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Dual-Band Slotted Millimeter Wave Antenna at 28/38 GHz for 5G Applications

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Abstract— Modern communication systems enable the rapid development of microstrip patch antennas. Their lightweight and compact profile makes patch antennas increasingly popular today. They are easy to manufacture and seamlessly integrate into feeding networks, making them highly versatile for modern applications. This paper presents a single-feed, dual-band slotted antenna designed for 5G applications, operating in the 28 GHz and 38 GHz millimeter-wave bands with enhanced bandwidth. The antenna design uses a Rogers 5880 substrate with a relative permittivity of 2.2 and a loss tangent of 0.0009, modeled with CST software. The microstrip antenna measures 20 x 20 x 0.787 mm^3 and features a cylindrical patch on top, with inner and outer radii of 3.00 mm and 4.32 mm, and a thickness of 0.787 mm. Initially, a cylindrical radiator is configured to resonate at 38 GHz; subsequently, a symmetrical four-cone slot is introduced on the cylindrical radiator to enable an additional resonant frequency at 28 GHz. Simulation results indicate reflection coefficients of -27.83 dB at 28 GHz and -49.47 dB at 38 GHz, with achieved bandwidths of 0.765 GHz in the lower band and 1.29 GHz in the upper band, and gains of 7.52 dBi and 6.67 dBi, respectively.

Keywords— four cone slots, 5G, Cylindrical Shape and millimeter wave.

1 INTRODUCTION

Antennas for fifth-generation (5G) wireless communication have recently attracted considerable interest [1]-[3]. Millimeter-wave (mmWave) antennas play a critical role in 5G applications due to their capabilities for high-speed, low-latency data transmission, and increased data rates. With the rapid growth of internet applications driving demand for higher data rates and expanded bandwidth, researchers are exploring new frequency bands to support the future of wireless communication technologies [4]. Numerous studies investigate various mmWave antenna designs to meet these demands [5]-[8].

The 5G Partnership Project has standardized several frequency bands to optimize 5G performance, including 28 GHz, 38 GHz, and 60 GHz, each tailored for specific applications. Consequently, patch antennas with single, dual, or multiband configurations are needed to accommodate these frequencies [4-9]. The FCC has allocated the 28 GHz, 37 GHz, 39 GHz, and 64–71 GHz bands specifically for 5G use [10]. Among these, the 28 GHz and 38 GHz frequencies are particularly prevalent in next-generation mmWave communication systems for 5G applications [9]. A dual-band antenna capable of operating at both 28 GHz and 38 GHz is highly beneficial for a range of applications [10-14]. In [6], a copper-tapered slot antenna with a simple design is proposed, covering the 24.25–28.35 GHz range. Another study [4] introduces an antenna with a U-slot in the ground plane to achieve a broader bandwidth for 5G mmWave applications, though its bandwidth is still limited and does not fully encompass the 28 GHz and 38 GHz mmWave bands. In [15], a four-element dual-mode planar monopole antenna, measuring 20 × 20 mm², offers a moderate bandwidth of 1.75 GHz in the lower band. According to references [21-25], the desired bandwidth for a dual-band antenna is approximately 1.9% at 38 GHz and 3% at 28 GHz. Reference [12] describes a 5G dipole antenna with a broad bandwidth ranging from 26.5 to 38.2 GHz and an approximate gain of 5 dBi. In [13], an antenna that operates at 24 GHz and 28.5 GHz achieves gains of 3.5 dBi and 4 dBi at these frequencies, respectively. A microstrip patch antenna in [14] provides a bandwidth of 1.3 GHz at 28 GHz and 1 GHz at 45 GHz, with gains of 7.6 dBi and 7.21 dBi, respectively. Reference [15] introduces a dual-band antenna operating at 28 GHz and 38 GHz, achieving bandwidths of 1.43 GHz and 3.54 GHz and gains of 2.7 dBi and 6 dBi, respectively. Additionally, an H-shaped slot dual-band patch antenna in [16] provides bandwidths of 3.2 GHz at 28 GHz and 5.3 GHz at 38 GHz, with gains of 8.4 dBi and 6.1 dBi, respectively. In [17], a novel rectangular dielectric resonator antenna is described for 5G applications, offering operation at 28 GHz and 38 GHz with bandwidths of 1.49 GHz and 1.01 GHz and gains of 5.41 dBi and 4.89 dBi, respectively. In [18], discusses a dual-band microstrip antenna with a defected ground structure (DGS), which achieves a bandwidth of 4.1 GHz and a gain of 6 dBi at both 28 GHz and 38 GHz. Various other studies [19-22] present dual-band antennas designed for 28 GHz and 38 GHz operation, each offering distinct bandwidth and gain characteristics tailored to specific applications. In [23], a notched antenna design is created by introducing a cut in the feed line, which enables effective radiation in the 30-34 GHz range while maintaining functionality at both 28 GHz and 38 GHz.

Dual-band antennas are typically favored over single-band designs due to their broader bandwidth and versatility in supporting multiple frequencies. This paper introduces a novel 5G antenna operating at 28 GHz and 38 GHz, incorporating a distinctive cross-shaped structure with four cone-shaped slots at the center of a cylindrical patch, which greatly enhances both bandwidth and gain.

This work presents a dual-band slotted millimeter-wave (mmWave) microstrip antenna with a symmetrical four-cone slot configuration, enabling efficient operation at both 28 GHz and 38 GHz frequency bands. The antenna design was modeled and simulated in CST Microwave Studio software, yielding detailed performance data that validate the proposed design's effectiveness in achieving the targeted dual-band functionality.

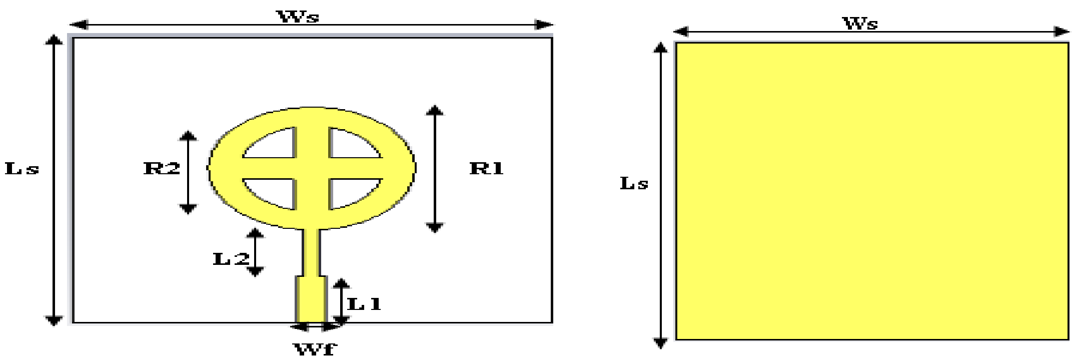

Fig. 1. The Proposed Dual Band Antenna Schematic Diagram (Front and back view)

The proposed dual-band antenna was initially designed to operate at 38 GHz. To achieve a second operational frequency at 28 GHz, a cross structure was introduced, creating four core slots at the center of a cylindrical patch, as illustrated in Fig. 1 above. This addition enables the antenna to effectively cover both 28 GHz and 38 GHz frequency bands, enhancing its versatility for dual band 5G applications.

TABLE I. VALUE OF THE PROPOSED DESIGN PARAMETERS

Parameter.	**Wf**	**L1**	**L2**	**Ws**	**Ls**
Values in (mm)	1.23	3.3	3.21	20	20
Parameter.	**R1**	**R2**			
Values in (mm)	4.32	3.0			

2 SIMULATION RESULTS

The prototype antenna has dimensions of L × L= 20 × 20 mm^2. It is built using Rogers RT 5880 substrate material, which has a thickness h = 0.787 mm and a dielectric constant Er = 2.2. To achieve a multi-mode resonance feature, a symmetrical design with four cone-shaped slots is introduced. The dual-band antenna design process involves two primary stages, as illustrated in Figure 1. In the first stage, a cylindrical antenna patch is created with an outer radius R1 = 4.32 mm and an inner radius R2 = 3.0 mm. Through parametric sweeps, this configuration achieves an initial resonance frequency at 38 GHz. A 50Ω microstrip line is used to feed the patch, with a width Wf = 1.23 mm and length Lf = 3.3 mm. In the second stage, to introduce a second resonance mode at 28 GHz, a cross-shaped structure is added to the center of the cylindrical patch, forming four cone-shaped slots. This additional structure enables dual-band operation by producing the desired second resonance mode. The antenna design is simulated in CST to analyse the reflection coefficient. The resulting design achieves two operational frequency bands, as shown in the figure 1, one centered around 28 GHz and the other around 38 GHz. The bandwidths for $|S_{11}|$ < -10 dB are 0.765 GHz covering from 27.473—28.238 GHz band as well as 1.29 GHz covering from 37.356—38.646 GHz band, making the antenna suitable for recent 5G applications.

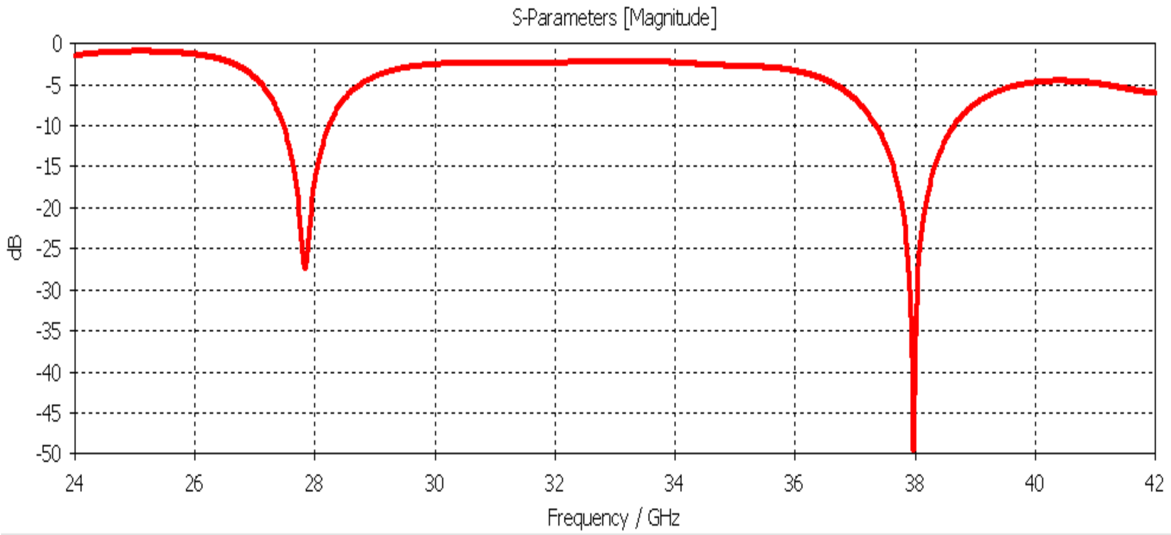

Fig. 2. The Reflection Coefficient of the Proposed Dual-Band Slotted Antenna.

The radiation patterns of the designed antenna are evaluated through numerical simulations. Figure 3 presents the 3D radiation patterns at the operating frequencies of 28 GHz and 38 GHz, llustrating the antenna's performance in terms of directionality and gain at these frequencies.

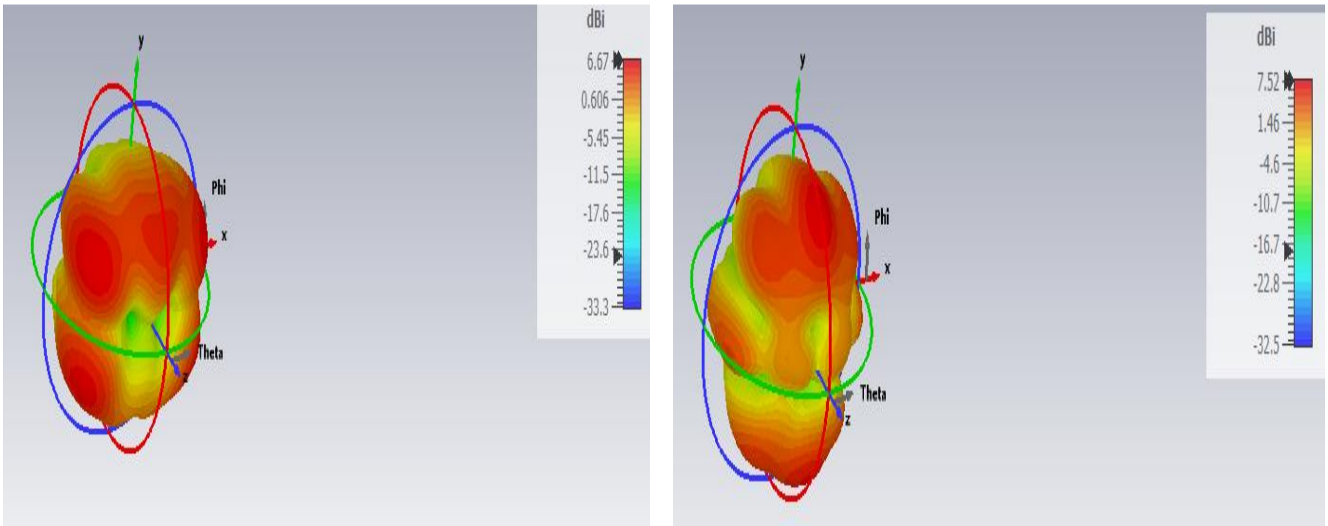

Fig. 3. The 3-D Radiation Patterns (a) f=28 GHz (b) f=38 GHz

3 CONCLUSIONS

This paper presents an enhanced dual-band millimeter-wave slotted antenna designed for 5G mobile networks. The resulting dual-band microstrip patch antenna operates at 27.29 GHz and 37.97 GHz, achieving S_{11} values of -27.8 dB and -49.47 dB, respectively. The antenna's design begins with a cylindrical patch intended to resonate at 38 GHz. To introduce a second resonance at 28 GHz, a cross-shaped structure is added at the center, creating four symmetrical cone-shaped slots in the cylindrical patch. This dual-resonance structure is fabricated on a Rogers 5880 substrate with a thickness of 0.787 mm and a dielectric constant of 2.2. Initially, the antenna is configured to resonate at 38 GHz. Then, by adding the cone-shaped slots at the center of the cylindrical radiator, a secondary resonance at 28 GHz is achieved. The design attains a maximum directivity of 6.67 dBi at 28 GHz and 7.52 dBi at 38 GHz. The -10 dB impedance bandwidths for each band are 0.756 GHz and 1.29 GHz, making this antenna suitable for dual-band operation in modern 5G applications.

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