Design of Multi-band Slotted mmWave Antenna for 5G Mobile Applications

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Abstract. In this paper, the design of a compact microstrip patch antenna for the 5G communication is proposed. The proposed antenna has a compact structure of 10×10×0.245 mm³ including the ground plane. The operating frequency for the antenna is in the 30 GHz band, which covers the 5G proposed band regarding the signal speed and data transmission, as well as the high spectral efficiencies. By using CST software, the analysis and performance of the antenna on a FR-4 dielectric substrate has been presented. Simulations show that the reflection coefficient of all operating frequencies is below -14 dB, which met the requirements of future 5G applications. In this work, the geometry of the presented antenna and its related parameters such as S-parameters and radiation pattern plots as well as gain values are presented and discussed in detail.

1. Introduction

There is a growing interest in achieving high data rates in today’s wireless communication systems, which is varied from 1G to 4G technology. However, the latter cannot approach the requirements of the future generation. For example, 4G generation failed to tackle the main communication problems such as of flexibility, crowded users, low quality and unreliable connection [1]. Currently, 5G is a good candidate to solve congestion problems in today’s 4G networks, which are mentioned above, and being a hot spot in the field of mobile communications at home and abroad [2]. 5G technology adds a significant impact on wireless communication systems. It provides data rates of at least 1 Gbit/sec for 10s of thousands of users simultaneously. Furthermore, the 5G system provides larger bandwidth and higher resolution for a cell. The security features are improved and the energy efficiency is increased as compared with 4G. Moreover, the utilize of 5G can support interactive multimedia including virtual reality and autonomous diving [3][4]. The range of frequencies that are covered by 5G includes two bands (>6 GHz and within 100 GHz). Designing of a patch antenna with relatively effective characteristics regarding beam width, bandwidth, and efficiency can fulfill the requirements of wireless mobile communication. Using this type of antenna can offer a low profile, planar structure, multiband characteristics. Furthermore, the patch antenna is less cost and moderate to high gain as compared with other antenna types [5].

It was recently reported in literature the use of 32.5 GHz band for 5G applications [2][6]; and in some recent works, the 28/38 GHz band was exploited [7]. The Structure of the proposed antenna in [7] was a spiral with two arms, each arm responsible for a different resonant frequency. Another recent study that proposed a design consist of two elements conventional rectangular microstrip patch antenna
with inset feed intended for the same range of frequencies 28/38 GHz [9]. In all these designs, the proposed antenna systems offer appropriate values of gain and radiation efficiency. In addition to the anticipated reflection and correlation coefficient characteristics that are dedicated for 5G smartphone applications.

However, in this work, a slotted patch antenna has been designed in the area 100 mm² exhibiting multiple resonances and covering the three aforementioned mmWave frequency bands of 28/32.5/38 GHz in one single design. Obtained results using computer simulation technology (CST) software show promising performance.

2. Antenna Design
The geometry of the slotted antenna is illustrated in Fig.1. The antenna consists of a patch with a crossed slot connected to a feed line and printed on a thin FR4 substrate with 4.4 relative permittivity and a thickness of 0.245 mm. The ground plane covers most of the backside of the substrate and has a small slot for impedance matching. The crossed-slot antenna is designed to exhibit multi-band operation at three 5G specific frequencies of interest. Hence, extensive simulations with careful consideration were performed to achieve this goal. The dimensions of the final design are presented in Tables 1 and 2.

![Figure 1](image1.png)

Figure 1. Geometry of the designed slot antenna: (a) front side and (b) backside.

| Parameter | WG1 | WG2 | LG1 | LG2 |
|-----------|-----|-----|-----|-----|
| Value (mm)| 0.3 | 10  | 5.85| 1.5 |

| Parameter | W1  | W1  | W3  | W4  | W5  | W6  | L1  | L2  | L3  | L4  |
|-----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Value (mm)| 0.8 | 4.1 | 3   | 3   | 1   | 0.5 | 3   | 5   | 1.5 | 1   |
3. Simulation Results

Fig. 2 shows the S-parameters of the proposed antenna within the frequency range 25-45 GHz. The antenna exhibits three major resonances at 28 GHz, 32.5 GHz, and 38 GHz, respectively. The value of the return loss was -27 dB, -14 dB and -22.5 dB for the frequencies 28 GHz, 32.5 GHz, and 38 GHz, respectively. The frequency bandwidth for 28 GHz and 32.5 GHz was almost similar (approximately 1 GHz), however, the antenna showed a wider bandwidth at 38 GHz (around 3 GHz).

![S-parameters of the proposed antenna showing the multiband behaviour.](image)

The 3D radiation pattern for the upper and lower frequencies are depicted in Fig. 3. It can be obviously noted that the designed antenna exhibits almost omnidirectional behaviour, which is preferred in this application. On the other hand, Fig. 4 shows the 2D radiation pattern for the same frequency bands indicating the direction of nulls. The antenna radiation pattern has two main nulls at 180° and 270° for the frequency band of 28 GHz. In contrast, the radiation pattern at 38 GHz showed one null only at 270°. The achieved gain was 4.73 dBi and 5.13 dBi for the 28 GHz and 38 GHz, respectively.

![3D radiation pattern for the upper and lower frequencies.](image)
Figure 3. Three-dimensional pattern of the designed slot antenna: (a) 28 GHz (b) 38 GHz.

Figure 4. 2D radiation pattern of the designed slot antenna: (a) 28 GHz (b) 38 GHz.

4. Conclusions
In this paper, a multiband antenna for 5G mobile applications was proposed. The antenna is designed with aim of covering the frequencies 28/32.5/38 GHz. To this end, a crossed-slot patch antenna is designed exhibiting excellent performance at the frequency band of interest. The antenna performance was quite satisfactory in terms of reflection, radiation pattern and gain; which makes it a suitable candidate for 5G mobile networks at the frequencies around 30 GHz. The achieved wide bandwidth supports the high rate requirements of 5G networks.

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