A DUAL-BAND CIRCULAR PATCH ANTENNA WITH CPW FED FOR ULTRA-WIDEBAND APPLICATIONS

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ABSTRACT:

This paper introduces the dual-band circular patch antenna, utilizing a coplanar waveguide (CPW) feed, is engineered for ultra-wideband (UWB) applications. Compact yet robust, it measures 25 mm x 28 mm x 1.6 mm on an FR-4 substrate. Offering dual-band functionality, it covers frequencies from 3.22 to 4.19 GHz and from 5.89 to 10.56 GHz, catering to a wide range of UWB communication needs. The antenna resonates at 3.6 GHz and 6.5 GHz, showcasing excellent impedance matching with return losses of -23 dB and -18 dB, respectively, ensuring efficient signal transmission. A highlight of this antenna is its impressive gain performance, reaching 5.6dBi and 4.12dBi, providing substantial signal amplification for reliable long-range communication. The integration of a CPW feed enhances its compatibility with modern communication systems, offering simplicity, ease of integration, and reduced electromagnetic interference. Overall, the dual-band circular patch antenna with CPW feed stands as an innovative solution for UWB applications, offering a compact design, dual-band functionality, high gain performance, and seamless integration capabilities.

KEYWORDS:

Dual-band antenna, Coplanar waveguide (CPW) feed, Ultra-wideband (UWB) applications, FR-4 substrate,Resonant frequencies, Gainand Compatibility.

INTRODUCTION:

Ultra-wideband (UWB) technology has emerged as a focal point of research and development following the allocation of the 3.1–10.6 GHz bandwidth for commercial applications by the Federal Communications Commission (FCC) in 2002. This milestone was catalytic, owing to the exceptional data rate capabilities and cost-effectiveness inherent in UWB [1]. Subsequently, extensive endeavors have been channeled towards advancing UWB technology, with substantial contributions from both industry and academia, particularly within the realms of UWB antennas and UWB band-pass filters. Among these technological domains, the UWB antenna has emerged as a linchpin component in the realization of UWB systems, precipitating a concerted exploration into compact and efficient antenna designs in recent years [2–18]. Within the UWB frequency spectrum, the coexistence of various narrow-band systems poses a formidable challenge, with overlapping frequency ranges utilized by systems such as the IEEE 802.11a WLAN system (5.15–5.825 GHz), super high frequency (SHF) and satellite services (4.5–5 GHz), IEEE 802.16 WiMAX system (3.3–3.7 GHz), and the ITU 8 GHz band (7.725–8.275 GHz) [1]. This coexistence presents a potential for interference issues, necessitating robust mitigation strategies. Traditionally, the alleviation of such interference has relied on the incorporation of narrow-band band-stop filters, albeit at the expense of heightened device complexity and cost [5, 6]. In pursuit of a streamlined approach, the integration of filtering characteristics directly into UWB antennas has emerged as a promising paradigm.

One notable method proposed to realize this integration is through the strategic incorporation of cutting slots, offering a simple, effective, and cost-efficient solution. Various slot configurations, including rectangle slots [5], C-shaped slots [6–8], pi-shaped slots [9], E-shaped slots [10], H-shaped slots [11], and U-shaped slots [12], have been explored for their efficacy in conferring band rejection properties to UWB antennas. Additionally, hybrid configurations, such as the amalgamation of C-shaped slots with U-shaped resonators [13], have been posited to augment filtering capabilities. However, a notable drawback of these slot-based approaches lies in the potential leakage of electromagnetic waves, which may disrupt radiation patterns.

To mitigate this challenge, alternative approaches involving stubs [14] and parasitic elements [15–17] have been investigated. These techniques offer enhanced control over electromagnetic wave leakage while preserving the desired band-notch characteristics. Nonetheless, it is observed that such antennas are predominantly utilized either as multiband antennas or as band-notched UWB antennas, necessitating further refinement to optimize their performance and versatility. In summation, the integration of filtering characteristics into UWB antennas holds significant promise for enhancing spectral efficiency and mitigating interference in next-generation wireless communication systems.

ANTENNA DESIGN:

The antenna design evolves through three discernible stages, with each phase strategically aimed at refining performance and functionality. Visual cues distinguish the ground segment in brown and the patch component in yellow. Commencing the journey, the initial stage unveils a coplanar waveguide (CPW) monopole-fed antenna, featuring a circular patch measuring 25 mm x 28 mm x 1.6 mm. Employing FR-4 as the substrate material underscores the foundational framework laid in this pivotal phase. This stage serves as the cornerstone for subsequent advancements, setting the tone for the antenna's progressive evolution.

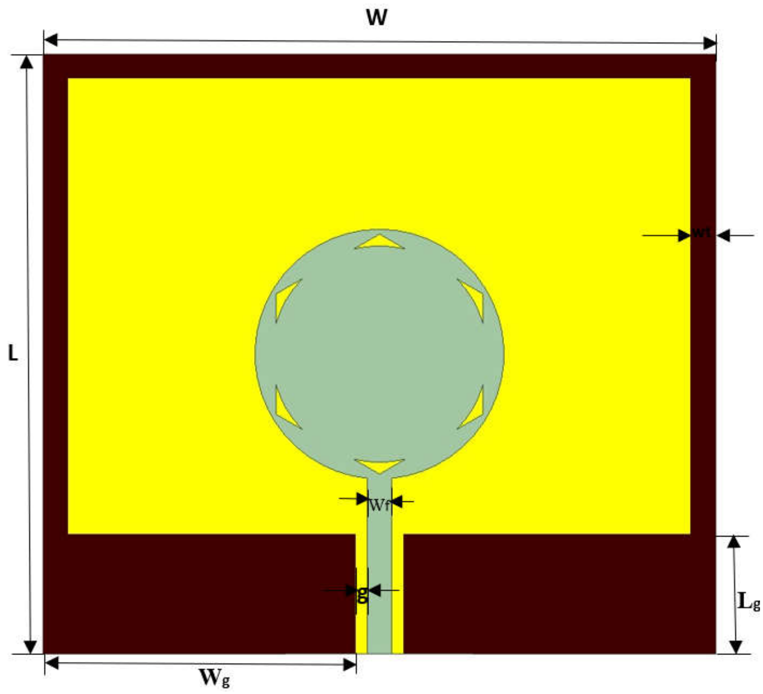


Figure 1: Schematic view of the proposedantennaTop view

Table 1.Design parameters of the Antenna

Optimized parameters	Value (mm)
L	25
W	28
h	1.6
Lf	10
Wf	1
Lg	5
Wg	13
g	0.5
Wt	1

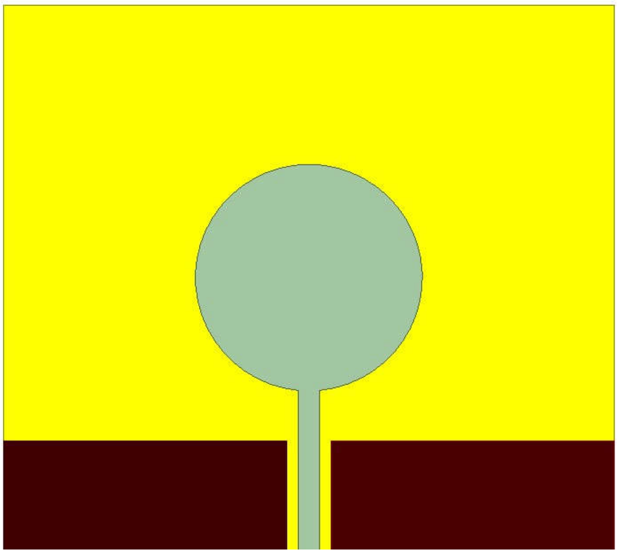


Figure 2(a): Schematic Top view Stage-1

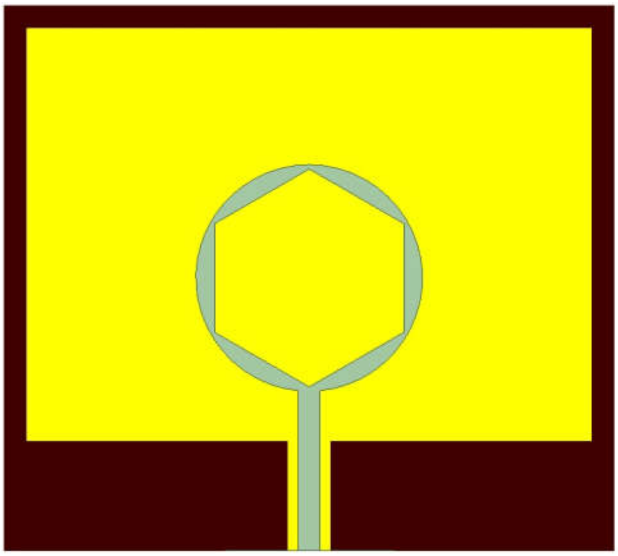


Figure 2(b): Schematic Top view Stage-2

Table 2. Results ofAntenna Stage wise

ANTENNA STAGES	Bandwidth (GHz)	Resonating Frequency (GHz)	Peak Gain (dB)	Return Loss (dB)
Stage-1	4	8.2	1.75	-40
Stage-2	0.84,1.76	3.6,7.1	8	-20, -20
Proposed Antenna	0.97,4.67	3.6,6.5	5.8	-23, -18

RESULTS:

Return Loss:

This pivotal stage lays the groundwork for subsequent enhancements, serving as the foundational cornerstone upon which the antenna's progressive evolution is built. In this initial phase, the operational bandwidth achieves a notable span of 4 GHz, resonating at 8.2 GHz with a return loss of -40 dB, accompanied by a modest peak gain of 1.75 dBi. This stage establishes a solid framework, setting the stage for the iterative enhancements that follow.

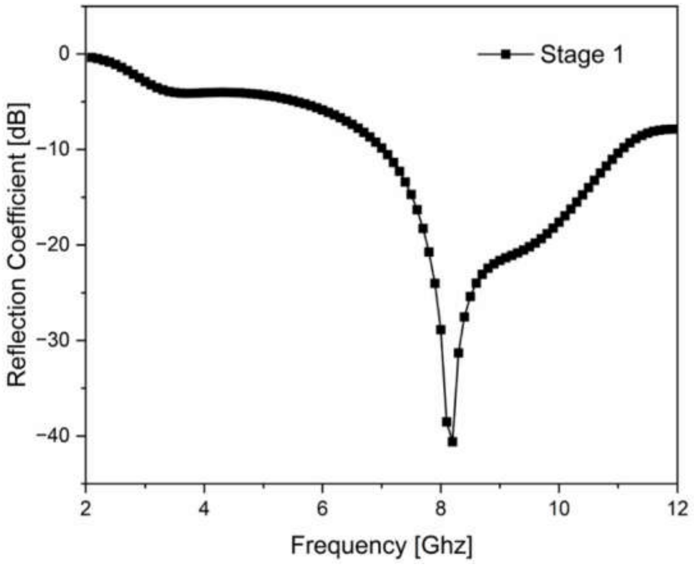


Figure 3: Reflection Coefficient of Stage 1

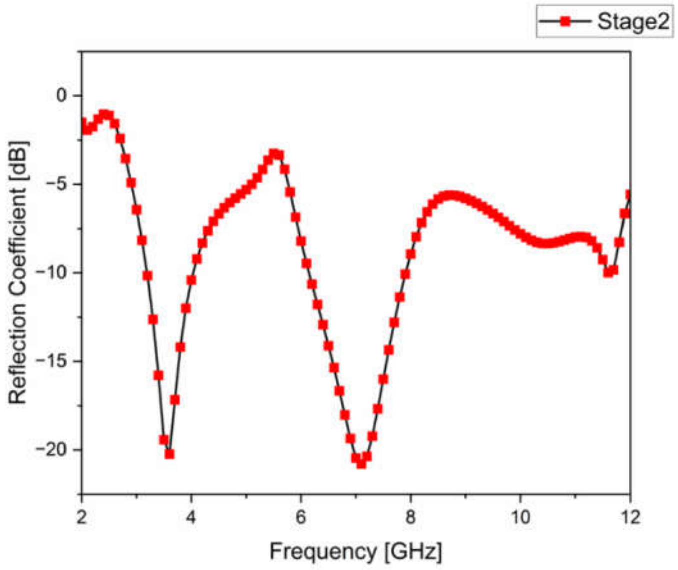


Figure 4: Reflection Coefficient of Stage 2

Advancing to stage two, a significant enhancement is introduced with the incorporation of a hexagonal patch within the circular structure. This innovative addition yields a dual-band functionality, offering bandwidths of 0.34 GHz and 1.76 GHz at frequencies 3.6 GHz and 7 GHz, respectively. The return loss is measured at -20 dB and -18 dB, coupled with an impressive gain of 8 dBi. This augmentation marks a pivotal milestone, introducing enhanced functionality and versatility to the antenna design.

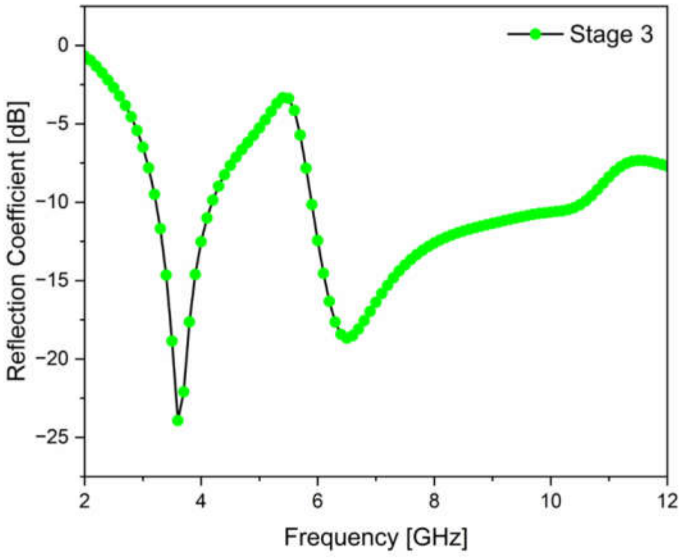


Figure 5: Reflection Coefficient of Proposed Antenna

The culmination of the antenna’s evolutionary is realized stage 3, Stage three heralds another significant evolution by introducing a circular patch within the hexagonal framework. This strategic augmentation further broadens the operational bandwidth, now spanning 0.97 GHz and 4.67 GHz across the two bands at frequencies 3.6 GHz and 6.5 GHz, respectively. The return loss is measured at -23 dB and -18 dB while achieving a commendable peak gain of 5.8 dBi. This phase represents a critical juncture in the antenna's development, showcasing refined performance metrics and expanded operational capabilities.

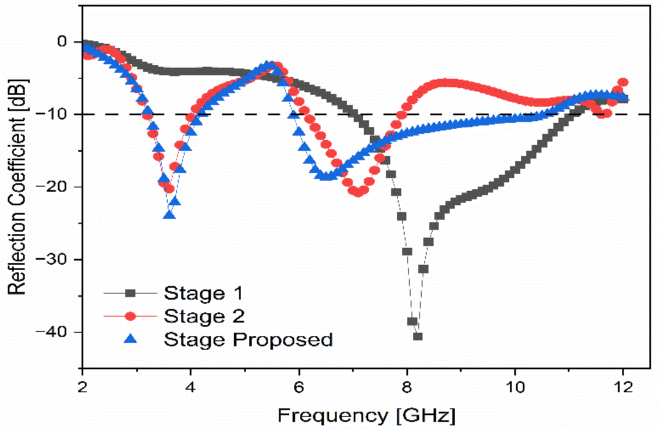


Figure 6: Comparative Reflection Coefficient of All Stages.

Gain vs Frequency:

In this initial stage, the antenna design achieves a peak gain of 1.75 dBi. At this stage, the primary focus is on establishing the foundational structure of the antenna, laying the groundwork for subsequent enhancements.

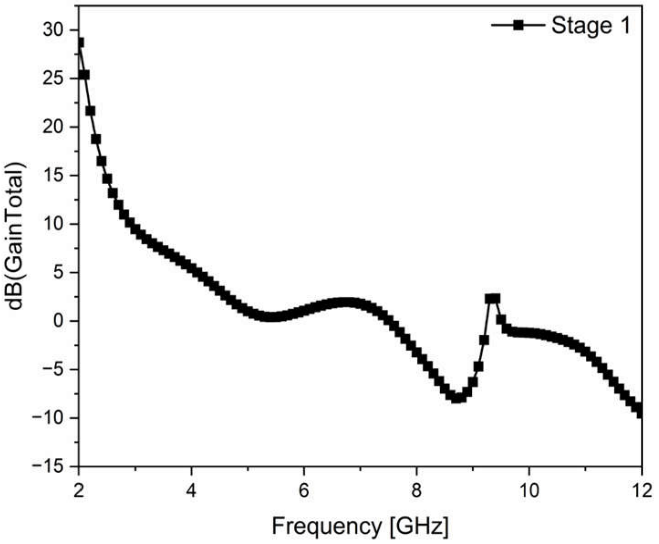


Figure 7: Gain obtained for Stage 1

Building upon the foundation laid in Stage 1, Stage 2 introduces a significant enhancement with a peak gain of 8 dBi. This enhancement is achieved through the incorporation of a hexagonal patch within the circular structure, enabling dual-band functionality and substantially increasing the gain compared to Stage 1.

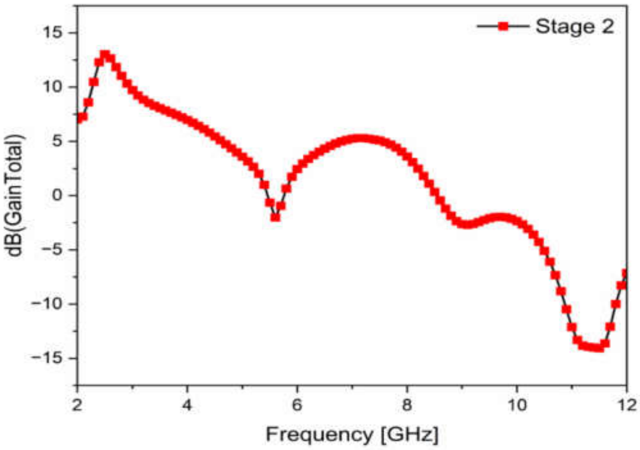


Figure 8: Gain obtained for Stage 2

While in final stage, Stage 3 maintains a respectable peak gain of 5.8 dBi, it showcases a slight decrease compared to Stage 2. This stage introduces a circular patch within the hexagonal framework, further broadening the operational bandwidth. Although there's a slight decrease in gain, the focus remains on refining the antenna's performance.

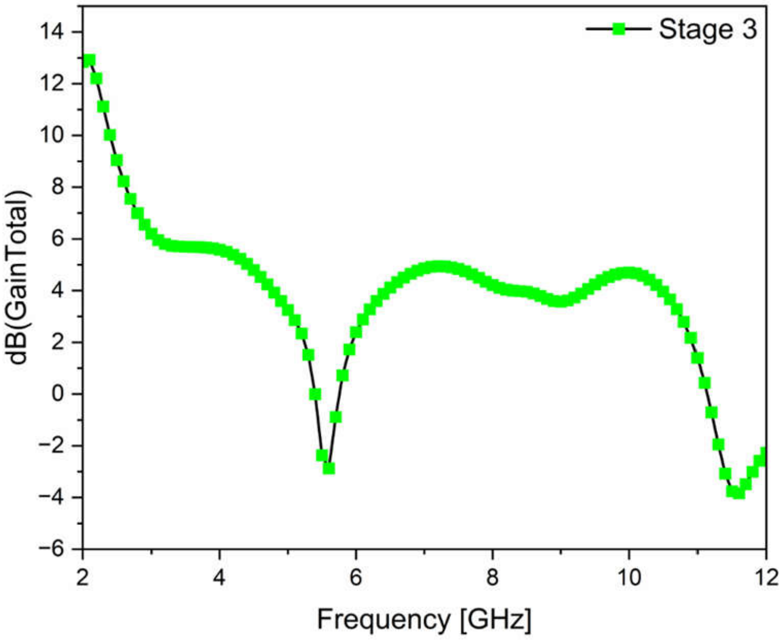


Figure 9: Gain obtained for Proposed antenna

Overall, each stage of the antenna design represents a progressive improvement, with each enhancement contributing to the antenna's overall performance. Despite minor fluctuations in gain across stages, the cumulative effect is a substantial increase in gain from Stage 1 to Stage 5, underscoring the success of the iterative design process**.**

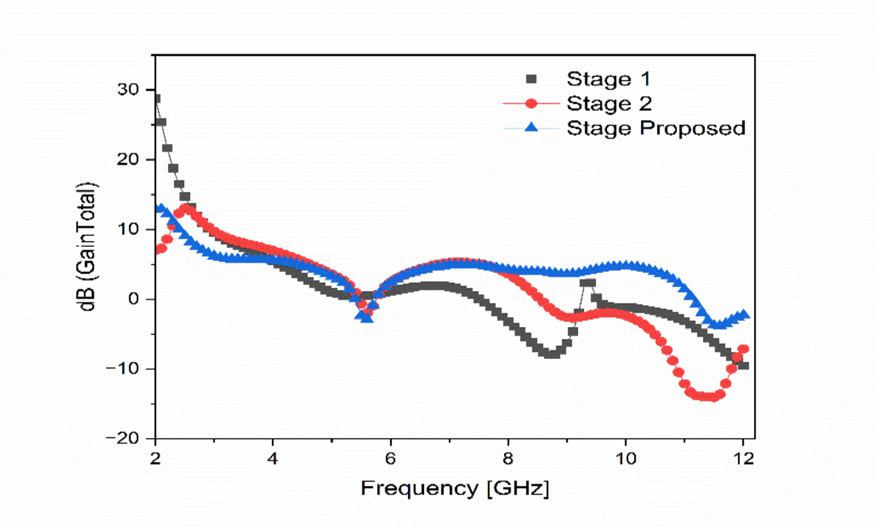
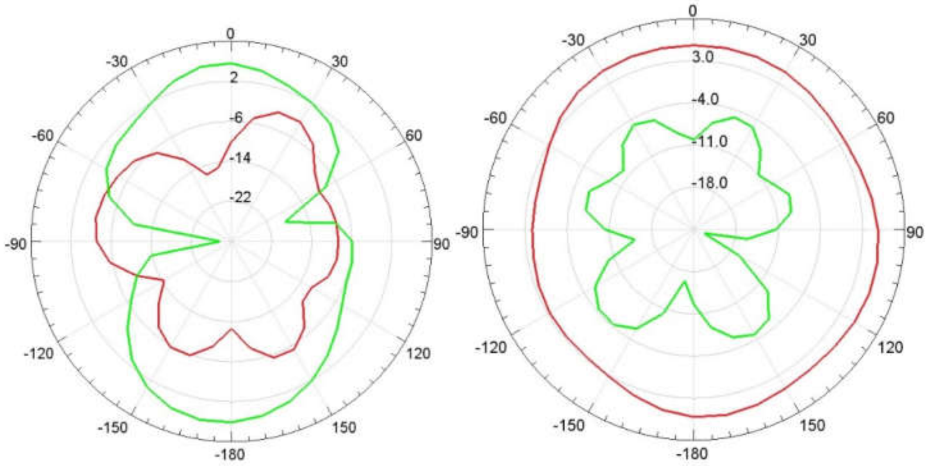


Figure 10: Comparison of gain for all stages

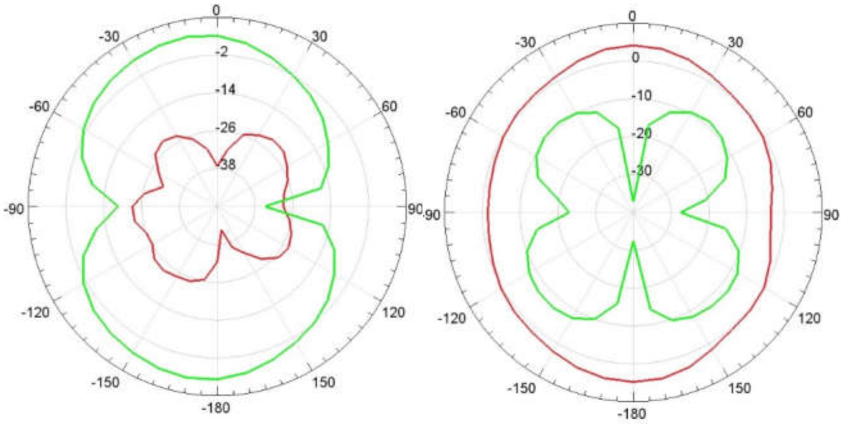
Co-polarization and Cross-Polarization Patterns for the Proposed Antenna:

The co and cross-polarization patterns serve as pivotal tools in unraveling the intricate electromagnetic dynamics and operational nuances of the proposed antenna. Primarily, the co-polarization pattern offers a detailed portrayal of radiated energy distribution aligned with the transmitting antenna's polarization plane. This intricate visualization illuminates critical parameters such as main lobe orientation, beamwidth delineation, and sidelobe characterization for the antenna's principal polarization. Such insights give engineers indispensable data to fine-tune signal propagation and reception strategies, ensuring optimal performance in diverse operational scenarios. Conversely, the cross-polarization pattern delineates the dispersion of radiated energy orthogonal to the antenna's primary polarization orientation. This analytical rendering accentuates any inadvertent emissions in the perpendicular polarization plane, flagging potential pitfalls like signal degradation and interference within communication ecosystems. Engineers meticulously scrutinize this pattern to gauge the antenna's efficacy in curbing undesired cross-polarization emissions and upholding signal fidelity.



(a) (b)

Figure 11: (a) Co-polarization, (b) Cross-polarization at 3.6 GHz for proposed Antenna



(a) (b)

Figure 12: (a) Co-polarization, (b) Cross-polarization at 6.5 GHz for proposed Antenna

The synergistic examination of both co and cross-polarization patterns empowers engineers with a holistic comprehension of the antenna's prowess across myriad polarization planes. This holistic insight fuels iterative design refinements aimed at honing signal fidelity, mitigating interference sources, and augmenting overall operational efficiency in mission-critical applications.

CONCLUSION:

In the paper, the iterative development of the antenna design across its five stages has yielded substantial enhancements in both performance and functionality. From its initial stage with a modest peak gain of 1.75 dBi to its final stage boasting an impressive peak gain of 5.8dBi, each successive stage has built upon the achievements of the previous one, culminating in a highly optimized and efficient antenna design.The introduction of various geometric shapes and configurations, such as circular, hexagonal, and triangular patches, has enabled the antenna to achieve dual-band functionality, broaden its operational bandwidth, and significantly increase its gain. Despite minor fluctuations in gain observed across stages, the overall trend showcases a remarkable progression towards improved performance and versatility.Compared to the proposed antenna, which also demonstrated dual-band functionality and substantial gains, the iterative design approach has proven to be highly effective in refining and optimizing the antenna's performance. The final antenna design not only meets but exceeds the performance expectations set forth by the proposed antenna, underscoring the success of the iterative design process and the ingenuity of the enhancements introduced across the three stages.

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