Ring Light Shaped Dual Band Microstrip Patch Antenna Design and Parametric Analysis for 5G Wireless Communications

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***Abstract*—The 20 × 20 x 1.5 mm³ small dual-band microstrip patch antenna used in this work was made on a FR4 substrate with a dielectric constant of 4.3. The antenna, which is intended for high-frequency wireless communication systems, exhibits resonant behavior in the 8G-band (28.4–29.4 GHz) and Ka-band (27.3–28 GHz), with precise resonance at 27.5 GHz and 29.05 GHz, respectively.It surpasses the -10 dB threshold in return loss values and achieves superior impedance matching with voltage standing wave ratios (VSWR) of 1.03 and 1.29. In order to provide sufficient gain and dependable performance throughout all bands, the antenna's design places a high priority on a wide impedance bandwidth, low VSWR, and a consistent radiation pattern. Parametric analysis confirms the antenna's operational integrity and highlights its potential for integration into next-generation wireless systems operating in complex environments. These features highlight the antenna's suitability for 5G applications.**

***Index Terms*—Patch, dual-band, Ka-band, 5G-band.**

1. INTRODUCTION

The development of satellite and wireless communication technologies during the last few decades has had a major influence on modern living. Reliable solutions for electromagnetic wave transmission and reception are required for many applications, including local area networks (LANs) and communication systems. For meeting these needs, microstrip patch antennas (MPAs) have become a popular option because to their low profile, structural simplicity, and ease of manufacture. Because MPAs have inherent design flexibility, many designs and methodologies have evolved to optimise antenna performance over a variety of frequency bands. [1-5].

Smaller and more effective phones have been developed in response to the growing demand for tiny mobile devices. Miniaturised components are becoming increasingly important as the need for mobile communication as a whole increase. When designing portable communication systems, antenna size is one of the most important factors. In these kinds of applications, microstrip patch antennas (MPAs) are commonly used because of their low profile, light weight, and simplicity of integration with small equipment. The main factors influencing an MPA's resonant frequency and overall performance are its essential design parameters, such as the radiating patch's width and length. Fifth-generation (5G) mobile networks have emerged. [5-10].

With a variety of use cases expected to emerge in 2020 and beyond, the 5G New Radio (NR) interface is built to satisfy their ever-increasing demands. Significant increases in device density, traffic volume, and user connectivity are among them. The availability of enough 5G spectrum across many frequency bands is crucial for supporting such varied and high-performance communication situations. Efficient management and allocation of spectrum resources is necessary to guarantee that 5G networks can provide increased capacity, extremely low latency, and excellent dependability across many application areas. [10-15].

The creation and analysis of the suggested antenna are presented in a methodical manner in this paper's structure. The design process, including the configurations and procedures used to build the antenna prototype, is covered in Section II. Additionally, this section describes the precise dimensions and materials needed to provide the required electrical properties. In order to optimize the antenna's performance, parametric research and optimization procedures are covered in Section III. In order to see how different design factors affect important metrics like bandwidth, gain, and return loss, they are adjusted and examined. Section IV assesses and compares the simulated outcomes with designs that have already been published in the literature.

II. GEOMETRY ANALYSIS

Figure 1 illustrates the development of asymmetric configurations of antenna that have been created and studied. The proposed antenna design, inner and outer curve has a diameter of 8 mm and 6 mm. Angular displacement between these two curves are 45 and 41degrees as shown in Fig.1.
The steps for calculating geometric design parameters are shown below.

Step 1: Calculation of the Width (W):
The width of the Microstrip patch antenna is given as:

$$\mathbf{W} = \frac{\mathbf{C}}{\mathbf{2fo}\sqrt{\frac{\in \mathbf{r} + \mathbf{1}}{\mathbf{2}}}}$$

Step 2: Calculation of Effective dielectric constant (ε_{reff}):
The effective dielectric constant is:

$$\mathcal{E}\mathbf{reff.} = \frac{\in \boldsymbol{r} + \mathbf{1}}{\mathbf{2}} + \frac{\in \boldsymbol{r} + \mathbf{1}}{\mathbf{2}}\sqrt{\mathbf{1} + \mathbf{12}\frac{\boldsymbol{h}}{\boldsymbol{w}}}$$

Step 3: Calculation of the Effective length (L_{eff}):
The effective length is:

$$Leff = \frac{c}{2fo\sqrt{\mathcal{E}\text{reff.}}}$$

Step 4: Calculation of the length extension (ΔL):
The length extension is:

$$\Delta L = 0.412h\frac{(\mathcal{E}\text{reff} + 0.3)(\frac{w}{h} + 0.264)}{(\mathcal{E}\text{reff} - 0.258)(\frac{w}{h} + 0.8)}$$

Step 5: Calculation of actual length of patch (L):
The actual length is obtained by:

$$L = Leff - 2.\Delta L$$

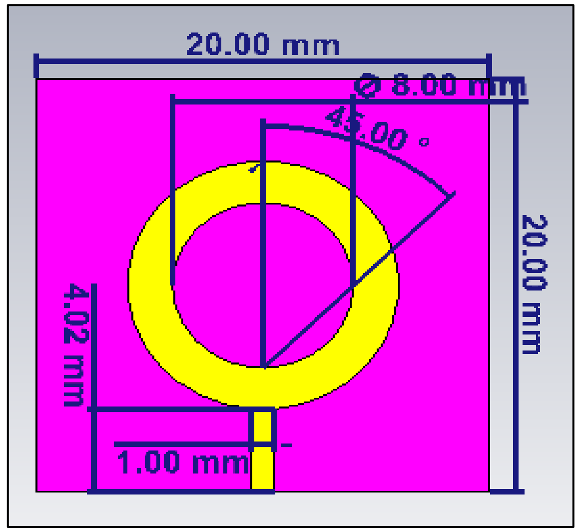

Fig.1 Proposed antenna design

3. PARAMETRIC RESULT ANALYSIS

4.

The proposed antenna design was simulated using CST Studio Suite Version 17, an electromagnetic (EM) simulation software that utilizes the Finite Integration Technique (FIT) within the antenna template's transient solver mode. The simulation results confirm that the antenna performs well across various evaluation criteria. A strong correlation was observed between theoretical expectations and CST simulation outcomes in terms of return loss, voltage standing wave ratio (VSWR), impedance bandwidth (IBW), radiation pattern, directivity, and gain. The optimized electrical

Antenna Geometry (mm^3)	VSWR (< 2)	Resonance frequency (f_r) in GHz	Antenna Bandwidth (GHz)	S_{11} (-dB)	Number of Bands
20×20×1.6	1.03	27.5	27.3-28.0	35	Dual
	1.29	29.05	28.4–29.4	17	

parameters obtained from the simulation are summarized in Table I.

Table 1: Result Analysis

The voltage standing wave ratio (VSWR) of the proposed patch antenna is presented in Fig. 2. Fig. 3 shows the return loss characteristics of the antenna. The directivity and antenna gain are depicted in Figs. 4 and 5, respectively. Finally, the radiation pattern of the antenna is shown in Fig. 6.

3.1 VSWR

The Voltage Standing Wave Ratio (VSWR) represents the ratio of transmitted to reflected voltage standing waves in a radio frequency (RF) transmission system. It is a key parameter used to evaluate the efficiency of power transfer from the source, through the transmission line, and into the load. As illustrated in Fig. 2, the VSWR at the resonance frequencies of 27.5 GHz and 29,05 GHz are 1.03 and 1.29, respectively, indicating excellent impedance matching at both frequencies.

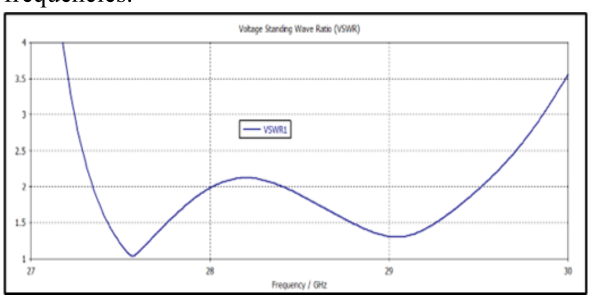

Fig. 2 VSWR of the proposed antenna

3.2 Return Loss

Return loss is the ratio of reflected power to incident power, measured in decibels (dB). For resonance frequencies of 27.5 GHz and 29,05 GHz the return loss is −35 dB, and −17 dB respectively as shown in Fig. 3.

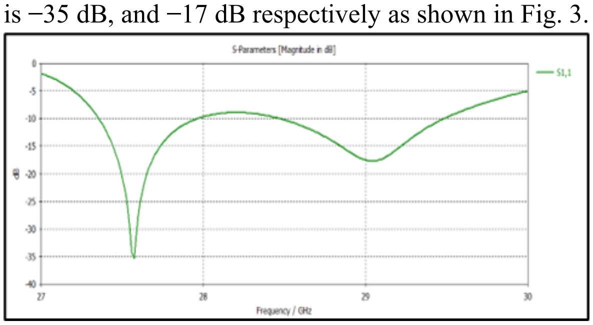

Fig. 3 Return loss of the proposed antenna at 27.5 GHz and 29,05 GHz

3.3 Directivilty

It is measured in relation to the concentration of energy emitted in a certain direction by the transmitting antenna. The primary lobe's directivity magnitude at 27.05 GHz is 9.37 dBi. According to Fig. 4, the major lobe magnitude of directivity is 5.82 and 8.41 dBi, respectively, for resonance frequencies of 29.05 GHz.

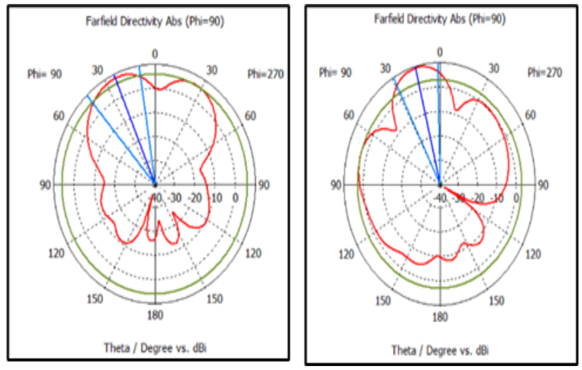

Fig.4 Directivity of proposed antenna at resonance frequencies of 27.5 GHz and 29,05 GHz

3.4 Gain

The amount of power that is transmitted from an isotropic source to the direction of the peak radiation is referred to as antenna gain. As shown in Fig. 5, the gain is 9.14 dB and 8.57 dB at resonance frequencies of 27.5 GHz and 29,05 GHz, respectively.

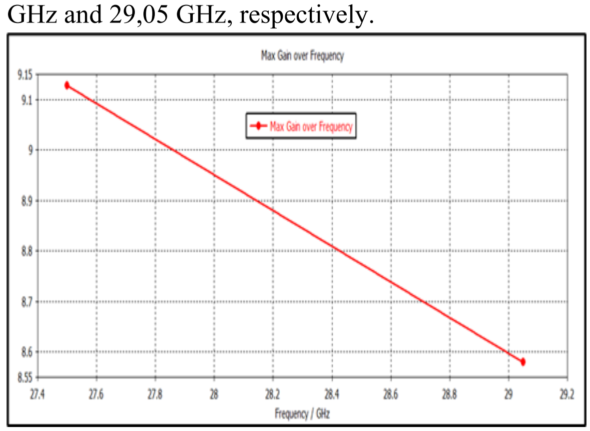

Fig. 5 Gain of the Proposed antenna at 27.5 GHz and 29,05 GHz

3.5 Radiation Pattern

Voltage and electric field are related; a higher E-field striking an antenna will result in a greater voltage differential between the antenna's terminals. As shown in Fig. 6, the major lobe magnitude of the E-field is 23.9 dB (V/m), 22.9 dB (V/m) at resonance frequencies of 27.5 GHz and 29,05 GHz, respectively.

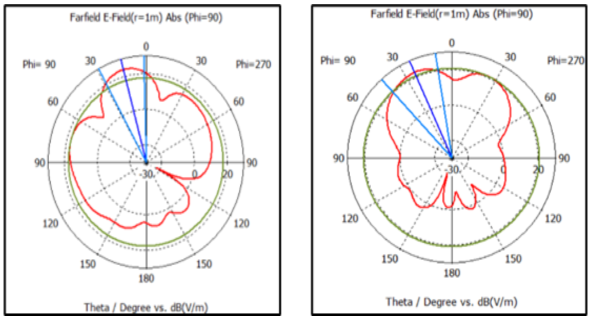

Fig. 6 Radiation pattern of proposed antenna at 27.5 GHz and 29,05 GHz

5. CONCLUSION

The necessary performance requirements have been met by designing a new and effective CPW-fed patch antenna. The suggested antenna has resonance frequencies of 27.5 GHz and 29.05 GHz, and it is small and capable of dual-band operation for Ka-band and 5G-band communications, this design is perfect. The antenna design offers great performance for a variety of wireless applications.

Operating in two frequency bands, the antenna has resonance frequencies of 27.5 GHz and 29,05 GHz, respectively. These bands are 27.3–28 GHz (Ka-band) and 28.4–29.4 GHz (5G-band). The physical size of the antenna can be decreased, and materials with various dielectric qualities can be used to increase the frequency bandwidth. With a wider range of resonance frequencies made possible by this method, the antenna may be utilised in new wireless applications at higher frequency bands.

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