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Optimized Design and Modelling of Microstrip Patch Antenna for 5G Mobiles

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***Abstract :*The purpose of this project is to improve performance within the frequency band suitable for 5G mobile applications in India by modifying the antenna design. In terms of efficiency and gain, the proposed antenna can be employed with a 2.1 GHz frequency, a low-cost FR4 substrate with εr=4.4, tan δ=0.02, and dimensions of 50 mm × 60 mm × 1.6 mm . Analysis of the proposed antenna has been done using the commercial program HFSS (High frequency structure simulator) from Ansoft. The designed antenna's return loss and radiation pattern are analyzed. S11 for the proposed antenna is less than 26.7613 dB.**

***Keywords*— Antenna design , HFSS , Return loss, and Radiation pattern.**

I. INTRODUCTION

Mobile communication systems have advanced quickly from the first generation (1G) to the fourth generation (4G), with each successive iteration providing significant improvement in performance. Numerous appealing applications are now feasible thanks to the current 4G systems' ability to deliver maximum data rates of over 1 Gbps. Furthermore, somewhere in the early 2020s, fifth-generation (5G) technologies are expected to be commercially implemented.[1].5G mobile communication system research has increased due to the growing need for improved data rates to support future applications such as wireless broadband, immense machine-type connections, and highly dependable systems.

The switch to higher frequencies is one of the primary differences between 4G and 5G wireless technology networks,where bigger bandwidths are more easily obtained. Compared to the 3G and 4G frequency bands, the centimeter/millimeter wave bands may have bandwidths that are several times larger. As a result, future applications requiring larger data rates can be supported by the centimeter/millimeter wave bands. Furthermore, there are a variety of frequency band options that may be utilized for 5G, and research is being conducted in each of these bands. However, switching to these millimeter/centimeter wave ranges might provide additional difficulties for mobile phone antenna designers[2]. matching are all important considerations when building an antenna. Costs, weight, volume, and maintenance refill supplies are all reduced as a result.

In wireless and mobile communication systems, microstrip patch antennas that are low - profile, and compact are often used., they are particularly well-suited for contemporary uses such as 5G. Its construction consists of a ground plane, a dielectric substrate, and a radiating patch, which is typically composed of a metal such as copper. Typically, the patch's shape is rectangular or circular that establishes the radiating pattern and resonance frequency of the antenna, while the substrate material influences its efficiency and bandwidth[3].

Microstrip antennas are perfect for certain, narrowband frequencies because they work by resonating at a particular frequency when electromagnetic waves are transmitted from the patch's edges. Generally speaking, microstrip antennas have a narrow bandwidth and a moderate gain (usually between 2 and 8 dB), while improvements like array arrangements might increase their usefulness[4]-[6]. They are an affordable, scalable solution for small devices like smartphones, Internet of Things sensors, and Wi-Fi equipment because of their thin, flat form factor, which makes it simple to integrate them onto printed circuit boards (PCBs). Although microstrip antennas have advantages, they have drawbacks in high-power applications and efficiency losses at millimeter-wave frequencies, which are typical in 5G. However, they are a crucial component of sophisticated communication systems due to their lightweight design, versatility, and simplicity of production.

II. ANTENNA DESIGN

To create a microstrip antenna on a FR-4 substrate, start by cutting a circular patch, referred to as Circle 1, from the top of the substrate. Ensure the center of this circle aligns with the substrate's center. Next, cut a second circular patch, Circle 2, underneath the first one, with its center also aligned with the substrate's center. Then, place a rectangular box on Circle 2 and remove the unnecessary portion to form a semi-circular shape[7]. Bring the two circular patches together and cut a rectangular shape below the semi-circular patch to form the ground plane.

The main radiating component of the antenna design is the circular patch, which has a diameter of 10 mm[8]-[10]. Because of its circular shape, which allows for omnidirectional radiation patterns, it is especially useful for 5G applications that require reliable coverage in a variety of orientations. By ensuring effective signal distribution, this function improves connectivity in a variety of settings.

The semi-circular patch, which is positioned beneath the circular patch and has a width of 13.5 mm, is essential to improving the performance of the antenna. Its main purpose is to enhance impedance matching and expand the impedance bandwidth, both of which are necessary for effective signal transmission and reception. It also affects the resonance frequency and return loss by precisely adjusting its size and positioning in relation to the circular patch. In this arrangement, the semi-circular patch functions as a reflecting patch and the circular patch as a feed patch[11]. They work together to create a resonant cavity that improves the efficiency and directivity of the antenna. A feedline that is connected to a transmission line powers the feed patch, and the reflecting patch is placed at the ideal distance from to establish a standing wave pattern between the two patches at a distance from the feed patch. The directivity and efficiency of the antenna are enhanced by this standing wave pattern.

Effectively transporting the RF signal to the radiating patch, the feed line, which is 3 mm wide and 27 mm long, serves as a conduit between the antenna and the feed source. To accomplish impedance matching, usually at 50 ohms, which is the norm for the majority of RF systems, its dimensions are carefully chosen. Maximum power transfer from the source to the antenna is ensured by this matching, which also reduces signal reflections. An essential part of the design, the feed line's width and length must be precisely adjusted to maximize signal transfer and preserve the antenna's overall performance[12].

A partial ground plane is incorporated into the design, which is crucial for maximizing the antenna's performance. The antenna is more effective over a larger frequency range thanks to the partial configuration, which improves the impedance bandwidth and lowers return loss in contrast to a full ground plane. Furthermore, the antenna can resonate at lower frequencies due to the lack of a complete ground plane, allowing for smaller designs that can reach lower resonance frequencies appropriate for 5G applications. Effective signal transmission and reception are further enhanced by this configuration, which also enhances metrics like Voltage Standing Wave Ratio (VSWR).

A substrate of this size helps achieve lower resonant frequencies and improves performance at these frequencies, which is beneficial for 5G applications targeting specific bands. However, the larger substrate also affects the overall size of the antenna, so it is important to balance compactness and performance. The thickness of 1.6 mm ensures adequate structural integrity while maintaining a low profile, which is in line with the design goals for compact and efficient 5G devices. The substrate dimensions are 50 mm x 60 mm x 1.6 mm.

Substrate	FR-4 Epoxy
Airbox	Air
Feed	Copper
Patch (Designed)	Copper
Ground	Copper

Table 1:Assigned materials

The following materials were allocated for the antenna design: The FR-4 epoxy used to make the substrate gives it mechanical support and affects the antenna's dielectric characteristics. To replicate open-space conditions, air is used to create an airbox around the antenna[13].Copper's superior electrical conductivity and appropriateness for radio frequency applications make it the material of choice for the feedline, radiating patch, and ground plane.

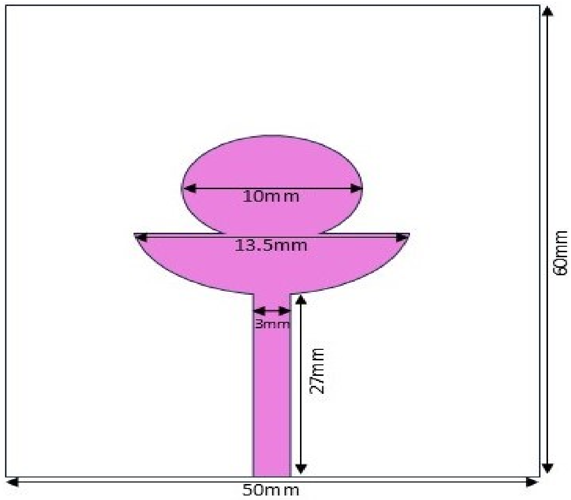
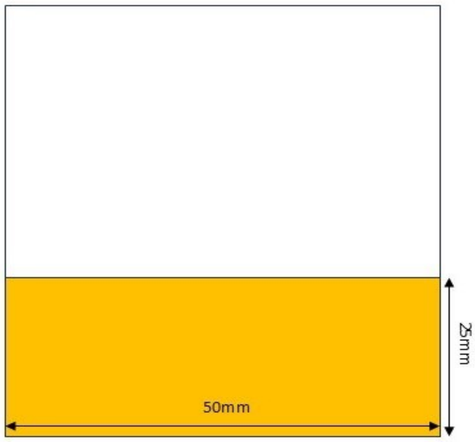


Fig. 1:Top view of Antenna Design



E			m)
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Air box	80	80	60
Feed	3	27	0.1
Ground	50	25	0.1

Fig 2: Bottom view of designed antenna

Table 2:Dimensions of antenna

The feed and ground plane dimensions guarantee appropriate impedance matching and signal integrity, while the substrate and air box dimensions establish the antenna design's physical bounds. To attain the best resonance frequencies and radiation patterns, the radiating elements (Circles 1 and 2) are made with particular radii and thicknesses.

Element	Axis	Radius(mm)	Height(mm)
Circle 1	Z	13.5	0.1
Circle 2	Z	10	0.1

Table 3: circles Measurement

By carefully lowering or eliminating the ground plane beneath the radiating element, a partial ground plane can be used in antenna design to improve performance in a number of ways. By reducing back radiation and increasing forward radiation, this method enhances the radiation pattern and produces more effective directional performance[14]. It also broadens the impedance bandwidth, which is crucial for wideband and multi-band applications, by reducing the antenna's quality factor (Q). Furthermore, by lessening the ground plane's impact on the input impedance, a partial ground plane improves impedance matching and maximizes signal transfer. Compact antenna configurations are supported by this design approach, allowing for smaller sizes without sacrificing performance, which makes it perfect for contemporary, space-constrained applications like 5G.

III. RESULTS

Return Loss:

The loss of power in the signal reflected by a transmission line into a load is known as return loss. Return loss must be at least -10dB for an antenna to match well. The quantity of electricity "lost" to the load and not reflected back is indicated by the return loss parameter. Because of this, the RL is a metric that shows how well the transmitter and antenna have matched.

A key idea in the operation of phased array antennas is in-phase operation. Two or more emitted signals are superposed in a phase-dependent manner. The amplitudes of these signals combine constructively when they are in phase, producing a stronger signal. In applications like radar and wireless communications, this approach is used to focus the antenna's radiation pattern and steer the beam direction, giving precise control over the coverage area and better signal performance.

In Fig.3 the return loss of -26.7613 dB is detected at 2.1GHZ.

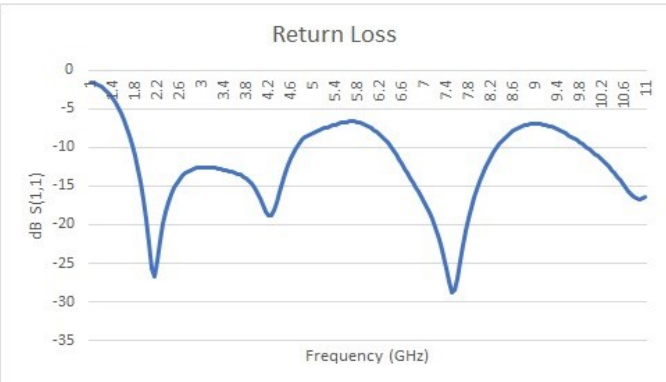

Fig. 3 Characteristics of Return Loss

The antenna's performance throughout a frequency range of 1.4 GHz to 11 GHz is depicted in the return loss graph. The efficiency of power transmission is demonstrated by return loss, which is expressed in decibels (dB); lower values indicate that source of power was reflected less. The graph displays clear resonant frequencies, where the antenna exhibits maximum radiation efficiency and is distinguished by steep falls below -10 dB. Resonances around 2.1 GHz and 7.5 GHz are noteworthy, demonstrating the antenna's capacity to function well at these frequencies. These performance indicators are essential for determining whether an antenna is appropriate for a given application, such 5G communication.

Radiation Pattern:

The radiation pattern graph shows the polar plot of the antenna's radiating properties. It illustrates how radiated power is distributed spatially in relation to direction. According to the plot, the antenna's radiation pattern is comparatively symmetrical, showing a steady power distribution in the majority of directions. According to this pattern, the antenna provides omnidirectional or almost omnidirectional coverage, which is advantageous for applications like 5G communication systems that need consistent signal strength in several directions. Focused energy distribution is ensured by the radiation pattern's smooth form, which also shows few side lobes.

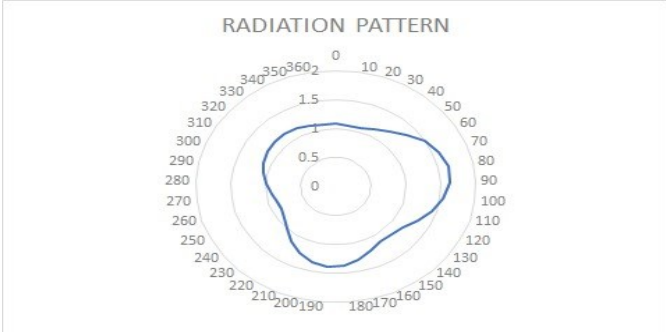

Fig. 4 :Radiation Pattern

IV. CONCLUSION

A single band micro strip patch antenna design concept that is appropriate for 5G mobile communications has been brought forth. The partial ground plane method serves as the foundation for the entire design. Both the lower and upper mobile bands can be covered by the suggested antenna. The suggested antenna shows promise for integration into the mobile device because of its low operating frequency and small area.

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