Design compact microstrap patch antenna with T-shaped 5G application

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Article Info

ABSTRACT

This paper presents a microstrap patch with a T-shaped rectangular antenna workings; the T-shaped patch operating at 3.6 GHz resonating frequency range for 5G application (from 2.9 to 4.4 GHz) respectively. The overall size of the proposed antenna is 22×24×0.25 mm3; the feeding technique using a 50 Ω feed line to the antenna. The proposed antenna is printed on compact Rogers RT 588 lz substrate having permittivity (εr) 2.00, loss tangent (tan δ) 0.0021, with thickness 0.2 mm. The proposed antenna introduces many advantages like small size, low profile, and simpler structure. The characteristics such as radiation pattern, reflection coefficient, gain, current distribution, and radiation efficiency are respectively presented and discussed, using CST microwave study in simulating and analysing. Introducing a slot with a rectangular T-shaped patch antenna achieved lower frequency with 98.474% radiation efficiency and peak gain of the proposed antenna at 2.52 dB. The fractional bandwidth is 42.81% (2.90 GHz to 4.48 GHz) with a resonant frequency of 3.6 GHz and return loss at 28.76 dB. This frequency band attributes suited 5G mobile application.

Keywords: Microstrap patch antenna, T-shaped slot 5G, Wireless communications

1. INTRODUCTION

The cellular services explosive growth calls for higher capacity and faster data speeds. A new spectrum with fifth generation (5G) technology and more bandwidth (BW). Many countries employ N78 (3.3-3.8 GHz) band for the new 5G radio in 6 GHz sub-band. Antennas were required in the 3.5 GHz range for the past worldwide interoperability for microwave access (WiMAX) network. With the advent of 5G, the 3.5GHz band experienced rapid growth. Many large scale 5G networks experiments are being successfully conducted around the world. In the past few decades, researchers have been studying to improve the radiative

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performance of communication antennas. The microstrip patch antenna is disused in [1], [2]. Therefore, the development of wireless networks is crucial because 5G technology uses high-frequency bands and wide signal bandwidth to increase the transmission bit rate, thus providing better coverage with less power consumption [3], [4]. Be developed in the wireless 4G and 5G communication generation to meet the required performance. Wireless communication is a multiple systems convergence wireless access technologies [5], [6]. Thus 3.5 GHz band has broad application prospects in 5G implementation [7]. In wireless communications system, one of the main goal is focuses on the next generation through some required must achieve are high data rate application and service such as image in local coverage network, web browsing, wireless teleconference and multimedia. This major challenge factor for next generations [8]. For most mobile data where internal traffic is generated, antenna distribution plays an increasingly significant role in indoor wireless communication systems. In addition, to provide better communication services, many frequency bands are designed and commercially used in different communications systems such as 4G WiMAX and wireless local area network (WLAN). Therefore, a capable broadband distribution antenna is required in simultaneously meeting multiple service frequency bands [9]. The microstrip (MSA) antenna with many advantages, such as small size, low cost, and easy integration with active circuits; suitable for multi-band design and dual-polarisation antennas [10], [11], are widely used in printed circuits. Main drawback of microstrip patch antenna is its narrow bandwidth. Therefore, many techniques have been used to increase the bandwidth [12]-[14].

Microstrip patch antennas have been used in wireless and communication systems, but their gain and power handling ability are small [15]. Wong in [16], Baudha and Kumar [17], methods such as U-shaped and rectangular segmentation have been proposed to improve the bandwidth of microstrip antennas. Many frequency bands have narrowband applications [18], [19] like 3.3 GHz to 3.7 GHz for WiMAX [20], lower frequency band (4.5-5.5 GHz) for 5G applications [21], 5.15 GHz to 5.35 GHz, and 5.725 to 5.825 GHz for WLAN [22]. Antenna bandwidth can also be enhanced through using two pairs of quarter wavelengths (λ/4) microstrip line resonators, paired close to the rectangular patch antenna [23], [24]. The T-shaped patch antenna is optimised to have a rectangular hole and can be directly inserted into the 50 Ω microstrip line using the following method, the IE3D emulator optimized bandwidth at 2.45 GHz by changing each of the four parameters while keeping the other three constants [25].

In this paper, compact size antenna with techni T-shaped microstrip patch antenna using material Rogers RT/588 Iz substrate having permittivity (εr) 2.00, loss tangent (tan δ) 0.0021, with thickness 0.25 mm, parasitic radiator has been analysed, designed, and fabricated for frequency band from 2.9 GHz to 4.4 GHz, of 5G application. The substrate material choice greatly influences the bandwidth and patch antenna size. Decreasing the dielectric constant will increase both the bandwidth and antenna size while increasing the dielectric constant increases the bandwidth, efficiency, and antenna size.

2. ANTENNA CONFIGURATION

The design microstrip patch by using CST software, in designing a rectangular microstrip patch antenna, the calculations for width and length of the rectangle patch is as follows [26].

\[
W = \frac{c}{2f_r} \sqrt{\frac{2}{\varepsilon_{reff}}} \quad (1)
\]

The speed of light in free space is \( c \) (3 x 108 m/s), \( \varepsilon_r \) is the dielectric constant of the substrate, while \( f_r \) is the design antenna frequency, the correction width is \( W \), and the effective dielectric constant \( \varepsilon_{reff} \), is given in [26].

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

Where the dimensions of the patch along its length have been extended on each end by a distance \( \Delta L \), which is a function of the effective dielectric constant \( \varepsilon_{reff} \) and the width-to-height ratio (W/h), and the normalized extension of the length, is

\[
\frac{\Delta L}{h} = 0.412 \left(\frac{\varepsilon_{reff} + 0.3}{\varepsilon_{reff} - 0.264}\right) \left(\frac{W}{h}\right)^{0.258} \quad (3)
\]

Thus, the actual length of the patch can be calculated as [26].
\[ L = \frac{c}{2fr\sqrt{\varepsilon_{ref}}} - 2\Delta L \] (4)

The rectangular microstrip patch, length and width of the ground plane can then be calculated as

\[ L_g = 6h + L \] (5)
\[ W_g = 6h + W \] (6)

3. DESIGN OF T-SHAPE MICROSTRIP ANTENNA

A miniaturised T-shaped microstrip structure as shown in Figure 1, is presented to enhance the antenna performance. The designed T-shaped microstrip patch antenna was fabricated on the R/Duroid 5880 LZ with a dielectric substrate constant of 0.0021 and 3.6 GHz in design frequency. The dielectric height of the substrate is 0.254 mm. This proposed microstrip is used for 5G application. The microwave studio program CST is used as the main program to design and simulate the antenna. One of the main issues that must be carefully considered in any design processes is the choice of materials. The thickness of the material can also play a decisive role in small tapes prompting for a careful selection during designing the antenna. In designing the microstrip arc structure, Roger’s RT/Duroid 5880 LZ is used as raw materials. These materials were chosen because they are cheap and readily available.

![Figure 1. The geometry of the proposed T-shape microstrap patch antenna](image)

4. ANTENNA STRUCTURE

The dimensions of the proposed microstrip antenna were calculated by applying (1-6). The simple rectangular microstrip patch antenna is excited by 50 ohms impedance microstrip line to get better impedance matching and the dimension of the feed line microstrip patch is 9.20 mm long and 2 mm wide; excitation was created using a 3.6 GHz resonance frequency. The T-shape microstrip patch antenna was designed following the specification parameters shown in Table 1. The maximum bandwidth of the T-shape microstrip patch is 2.9 to 4.4 at 3.6 GHz resonating frequency with return loss (S11) is -28.809 dB. Inserting edge pieces into the design makes the resonating Hulk works in a band operation. Strings in the slot will enhance the antenna gain. The tapered ground is inserted into the rear of the chassis to improve the bandwidth and feeder. Matching the proper impedance will make the design resonate in enhanced performance of the antenna design parameters. The structure of the designed antenna with the optimised dimensions is shown in Figure 1.
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Table 1. The specification of antenna design

| Parameters                  | Value          |
|-----------------------------|----------------|
| Design frequency \( (f_r) \) | 3.6 GHz        |
| Dielectric constant \( (\varepsilon_r) \) | 2              |
| Height of the substrate \( (h) \) | 0.25 mm        |
| Loss tangent \( (\tan \delta) \) | 0.02           |
| Width of the T-shape patch \( (W_p) \) | 22 mm          |
| The ground plane width \( (W_g) \) | 24 mm          |
| The ground plane length \( (L_g) \) | 36 mm          |
| The feed line strip length of \( (L_f) \) | 9.2 mm         |
| The feed line strip width \( (L_w) \) | 2 mm           |
| Width of the edge cut \( (C_w) \) | 1.5 mm         |
| Length of the edge cut \( (C_l) \) | 1.2 mm         |

The microstrip patch antenna length and width are 22 mm and 34 mm, respectively. The overall size of the proposed microstrip patch antenna ground plane is 24×36×0.25 mm³. Shown in Table 1 and Table 2 are the specification parameters of the T-shaped rectangular patch antenna. These different parameters keep the other parameters separately stable. The strings in the slot will enhance the antenna gain. The ground is inserted into the rear of the chassis to improve the bandwidth and feeder. Two rectangular T-shaped in the patch antenna with diminutive 5x2 mm and 12x2 mm were designed with horizontal and vertical arms of the rectangular T-shaped patch antenna, respectively. The simulation results in the return loss at resonant frequency 3.6 GHz and the matching of the return loss \((S_{11})\) is -28 dB. The maximum bandwidth of 1.5 GHz is observed at 3.6 GHz and VSWR of the structure is shown in Figure 2.

Table 2. T-shape patch antenna parameters

| Parameters | Value |
|------------|-------|
| W1         | 5 mm  |
| W2         | 3 mm  |
| W3         | 4 mm  |
| W4         | 3.5 mm|
| W5         | 2 mm  |
| W6         | 10.5 mm|
| L1         | 9.5 mm|
| L2         | 12 mm |
| L3         | 4.5 mm|
| L4         | 3 mm  |
| L5         | 10 mm |

Figure 2. These figures are: (a) return loss for proposed antenna, (b) VSWR plot

5. RESULT AND DISCUSSION
The simulation and fabrication results in the T-shape patch antenna incorporating RT/Duroid 5880LZ materials as the substrate with a thickness of 0.25 mm and loss tangent \((\tan \delta)\) 0.02. It can be seen in Figure 3 that the antenna was matched in the \((S_{11})\) at about -28.76 dB for the simulation while the measurement \((S_{11})\) was about -20.4 dB, respectively. The bandwidth \((BW)\) of T-shape microstrip patch antenna was simulated from 2.90 GHz to 4.48 GHz, at 42.81% efficiency, meanwhile, the measured...
bandwidth is from 3.27 GHz to 4.22 GHz. Four parameters of the T-shape microstrip patch antenna were found enhanced; simulated and analysed using CST Microwave studio at the resonant frequency of 3.6 GHz. The performance indicators such as return loss (simulated and measured). The proposed antenna gain is 2.52 dB and the antenna efficiency is 98.474% at 3.6 GHz resonant frequency, respectively. While bandwidth is 42.81% (2.90 GHz to 4.48 GHz) with a resonant frequency of 3.6 GHz and return loss -28.76 dB. Comparison return loss between simulated and measured, gain, radiation pattern directivity, and surface current distribution of the proposed T-shape patch antenna are plotted for this frequency range of 2-5 GHz in Figures 3-9.

Figure 3. The comparison (S11) for simulated and measured return loss of T-shape patch antenna

Figure 4. Radiation pattern characteristic for both, (a) phi=0° at 3.6 GHz, (b) 90° at 3.6 GHz

Figure 5. Realized gain of the proposed antenna

Figure 6. 3-D plot of the gain characteristics
6. CONCLUSION
In this proposed, compact T-shape microstrip antenna is proposed for 5G wireless communication system. The proposed microstrip patch antenna was simulated and printed by using R/Duriod 5880 LZ, with an overall size of the microstrip patch antenna was 22x24x0.25 mm$^3$. Designing T-shape microstrip patch is done to overcome the narrow bandwidth limitation of the conventional microstrip patch antenna. This structure provides the best impedance matching at different frequencies and thus has stable radiation characteristics at different frequencies. Introducing a rectangular T-shaped aperture at ground level can improve the bandwidth of the low-frequency band. The optimize antenna’s fractional bandwidth is 42.81% (2.90 GHz to 4.48 GHz) with a resonant frequency of 3.6 GHz and return loss -28.76 dB. The proposed antenna gain is 2.52 dB and the antenna efficiency is 98.474% at 3.6 GHz resonant frequency. This type of structure is more suitable for a long term information technology due to the direction of their development. This feature has improved the proposed architecture making it suitable for various wireless communications such as 5G mobile applications.

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