions of the proposed antenna units(mm)

Parameter	Value	Parameter	Value
L	50	W	32
L1	5.5	W1	46
W2	1.5	W3	2.5
W4	1.6	R1	8.5
R2	12	D	3
H1	7.5	H2	5

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IV. RESULTS AND DISCUSSIONS

1) Basic Structure Antenna: This diagram illustrates the 3D model of a microstrip patch antenna designed at 6.5 GHz using HFSS. It includes an FR4 substrate (ε_r = 4.4, thickness = 1.6 mm), rectangular patch, ground plane, and feedline. The model forms the foundation for simulation and frequency-domain analysis.

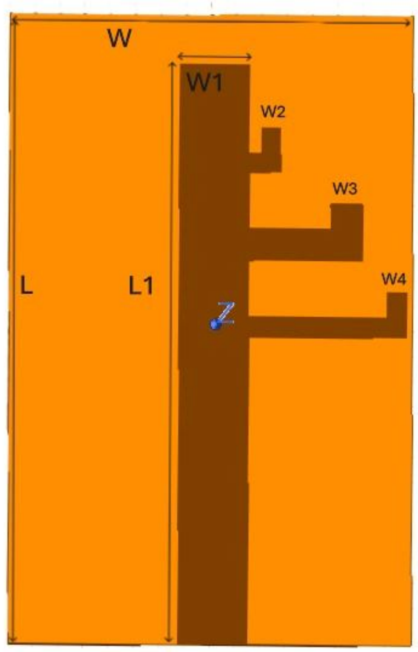

Figure.1 Antenna Structure in HFSS

2) Mesh Structure Antenna: This visualization displays the mesh applied to the antenna geometry in HFSS. Adaptive meshing is used for high accuracy, with finer elements near the feed and patch edges. The mesh enables precise electromagnetic field simulation at the target resonance frequency of 6.5 GHz.

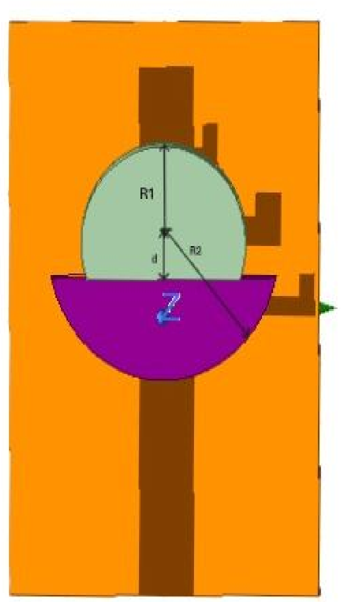

Figure.2 Antenna Mesh Structure

3) Return Loss: This graph plots the return loss (S11) from 5 GHz to 8 GHz. A sharp dip to -26.10 dB at 6.5 GHz indicates excellent impedance matching and minimal reflection. The antenna operates efficiently at the design frequency with a wide bandwidth and strong resonance.

A. *Graphs*

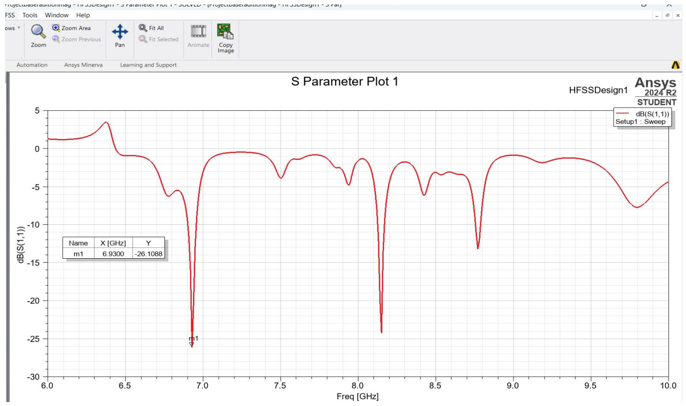

Figure. Return loss Plot

VWSR (Voltage Standard Wave Ratio): This plot shows the VSWR performance of the antenna over the frequency range. At 6.5 GHz, the VSWR value is 1.06, which reflects near-perfect matching and low power loss. The curve confirms that the antenna radiates most of the input power effectively.

Figure.4 VSWR Plot

Current Density Without Hemisphere: This HFSS output shows the surface current density at 6.5 GHz without the hemispherical dome. The current is mostly concentrated at the patch edges and feedline, peaking at 19.342 A/m, indicating effective excitation and resonance of the antenna in its base configuration.

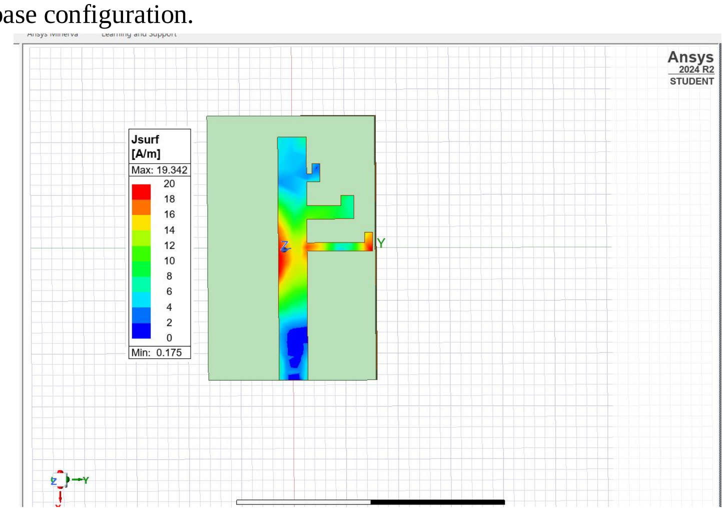

Figure.5 Current Density Without Hemisphere plot

Current Density with Hemispherical Structure: This result presents the surface current density distribution with a hemispherical dielectric dome added above the antenna at 6.5 GHz. Current density increases to 352.2 A/m, showing enhanced field concentration and improved surface excitation, which contributes to higher directivity and better gain performance.

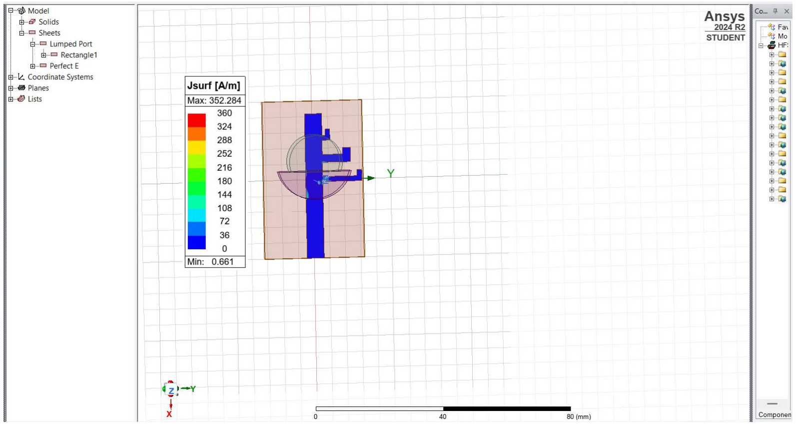

Figure.6 Current Density with Hemispherical Structure plot

Gain: This chart plots the gain response from 5 GHz to 8 GHz. The antenna achieves a peak gain of 6.43 dBi at 6.5 GHz, demonstrating strong directional radiation. The gain curve validates the antenna's performance for high-frequency applications such as radar and 5G systems.

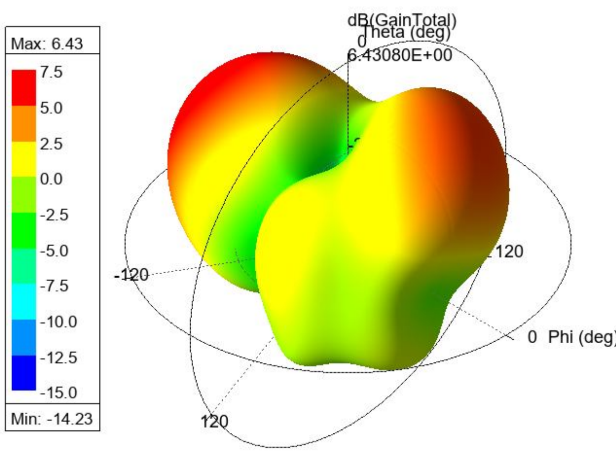

Figure.7 Gain vs Frequency Plot

V. CONCLUSIONS

A triple-band dielectric resonator antenna (DRA) was successfully designed and analysed using Ansys HFSS to operate efficiently at 6.5 GHz and two additional frequency bands. The antenna comprises a microstrip-fed rectangular patch on an FR4 substrate (ε_r = 4.4), enhanced with a hemispherical dielectric dome. Simulation results confirmed strong performance, with a return loss of -26.10dB and VSWR of 1.06 at 6.5 GHz, indicating excellent impedance matching and minimal reflection. Current density analysis showed a peak of 19.3 A/m without the dome and 352.2 A/m with the dome, validating the dome's role in enhancing field concentration and radiation efficiency. The antenna achieved a peak gain of 6.43 dBi, confirming its suitability for high-frequency applications such as 5G, radar, and satellite systems. The use of a low-cost FR4 substrate and a simple patch geometry ensures fabrication ease and scalability. Overall, the proposed DRA demonstrates strong performance across multiple bands, and the inclusion of a hemispherical dome effectively enhances current flow and gain without increasing design complexity.

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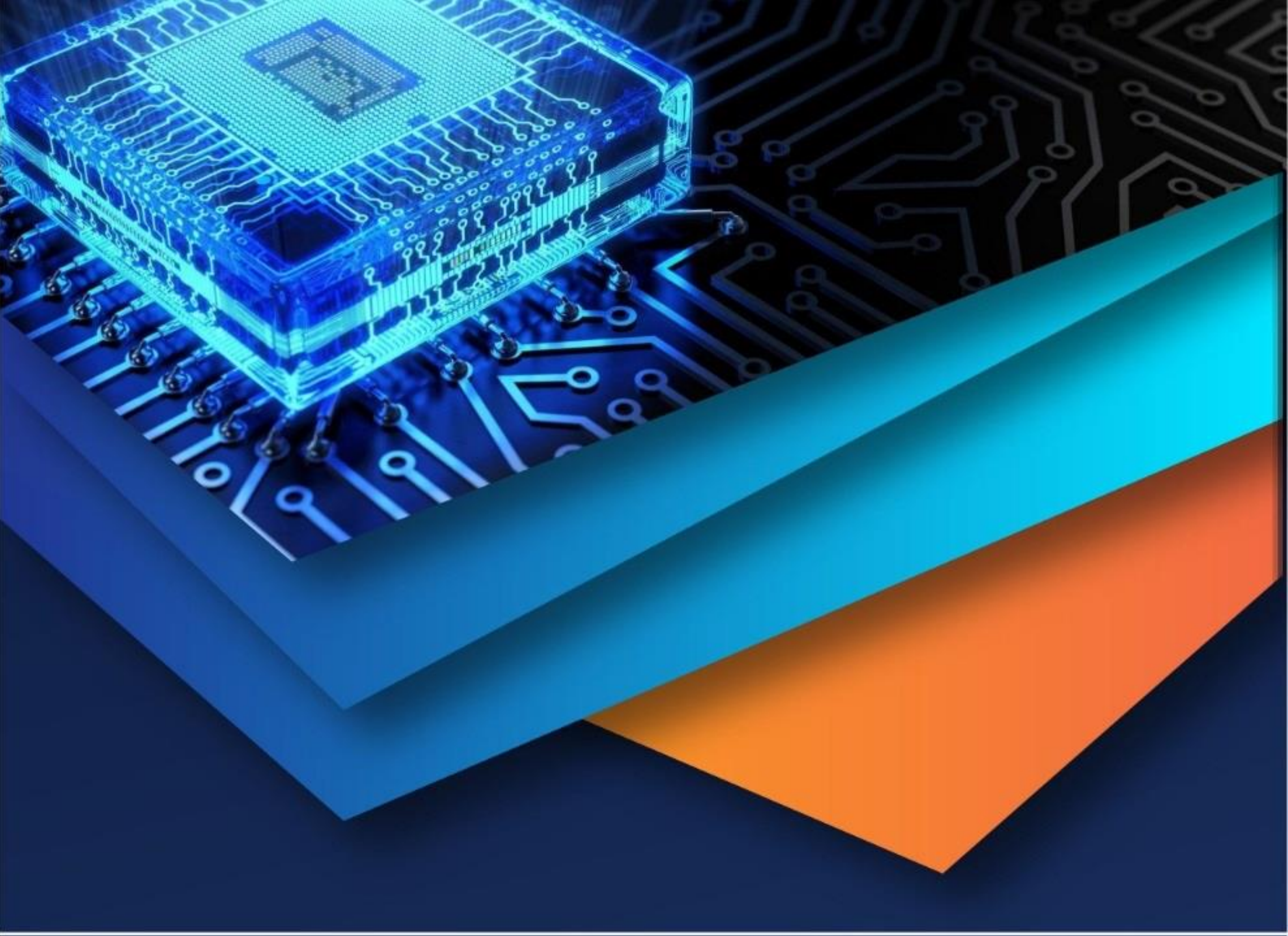

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