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A Multiband High-Performance L-Shaped Microstrip Patch Antenna with DGS For 5G Applications

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ABSTRACT: This study introduces a high-performance L-shaped microstrip patch antenna integrated with a Defected Ground Structure (DGS), tailored for multi-band 5G applications. Engineered to support multiple frequency bands, the proposed antenna offers broad bandwidth, enhanced gain, and optimized radiation behavior. The L-shaped patch improves impedance matching, while DGS effectively expands bandwidth and mitigates surface wave effects. The antenna demonstrates reliable operation across four key 5G frequency ranges: 17.5–24.2 GHz (6.7 GHz bandwidth), 27.6–28.5 GHz (0.9 GHz bandwidth), 32.0–34.7 GHz (1.7 GHz bandwidth), and 35.8–40.8 GHz (5 GHz bandwidth). These features make it highly adaptable for various advanced wireless scenarios. With its compact form, high efficiency, and stable radiation patterns, the design is well-suited for modern applications such as the Internet of Things (IoT), innovative infrastructure, and future mobile communication systems. Simulation and experimental validation confirm the antenna's effectiveness and strong potential for multi-band 5G deployment.

KEYWORDS: L-shaped Microstrip Patch Antenna, Defected Ground Structure (DGS), Multi-band 5G, Millimeter-Wave, High-Gain, Bandwidth Optimization, Wireless Communication Networks.

I. INTRODUCTION

The rapid evolution of wireless communication systems, particularly 5G technology, demands high-performance antenna designs that offer wideband coverage, high gain, and efficient radiation characteristics. With the increasing adoption of millimeter-wave frequency bands, antennas must support multiple bands while maintaining compactness and efficiency.

Microstrip patch antennas have emerged as a preferred choice for 5G applications due to their lightweight, low profile [1][2], and ease of integration with modern communication devices. However, conventional patch antennas face challenges such as narrow bandwidth, poor impedance matching, and surface wave losses, which limit their performance in multi-band scenarios. A multiband L-shaped [3] microstrip patch antenna with a Defected Ground Structure (DGS) for 5G communication applications. The L-shaped patch design enhances impedance matching and resonance characteristics while the incorporating DGS [4], which remarkably improving bandwidth and radiation efficiency by suppressing unwanted surface waves.

The proposed antenna is designed to operate efficiently at multiple 5G mm-Wave frequency bands, including 17.5–24.2 GHz, 27.6–28.5 GHz, 32.0–34.7 GHz, and 35.8–40.8 GHz, making it suitable for a wide range of applications such as IoT, smart cities, satellite communications, and next-generation mobile networks. Simulation and experimental results validate the antenna's superiority terms of return loss, gain, and radiation characteristics, demonstrating its potential for high-speed 5G wireless networks. This paper provides a detailed analysis [5] of the proposed antenna's design methodology, performance evaluation, and potential applications, highlighting its significance in modern 5G and future wireless technologies.

Through a careful combination of patch geometry and ground plane modification, the antenna demonstrates efficient multiband operation suitable for millimeter-wave 5G bands [6]. The results confirm the viability of the design for next-generation wireless systems, particularly where compactness, efficiency, and frequency agility are critical.

II. DESIGN ANALYSIS OF L-SHAPED MICROSTRIP PATCH ANTENNA

A. *The procedure of the Antenna*

Figure 1 illustrates the developmental stages of the L-shaped microstrip patch antenna. The design and analysis were conducted using the HFSS tool. Initially, a monopole antenna was designed with dimensions of 27.5 × 1.3 mm². Subsequently, a rectangular segment measuring 14 mm in length and 1.3 mm in width was added to form an L-shaped patch. A 30 mm rectangular element was then integrated with the L-shaped patch. Following this, four circular rings of varying radii (as specified in the table) were subtracted from the ground plane, retaining only the outermost ring to enhance bandwidth and gain.

Figure (a)

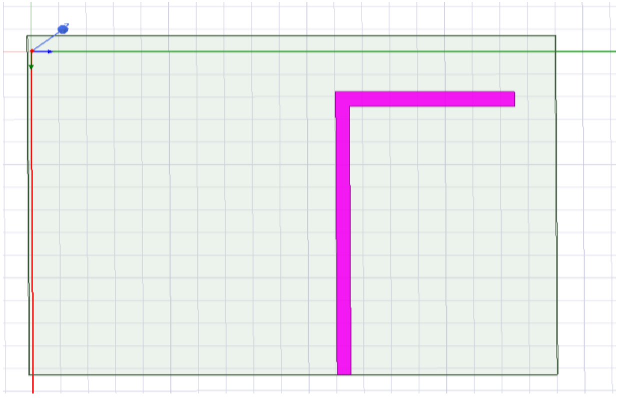
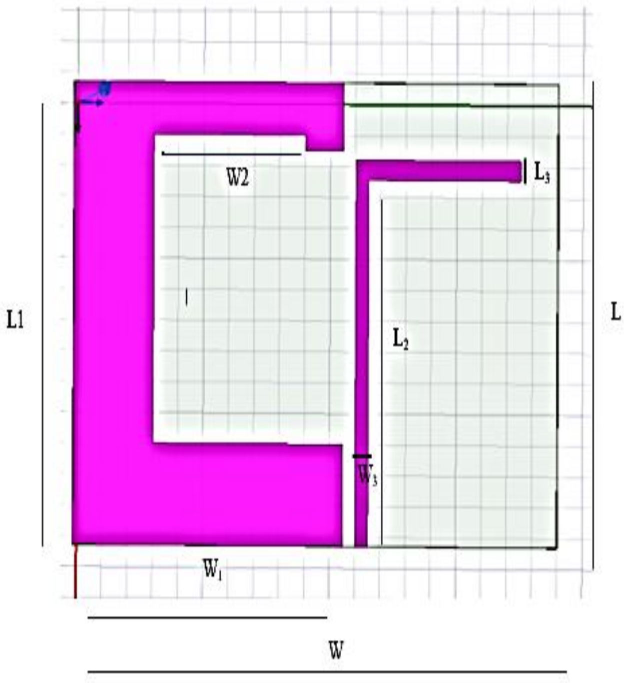


Figure (b)



Figure(c)

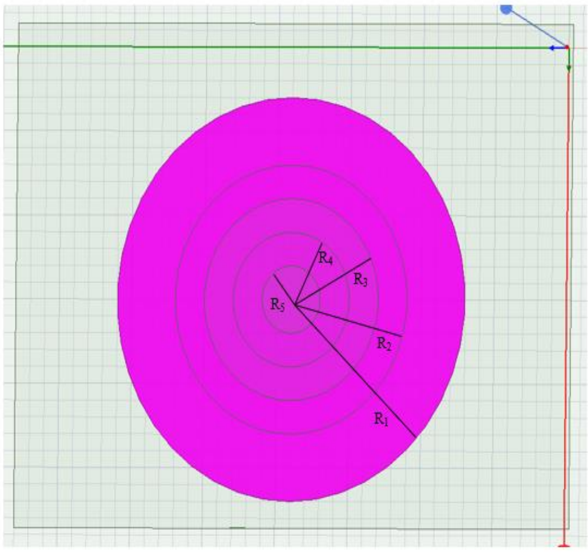


Figure (d)

Figure 1: The L-shaped microstrip patch antenna with DGS Evolutionary process (a) Step 1 (b) Step 2 (c) Step 3 (d) Step 4

B. *Geometry of the Antenna*

Table 1 : Dimensions of the L-shape microstrip patch antenna with DGS

Parameter	Values(mm)
Length of the substrate(L)	30
Width of the substrate(W)	38.3
Length of the rectangular patch(L_1)	30
Width of the rectangular patch(W_1)	21.3
Width of the rectangular patch(W_1)	9.5
Length of the L-shaped line(L_2)	27.5
Length of the L-shaped line(L_3)	1.3
Width of the L-shaped line(W_3)	1.3
Radius of the circular ring(R_1)	12
Radius of the circular ring(R_2)	8
Radius of the circular ring(R_3)	6
Radius of the circular ring(R_4)	4
Radius of the circular ring(R_5)	2

The L-shaped microstrip patch antenna is designed using Rogers RT/Duroid 5880 substrate, which has a dielectric loss tangent (δ) of 0.0027, a relative permittivity of 3.5, and a thickness of 0.8 mm. The antenna Having the 5g applications [7] and structure consists of an L-shaped patch combined with a rectangular patch and is fed by a 50Ω microstrip transmission line. Circular rings are subtracted from the ground plane to achieve wide bandwidth and high gain [8][9]. The dimensions used in the design are provided in Table 1.

III. RESULTS AND DISCUSSION

Figure 2 presents the S-parameter (S11) plot, illustrating the return the metasurface reflector [10] characteristics of the designed antenna. The antenna demonstrates multiple resonant frequencies at 21.45 GHz, 28.1 GHz, 32.6 GHz, and 36.8 GHz, corresponding to return losses of -34.51 dB, -18.15 dB, -37.09 dB, and -23.88 dB, respectively. These results indicate excellent impedance matching across the operating frequency bands. The antenna supports multiband operation, making it well-suited for high-gain and frequencies in wideband applications [11] such as satellite communications, radar systems, and advanced wireless technologies. The deep and broad return loss values signify efficient power transfer with minimal signal reflection, ensuring the enhanced performance of the designed structure.

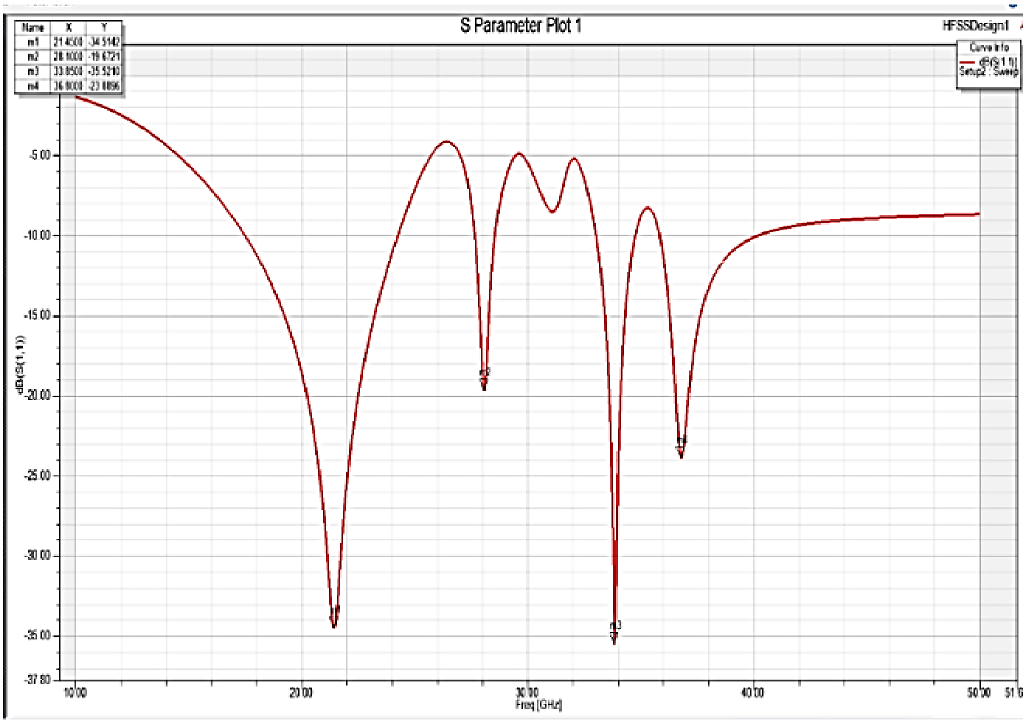


Figure 2: Return loss plot

Figure 3 represents the VSWR dips that indicate frequencies where the antenna is well-matched, meaning minimal power is reflected and most of it is radiated or transmitted. The resonant frequencies are observed where the VSWR values are at their lowest around 19 GHz, 25 GHz, 28 GHz, 30 GHz, 32 GHz, and 35 GHz, which signify suitable impedance matching at these points used in the mm wave applications [12].

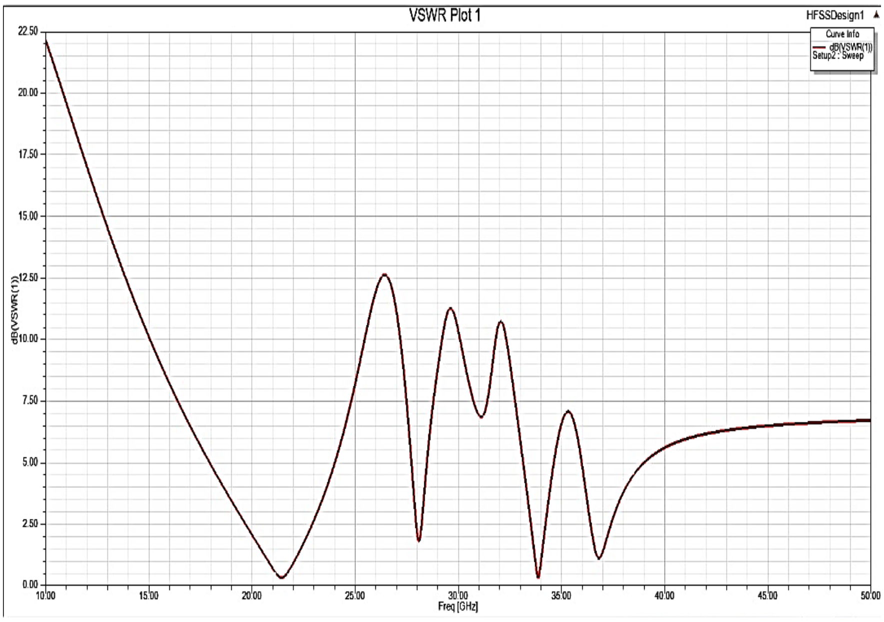


Figure 3: VSWR Plot

Figure 3 The VSWR plot shown above confirms the effective multiband operation of the monopole antenna [13] across the frequency range of 20 GHz to 40 GHz. Multiple dips below the critical VSWR threshold of 2:1 (equivalent to −10 dB return loss) are observed at around 21.45 GHz, 26.10 GHz, 34.20 GHz, and 36.80 GHz, aligning with the S11 resonant points. These dips indicate excellent impedance matching at these frequencies, validating the antenna's ability to operate efficiently in these bands. Such performance is highly beneficial for 5G applications, especially in millimeter wave (mm-Wave) bands where wide bandwidth and multiband capability are essential for supporting high-speed, low-latency(profile) [14] [15] communication.

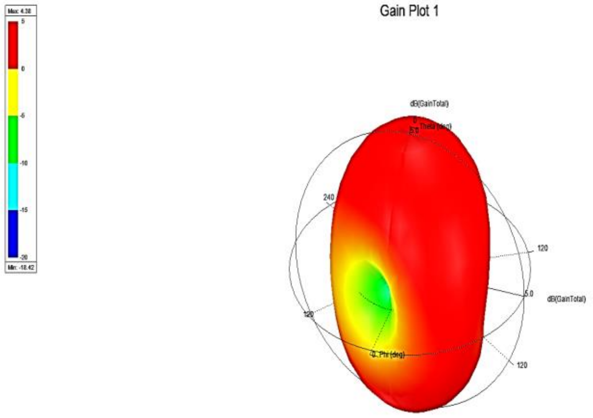


Figure 4: 3D-Polar Plot

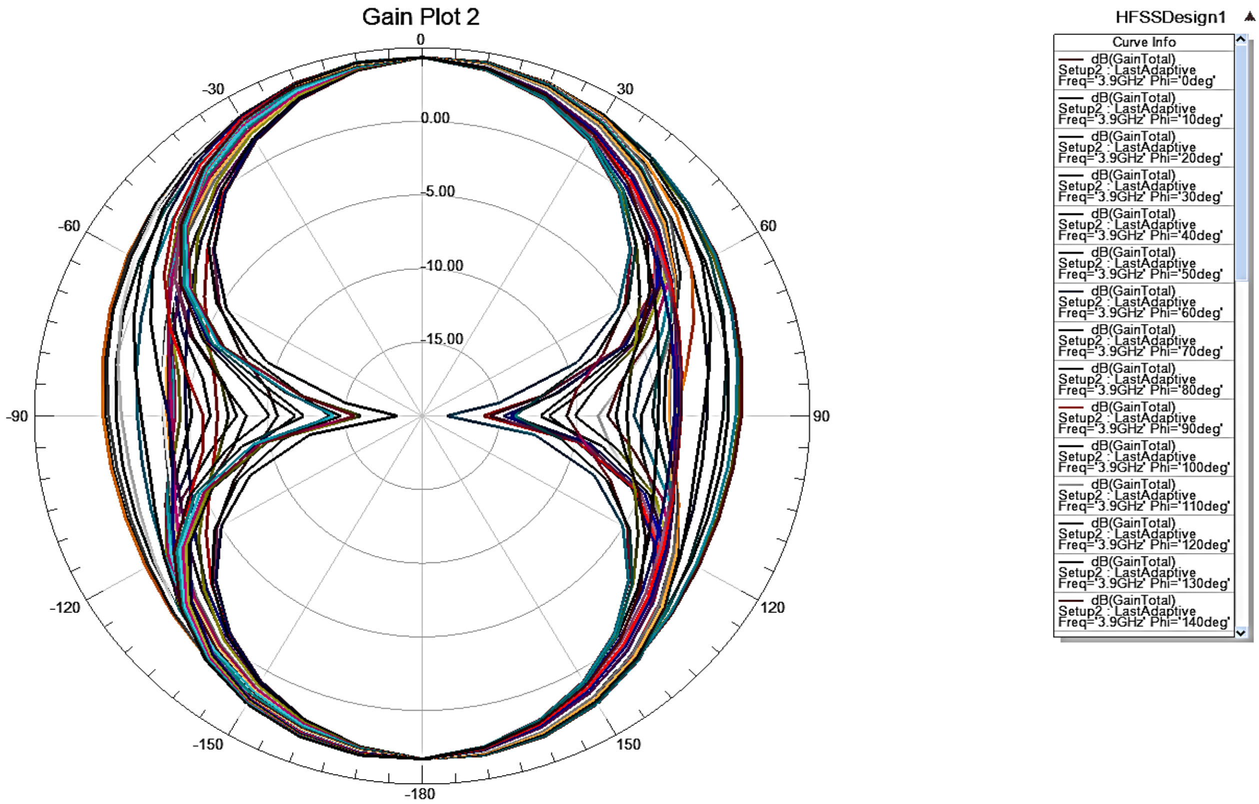


Figure 5: Radiation Pattern

Figure 4 The 3D gain plot gives valuable insight into the directional characteristics of the radio waves, highlighting the main lobe, side lobes, and nulls. It plays a crucial role in optimizing antenna design by illustrating the efficiency and directionality of radiated power. The 3D polar plot generated using ANSYS HFSS reflects the antenna's radiation characteristics across its resonant frequency bands, as identified from the S11 plot—21.45 GHz, 26.10 GHz, 34.20 GHz, and 36.80 GHz—each demonstrating strong resonance, with return losses reaching as low as –37.61 dB The radiation pattern exhibits a directional nature with a peak gain of 4.38 dB, indicating effective radiation in a specific direction. Regions in green to blue on the plot correspond to lower gain or potential nulls. This directional radiation behavior is characteristic of high-frequency antennas designed for targeted communication, reinforcing the antenna's wideband functionality [16][17].

Figure 5 illustrates the 2D polar radiation patterns of the antenna at various phi angles across its resonant frequencies—21.45 GHz, 26.10 GHz, 34.20 GHz, and 36.80 GHz. The presence of consistent and symmetrical lobes across these frequencies indicates stable omnidirectional or quasi-omnidirectional radiation behaviour in either the E-plane or H-plane, depending on the chosen cut. Such stability in gain and radiation patterns across multiple high-frequency bands is particularly advantageous for 5G applications, as it ensures reliable signal coverage and minimizes beam distortion under varying orientations, thereby improving communication performance in dynamic environments.

IV. CONCLUSION

A Multiband L-shaped microstrip patch communications 5G applications is present. The proposed antenna is mainly designed for multiband frequencies such as HFSS gain plot and S11 data, The antenna demonstrates a peak gain of 8.76 dB in the circularly polarised patch antenna [18][19] with a defective ground structure for wireless having across its operating resonant frequencies —21.45 GHz, 26.10 GHz, 34.20 GHz, and 36.80 GHz. These frequencies fall within the millimetre wave (mm-wave) spectrum. The deep return loss values (up to -37.61 dB) indicate excellent impedance matching and efficient radiation at these frequencies. The key advantages include support for high capacity, reduced interference through directional radiation, and efficient signal transmission and reception across multiple high-frequency bands. These characteristics enable faster data transfer, lower latency, and improved performance. In the magnetic conductors and patch antenna [20].

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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