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Design and Analysis of Circular Microstrip Patch Antenna for 5G Communications

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***Abstract*— Currently, wireless networks can only operate at 4G, but 5G is being developed. Many software programmes these days operate on fourth-generation communication technology. We are still in the early stages of 5G communications research. Because circular Microstrip patch antennas may be used in cutting-edge 5G technology, study into them is essential. The high bandwidth, directivity, and gain of the circular Microstrip patch antenna are essential for meeting 5G communication needs. This paper proposes the use of a circular Microstrip patch antenna with an imperfect ground structure in 5G wireless communication systems. With a S 11 value of -8.10 dB at 8.209 GHz, FR4's return loss is substantially lower than that of the other dielectric materials employed in this investigation. Furthermore, a respectable 2.29 VSWR.**

Keywords*— *Return Loss, Bandwidth Patch, Circular Microstrip, gain, Directivity, Voltage Standing Wave Ratio.

I. INTRODUCTION

While 4G is the fastest that existing wireless networks can achieve, 5G is on the horizon. These days, fourth-generation communication technologies support a lot of programmes. The field of 5G communications research is still in its infancy. The study on circular microstrip antennas is crucial because of its potential applications.

In addition to enhancing user experience, 5G paves the way for previously unheard-of degrees of machine-to-human communication. It may be used to develop cutting-edge applications like virtual and augmented reality in healthcare, driverless cars, and more as it permits low-latency communications. In their attempts to alleviate the global bandwidth shortage, wireless service providers are facing previously unheard-of difficulties due to the widespread use of smartphones and the expansion of mobile data [1].

The perimeter of material inside a given total surface area or volume that may receive or transmit electromagnetic radiation, either on interior components or the exterior structure, is maximised by an antenna with a patch, self-similar design.

Patch antennas have the feature of pattern repetition over two or more scale sizes, referred to as "iterations." Despite their small size, circular microstrip patch antennas are wideband or multiband, which makes them perfect for use in wireless networks such as those found in microwaves and cell phones. Patch antennas have the ability to operate well to well over a wide range of frequencies simultaneously, in contrast to classic antennas. Because they need to be "cut" to match the operational frequency, conventional antennas can only be utilised effectively on that frequency [3].

Wi-Fi communication uses circular microstrip patch antennas and works in the 2.4 GHz frequency band. The design and performance study of a circular microstrip patch antenna for a Wi-Fi communication system are covered in this research article. This article's primary goal is to build a circular microstrip patch antenna and evaluate its performance with various dielectric material types. With FR4, performance is enhanced. With a S 11 value of -8.10 dB at 8.209 GHz, FR4's return loss is substantially lower than that of the other dielectric materials employed in this investigation. A 2.29 VSWR that was deemed adequate was also noted. [4].

Serving consumers with more advanced, contemporary smartphones as well as legacy users with outdated, less effective mobile phones requires managing many technologies concurrently in the same band-limited spectrum. Currently, spectrum allotments to operators are divided into discrete frequency bands, and each of these bands employs a unique set of radio networks with unique propagation and building penetration loss characteristics. Since many base stations are deployed at each location (one for each frequency or technological application, such as 3G, 4G, and LTE-A), base station designs must support a wide range of frequencies across a vast diversity of cell sites [5].

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It might take up to ten years to purchase more spectrum through agencies like the Federal Communications Commission of the United States (FCC) and the International Telecommunications Union (ITU). After licencing is completed, current users must be relocated off the spectrum, which prolongs the process and increases costs [6].

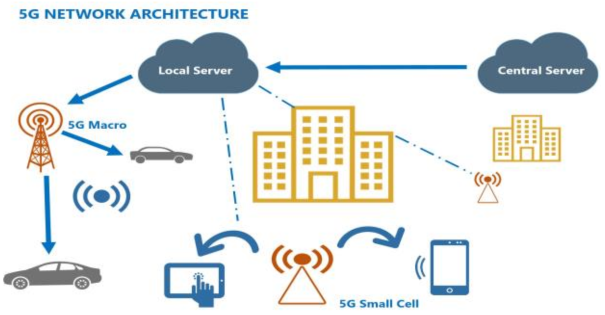

Figure 1: 5G service models

Figure 1 illustrates that 5G networks will require 1000 times more capacity and 10 to 100 times greater data rates in order to deliver 5G services. An antenna with a patch, self-similar design maximises the perimeter, or effective length, of material inside a given total surface area or volume that may receive or transmit electromagnetic radiation (on inner sections or the exterior structure). The motif's recurrence over two or more scale factors is what sets these fractal antennas apart. [7], also known as "iterations."

Despite their small size, patch antennas are wideband or single band, which makes them perfect for use in wireless networks such as those found in mobile phones and microwaves. Fractal antennas, in contrast to traditional antennas, may function effectively across a broad range of frequencies at the same time. Patch antennas are therefore ideal for both single band and wideband applications [8].

This research is composed of four primary parts. The study's purpose, justification, and context are presented in Section I. The research technique and mathematical investigations are covered in Section II. The findings of the study's simulation are described in Section III. Suggestions for further investigation are provided at the end of Section IV.

These issues with preexisting antennas have been identified after reviewing:

- Inadequate bandwidth.
- Low productivity.
- Reduced gain.
- The feeds and connectors emit additional radiation.

Antenna length and width.

The following is a objective of the planned study:

- As part of the development of 5G wireless networking, it is necessary to create ultra-wideband (UWB).
- To expand data transfer rates and minimize reflected interference.
- To derive new parameters and evaluate them against preexisting design outcomes.

II. PROPOSED ANENNA DESIGN

Compared to other patch antenna configurations, the design of a circular patch antenna is simpler since it only requires one important parameter: the circular patch's radius.The steps involved in designing a circular microstrip patch antenna for the dominant TM100 mode are described, culminating in a working prototype.

The proposed antenna was designed using the CST software. The suggested circular microstrip patch antenna is seen in Figure 2 in top view, with one side of a dielectric substrate serving as an emitting patch and the other as a ground plane. A rectangular patch radio wire with a thin circular microstrip feed is shown in top view in Figure 2. The surrounding fields that are produced by the patch and ground plane work together to produce the radiation that comes from the antenna. The microstip patch reception equipment is presented due to its small size and enhanced reference. With a resonance frequency of 8.209 GHz, the proposed receiver device is well within the X-band frequency range. Once these three factors are modified, the size of the radiating patch may be determined.

$$R_p = \frac{F}{\sqrt{1 + \frac{2h}{\pi \varepsilon F}\left[\ln\left(\frac{F\pi}{2h}\right) + 1.7726\right]}}$$

$$F = \frac{8.791 \times 10^9}{f\sqrt{\varepsilon}}$$

Rp the radius of the patch

h = the height of the substrate

f = the resonance frequency in hertz

ε = the effective dielectric constant of substrate

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A microstrip antenna is made up of a substrate that is positioned between the radiating patch and the ground plane, a very tiny conducting patch, and a ground plane.

Step 1: Estimate of dimension in term of width (W)

Practical width for an effective radiator that results in good radiation efficiency is:

$$W = \frac{1}{2f_r\sqrt{\mu_0\varepsilon_0}}\sqrt{\frac{2}{\varepsilon_r+1}}$$

Where, μ_0 = free permeability, ε_0 = free space permittivity and ε_r = relative permittivity.

Step 2: Assuming a dielectric constant of, the second step is to calculate the effective dielectric coefficient.

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{1/2}$$

Step 3: Calculation of the Effective Length (L_{eff})

The effective length is

Step 4: Calculation of the Length Extension (ΔL)

$$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon_{reff}+0.3}{(\varepsilon_{rff}-0.2!}$$

Step 5: Calculation of the actual Length of Patch (L)

The actual length of radiating patch is obtained by

$$L = L_{\_eff} - 2\Delta L$$

Step 6: Calculation of the Ground Dimensions (Lg, Wg)

Only infinite ground planes are compatible with the transmission line model. But minimising carbon effect is essential for practical reasons. If the ground plane is larger than the patch dimensions by a factor of several times the substrate thickness throughout the perimeter, results that are comparable to those for a finite ground plane can be achieved, as demonstrated by:

$$L_g = 6h + L \ , \ W_g = 6h + W$$

The simulation results are obtained by treating the ground plane as infinite.

$$Z_{in} = j\omega L_p + \frac{R}{1+jQ\left(f_R-\frac{1}{f_R}\right)}$$

With a little knowledge of circuit theory, you can calculate the patch's input impedance as follows: j The frequency ratio is defined as fR= f/f0, where f0 is the patch hole resonance frequency (the resonance frequency of the RLC circuit).

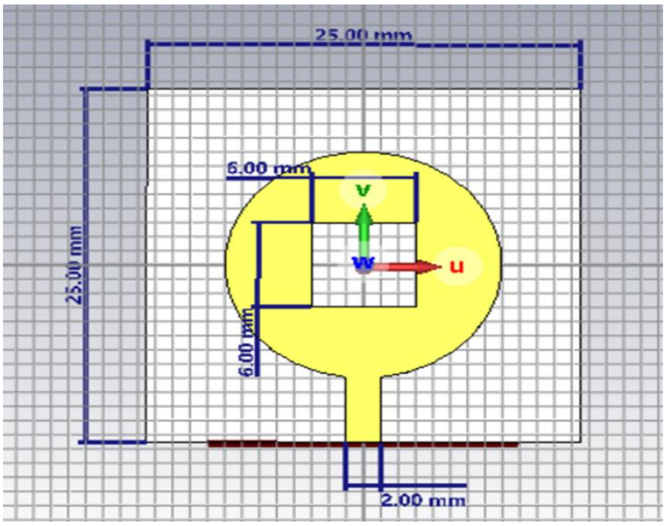

Figure 2: Top view of proposed design with Dimension

The suggested circular microstip patch antenna design is seen in Figure 2. The top and bottom layers are made of lossy copper, while the substrate is made of FR4 material, which has a dielectric constant of 4.4.

III. SIMULATION AND RESULTS

The recommended Circular Microstrip patch shape for X-band applications is shown in Figure 2. The structure has an overall dimension of 25 mm by 25 mm by 1.6 mm, is etched on fire resistant 4 (FR4), has an overall permittivity of 4.4, and a loss digression of 0.024. Table 1 is a list of the antenna components used in this proposal. The antenna is taken care of by a 50- and 0.5W micro thin link or a straight forward connection.

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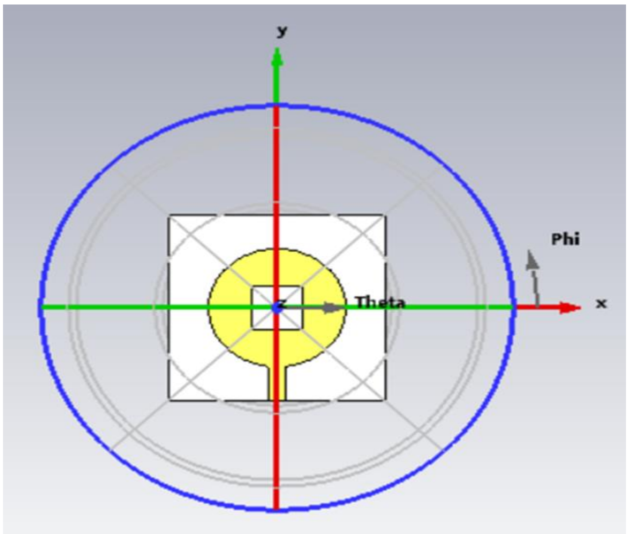

Figure 3: Simulation and fields of proposed antenna

CST microwave studio simulation and suggested antenna fields utilised to reproduce the design. Figure 3 depicts a circularly organised electric and attractive field simulation.

Table 1: Design parameters for proposed Antenna

Sr No.	Parameter	Value
1	Lower Frequency(f_L)	1 GHz
2	Higher Frequency(f_H)	10 GHz
3	Dielectric constant(ε_r)	4.4 / FR4
4	Ground (LxW)	25mm X25mm
5	Ground height	0.035mm
6	Substrate(LxW)	25mmX25mm
7	Substrate Height(h)	1.6 mm
8	Radius of Patch	8 mm

Return loss

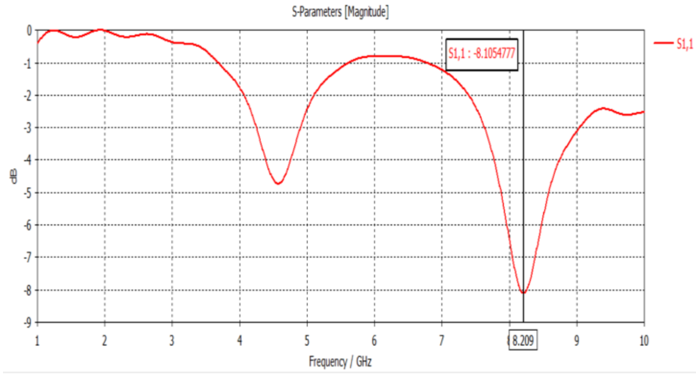

Figure 4: Return loss

The suggested structure's return loss is shown in Figure 4. By looking at this graph, we can easily deduce that The obtained value of S_{11} or return loss is -8.10 dB for 8.209GHz resonant frequency.

Bandwidth

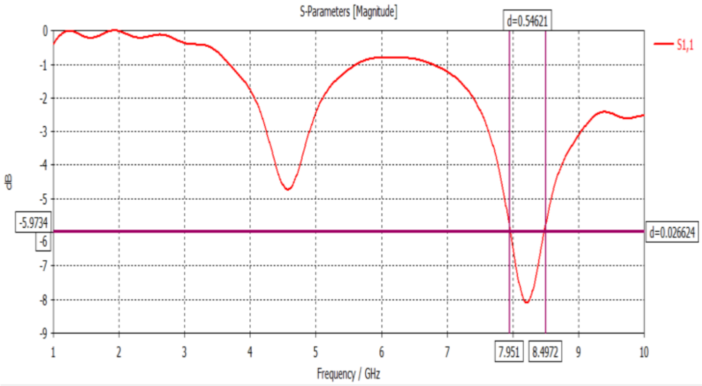

Figure 5: Bandwidth

The bandwidth of a broadband antenna may also be stated as a percentage of the frequency difference between the highest and lowest frequencies and its fundamental frequency. The suggested antenna has a bandwidth of 0.54GHz (8.49GHz – 7.95GHz).

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Voltage Standing Wave Ratio (VSWR)

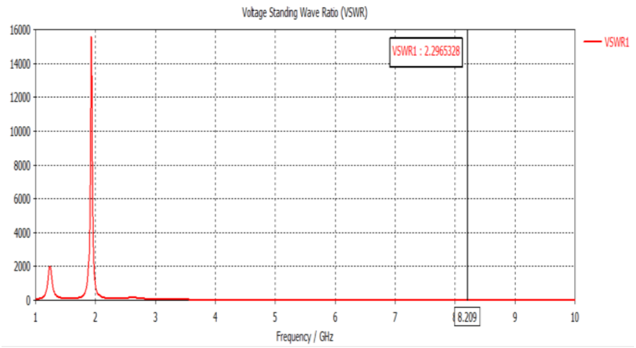

Figure 6: VSWR

VSWR must lie in the range of 1-3, which has been achieved for the frequencies 8.209GHz. The value for VSWR is 2.29.

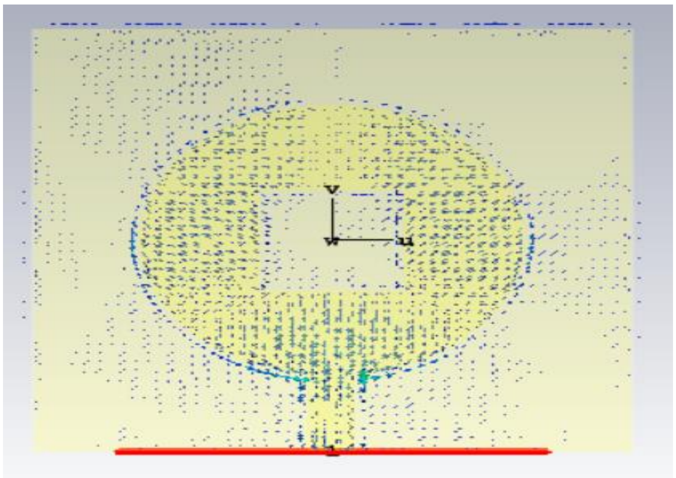

Figure 7: Surface current of proposed antenna

Figure 7 displays the suggested antenna's surface current. The electric and magnetic fields of the suggested antenna are also displayed, with the magnetic field represented by green dots and the electric field by blue dots.

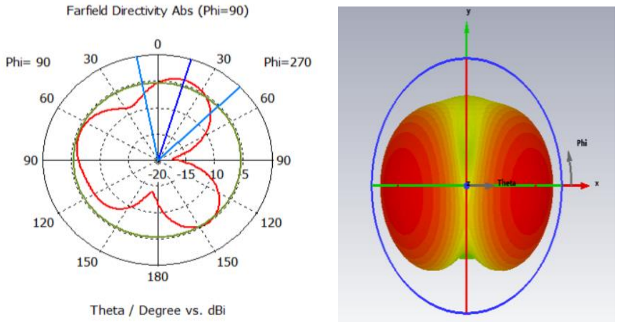

Figure 8: Radiation pattern

The recommended antenna bands have a certain radiation pattern, as shown in Figure 8. It is a diversion from the force that an antenna consistently emits in response to the direction of the signal that it receives.

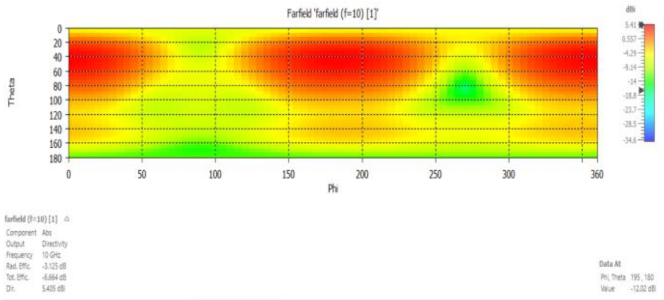

Figure 9: Directivity Analysis

An illustration of the proposed antenna's directional characteristics is shown in Figure 9. Value of directivity is 5.405dBi. "

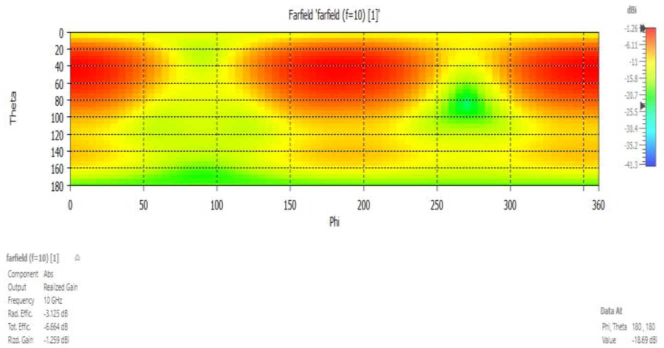

Figure 10: Gain Analysis

An illustration of the proposed antenna's directional characteristics is shown in Figure 10. Value of gain is -1.25dBi.

Table 2: Simulated Results of Proposed Antenna

S.NO	Parameter	Value
1	Return loss or S11	-8.10 dB
2	Bandwidth	0.54GHz
3	VSWR	2.29
4	Resonant Frequency	8.209GHz
5	Directivity	5.4dBi
6	Gain	-1.25dB

Parameters such as return loss, bandwidth, VSWR, and resounding recurrence are summarized in Table 2. Table 2's recalculated data show that the proposed antenna produces a significant improvement over the status quo.

IV. CONCLUSION

The suggested antenna's structure is small, measuring around 25 by 25 by 1.64 mm3. The developed antenna's modest size makes it simple to integrate into tiny devices. The programme CST microwave studio is used for simulation and suggested antenna design. The antenna's resonance frequency, according to the results, is 8.209GHz. The suggested antenna's total bandwidth is 0.54GHz. Applications for 5G, or next-generation, connectivity can benefit from the high bandwidth. The designed antenna's good impedance matching and low return loss make it effective in any setting. The recommended antenna complies with 5G wireless communication standards and is appropriate for X band applications.

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