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Original Research

# DESIGN AND ANALYSIS OF MICROSTRIP ANTENNA FOR 5G APPLICATIONS

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**Abstract:** A new proposed antenna is presented in this article for 5G applications. The dimensions of this antenna are (32×32×0.8) mm³. The antenna that is suggested is built upon FR-4 epoxy dielectric substrate, with a loss tangent of 0.025 and relative permittivity of dielectric is 4.3 and, on the top layer of this substrate a polygon patch is etched with specific dimensions, also a ground plane on the bottom layer of the substrate is built. The patch of the antenna is fed from a microstrip feed line with a 50Ω characteristic impedance. The proposed antenna operates at 3.6 GHz as a resonance frequency with a bandwidth of (3.15 - 4.3) GHz, and gain (3.3) dBi at the operating frequency, these characteristics are suitable for 5G applications. To attain the targeted bandwidth and gain, distinct slots are carved onto both the patch and ground plane. The simulation outcomes are gathered using CST-MW 2020.

***Keywords:*** *5Generation; microstrip patch antennas; compact antenna; defected ground structure*

## 1. Introduction

Recently, 5G technologies have attracted attention in both academic and industrial areas as a result of the rapid development of wireless communication technology brought on by the growing popularity of the web, high-velocity streaming, and the growth of smartphone users [1-4]. Because of their advantages of short latency, good Quality of Service (QoS), high access rate, high transmission rate, and high spectral efficiency [5-7]. Many objects can connect wirelessly to the internet in the 5G era, including offices, cars, homes, and electrical devices. The most important difference between 5G cellular systems and 4G technology is expanded to new frequency bands, which makes it simpler to achieve a wider bandwidth [8]. For the 5G network, there are three main bands, the first one is a low band which includes up to 1GHz, the second band is a sub-6 GHz band which is named mid band, the last one is a high band which includes mm Wave [9,10]. 5G sub-6 GHz has attracted much more attention than mm-Wave due to its compatibility with existing 3G and 4G networks. It can also cover a very long distance and is not easily obstructed by obstructions, even with advanced beamforming. [11].

Due to the attractive properties of microstrip patch antennae that are preferred for 5G applications, such as lightweight, low profile, ease of fabrication, low cost, and wide bandwidth [12,13]. However, low gain with lower power handling capability, narrow bandwidth, and

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surface wave excitation are the main drawbacks of patch antenna [14]. The microstrip antenna type patch antenna consists of two main components, the first one is a radiating patch and the other is the ground plane these two components are etched upon the top layer and bottom layer of the dielectric substrate respectively [15,16]. To feed a microstrip antenna there are several techniques. These techniques are divided into two groups: contacting feed, when the power transfers from the feeder to patch through the transmission line, such as coaxial cable and microstrip feed line. The other type of feeding is the indirect feeding technique or non-contacting technique when the power transfer electromagnetic coupling from the feeder to the patch, such as proximity coupling and aperture coupling [17,18].

Thaher [19] introduced a novel design of a heptagonal slot antenna tailored for UWB applications. The antenna features a heptagonal slot in the ground plane and a beveled rectangular shape with a rectangular notch-cut tuning stub. Notably, this antenna design exhibits triple resonance frequencies at 3.5 GHz, 7.5 GHz, and 8.5 GHz. Abdullah and Farhan [20] showed a rectangular microstrip antenna for 5G technology with a frequency range of (3.1-4.2) GHz, this antenna is printed on an FR-4 substrate and a coaxial feed is used to adjust the bandwidth and resonance frequency. González and Márquez [21] A new broadband patch antenna tailored for 5G sub-6 GHz mobile systems was introduced. This antenna comprises a log-periodic patch shaped as an equilateral triangle, accompanied by a 50-microstrip line feed and a rectangular ground plane. Notably, the antenna operates within a frequency range spanning from 3.4 to 4.2 GHz. In [22], a T-shaped rectangular antenna for 5G applications is presented with a frequency bandwidth (2.9-4.4) GHz, it printed on a compact Roger RT 5880 substrate.

The primary aim of this study is to design and analyze a compact microstrip antenna with a resonant frequency of 3.6 GHz with acceptable gain for 5G applications. The antenna's dimensions allow it to be integrated into any small communication device from new technology.

## 2. The proposed Antenna Design

The proposed antenna is constructed of four sections: the first part is named patch (radiating part), the second one is the ground plane, in the middle between them is the dielectric substrate, and the last part is the feed port. The most geometrical shapes which are used for patch antennae are rectangular, square, circular, and elliptical.

The basic design equations which are used to estimate the dimensions of rectangular patches are listed below: [17, 23]

$$W = \frac{c}{2\,fr}\sqrt{\frac{2}{\varepsilon r+1}} \tag{1}$$

$$L = \frac{c}{2\,fr\,\sqrt{\varepsilon e}} - 2\Delta L \tag{2}$$

$$\varepsilon e = \frac{(\varepsilon r+1)}{2} + \frac{(\varepsilon r-1)}{2}\left[1+\frac{12\,h}{W}\right]^{-1/2} \tag{3}$$

$$\Delta L = \frac{0.412\,h\,(\varepsilon e+0.3)(W/h+0.264)}{(\varepsilon e-0.258)(W/h+0.8)} \tag{4}$$

$$Ls = L + 6h \tag{5}$$

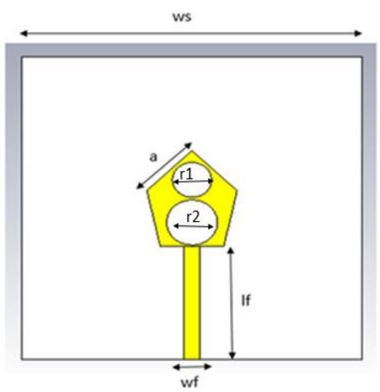
$$Ws = W + 6h \tag{6}$$

The characteristic impedance ($Zc$) can be written as [24]:

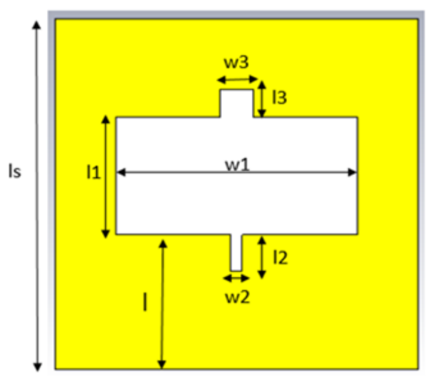
$$\mathrm{Zc} = \frac{120\pi}{\sqrt{\varepsilon e}\,\left[\frac{\mathrm{Wf}}{\mathrm{h}}+1.393+0.667\,\ln\left(\frac{\mathrm{Wf}}{\mathrm{h}}+1.444\right)\right]} \tag{7}$$

Where $c$ speed of light in free space, $W$ is the patch width, $fr$ is resonance frequency, $\varepsilon r$ is the relative dielectric constant of the substrate, $h$ is the substrate height, $L$ is the patch length, $\Delta L$ is the effective length of the patch, $\varepsilon e$ is the effective dielectric constant, $Ls$ the substrate and ground plane length, $Ws$ is a substrate and ground plane width, $Wf$ is the feed line width.

The suggested antenna operates at 3.6 GHz which is suitable for 5G applications. With a frequency band of (3.15-4.3) GHz, as shown in Fig. 1.




(a)




(b)

**Figure 1.** The suggested antenna from both (a) the top view and (b) the back view.

The main parts of the designed antenna are the polygon patch (the radiator) and rectangular ground plane except the etched slots are made of copper with a thickness of 35µm These components are constructed on both sides of an FR-4 dielectric substrate, which is the most commonly used for its availability and cheapness, this substrate having a relative permittivity of 4.3, a tangent loss of 0.025, and a thickness of 0.8 mm, the overall dimensions of antenna designed are (32×32×0.8) mm³. This antenna is designed and simulated by using CST-MW 2020. A microstrip feed line with 12mm length and 1.568mm width (Lf and Wf respectively) is used to feed the patch of the proposed antenna to satisfy 50Ω impedance to be compatible with a characteristic impedance of transmission line to achieve the best impedance matching, these feeder dimensions are set up to work at 3.6 GHz resonance frequency.

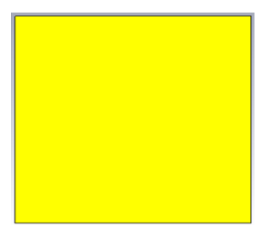
## 3. The Antenna Results

### 3.1. Parametric Analysis

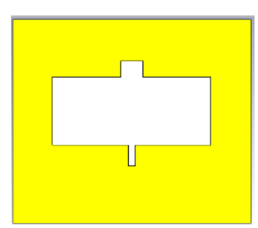
Many parameters and their effects are studied and used to enhance antenna performance.

#### *3.1.1. The Effect of Etching Slots in the Ground Plane.*

Creating square slots on the ground plane can affect the antenna performance, as depicted in Fig. 2. Simulated results are presented in Fig. 3.



(a)



(b)

**Figure 2.** The antenna (a) without DGS, (b) With DGS.

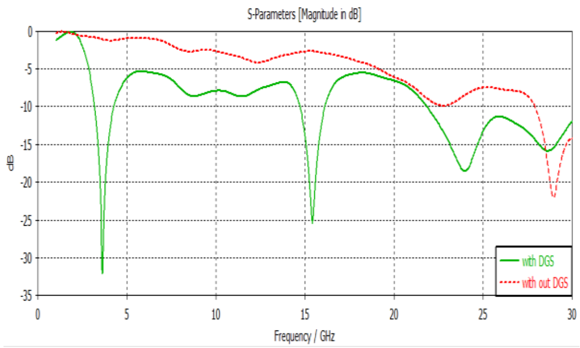



**Figure 3.** S11 result with and without DGS.

The proposed antenna without defected ground structure (DGS) operates at a frequency greater than 25 GHz. In contrast, the antenna with DGS operates at 3.6 GHz without Increasing the antenna dimensions, which is proportional to the operating frequency as shown in the previous equations.

*3.1.2. The Effect of Varying the Feeder Length*

The feed line (Lf) length varies, namely 6, 8, 10, 12, and 14 mm, which is illustrated in Fig. 4. The best results were obtained when lf=12 mm.

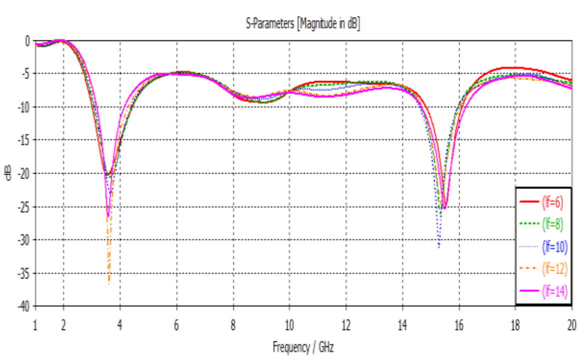



**Figure 4.** S11 results for various values of (Lf).

*3.1.3. The Effect of Varying the Side Length of Patch*

The effect of changing the side length (a) of the patch is shown in Fig. 5.

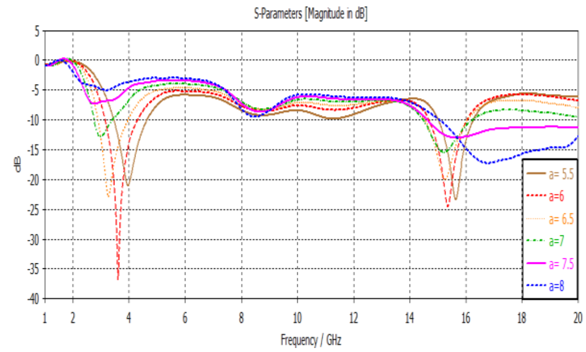



**Figure 5.** S11 results for various values of a.

Table 1 shows the optimal value for the proposed antenna, with all parameters that influence the antenna's efficiency.

**Table 1.** The designed antenna's dimensions.

| Parameters | Value in (mm) | Parameters | Value in (mm) |
|---|---|---|---|
| Ws | 32 | w1 | 21.3 |
| Ls | 32 | l1 | 10.7 |
| Wf | 1.568 | w2 | 1 |
| Lf | 12 | l2 | 3.3 |
| A | 6 | w3 | 3 |
| L | 12.3 | l3 | 2.5 |
| r1 | 2 | r2 | 2.4 |

### 3.2. Return Loss

Return loss is also known as the reflection coefficient due to the impedance mismatch, a proportion of the incident RF power is reflected to the source. It is denoted as (S 11); it should be less than -10 dB, and the frequency range below this value is the bandwidth of the antenna. The reflection coefficient of the optimal design of the antenna is shown in Fig. 6.

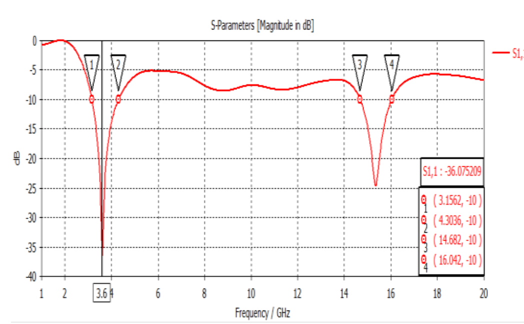



**Figure 6.** Simulated S11 of the design antenna.

### 3.3. Radiation pattern

As shown in Fig. 7, the radiation patterns at the far-field distance of the designed antenna exhibit omnidirectional properties across the entire desired bandwidth, which are essential for 5G applications.

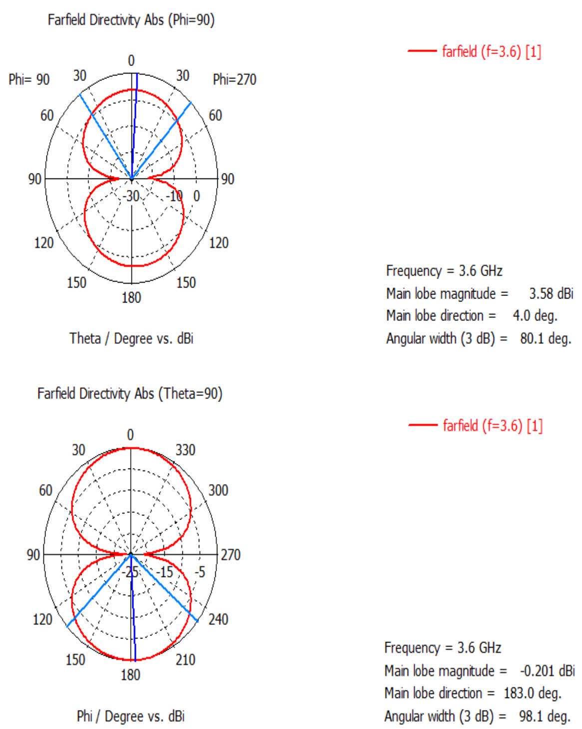



**Figure 7.** The antenna radiation pattern is at 3.6 GHz.

### 3.4. Gain and Efficiency

Antenna gain is a measure of the effectiveness of an antenna in a specific direction. It is described as the power transmitted by an isotropic source in the direction of its highest radiation. Since it takes into account the actual losses that occur, antenna gain is more frequently quoted than directivity. A higher gain value indicates that the antenna can radiate more power in a particular direction, making it more effective at receiving or transmitting signals in that direction. Antenna gain is an important parameter in many applications, including telecommunications, radio astronomy, and satellite communications.

According to Fig. 8, at the resonance frequency, the proposed antenna has a gain of 3.3 dBi.

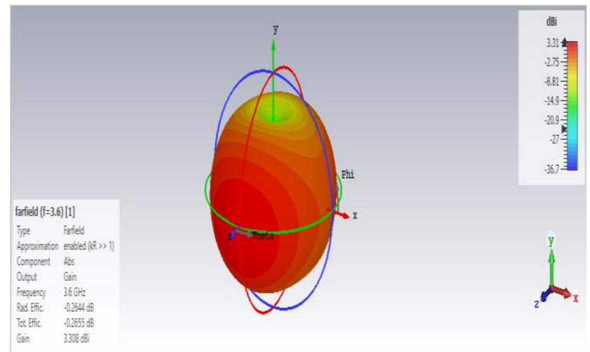



**Figure 8.** The antenna gains IEEE.

Fig. 9, illustrates the radiation efficiency at the operational frequency, which is 94%.

The relationship between the power an antenna radiates and the power applied to its excitation port is known as radiation efficiency.

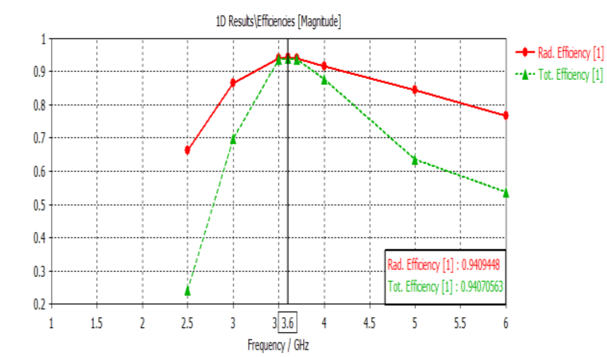



**Figure 9.** The antenna efficiency.

### 3.5. Surface current distribution

Fig. 10, shows the simulation of the surface current distribution of the designed antenna at 3.6 GHz, it is obvious that the current concentrated mainly on the edge of the radiating part, this occurred due to the slots etched on the patch, which increases the electrical path length, and that leads to increase the gain of the proposed antenna.

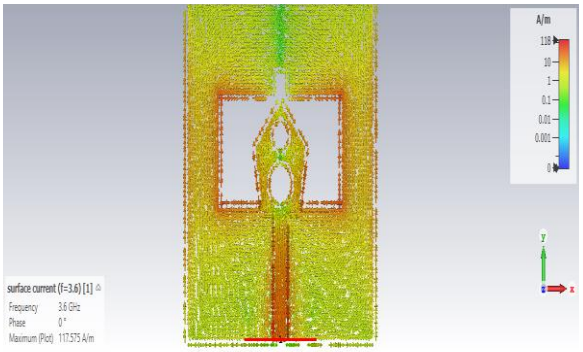



**Figure 10.** Surface current distribution.

### 3.6. Antenna impedance

The input antenna impedance consists of two parts one of them is real and the other is imaginary. With optimum matching between the transmission line characteristic impedance and the input impedance, the imaginary part must vanish while the real part must represent all values of the input impedance of 50Ω. As shown in Fig. 11, and at operating frequency (3.6GHz), the proposed antenna achieved this goal with the input impedance of (48.34 + j1.43)Ω. this value of input impedance is acceptable and very close to the ideal case.

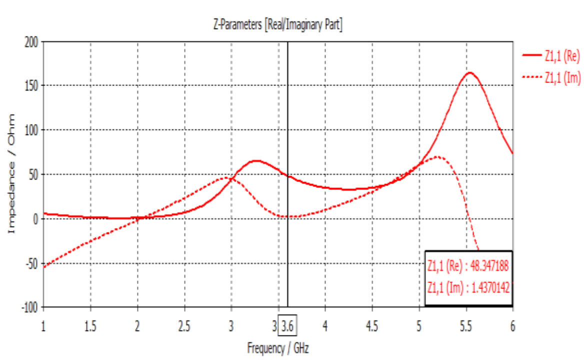



**Figure 11.** The real and imaginary part antenna impedance.

## 4. Conclusions

The suggested microstrip patch antenna is a suitable antenna design for sub-6 GHz 5G applications based on the simulation results and performance analyses. With its compact size of (32×32×0.8) mm³ and bandwidth of 1.14 GHz (3.15 - 4.3) GHz, the antenna is well-suited for 5G mobile phones and other devices that require high data rates, low latency, and reliable connectivity. A cheap and available dielectric substrate FR-4 is used to build this antenna. The antenna's gain of 3.3 dBi and radiation efficiency of 94% are excellent performance characteristics, which demonstrate its potential to meet the requirements of 5G applications. The ground has been modified to conform to 5G requirements, and some slots have been etched into the patch. Moreover, the antenna's lightweight and low-profile design makes it an attractive option for integration with other components in 5G devices. The proposed antenna shows good gain, bandwidth, return loss, and efficiency, which are important parameters for antenna performance.

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### Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

### Author Contribution Statement

N. Haider conceptualized the idea and outlined the main concepts and proof. M. Jasim and A. Al-Sherbaz contributed to the planning and supervision of the work. N. Haider processed the experimental data, conducted the analysis using CST, and drafted the manuscript. M. Jasim assisted in interpreting the results and contributed to the manuscript

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