An Ultra-Wideband Antenna for IoT Connectivity

[1,2]MASTANEH MOKAYEF, [1,3]MHD AMEN SUMMAKIEH
[1] Faculty of Engineering, Technology & Built Environment, UCSI University, 56000 Kuala Lumpur, Malaysia
[2] Process System Engineering Center, Faculty of Engineering, Technology & Built Environment, UCSI University
UCSI University, 56000 Kuala Lumpur, Malaysia
[3]Multimedia University (MMU)
Kuala Lumpur Malaysia
mastaneh@ucsiuniversity.edu.my, amens1994@gmail.com

Abstract: The revolutionized way to change our current lifestyle is to utilize the promised technology called Internet of Things (IoT). In this context, the fifth generation of wireless communication known as 5G is an umbrella under which, the IoT can grow up. This paper proposes a dual band printed slot antenna for IoT connectivity landscape based on the 5G characteristics requirements. The proposed antenna is a microstrip patch with a compact size of 16×26mm^2 at sub-GHz frequency bands. Matching between Rook shaped radiating patch and the 50Ω microstrip feed line is manipulated through approximated feed technique. In order to increase the antenna bandwidth, rectangular slots are etched off in the middle part of the rook crown. The simulated results show that the designed antenna has a flat gain and high radiation efficiency and thus making it suitable for a 5G platform that ensures a prosperous IoT scheme.

Keywords: IoT, 5G, Ultra wide-band, Microstrip Patch, microstrip feedline

1 Introduction

Due to the tremendous evolution in the field of communication and the undeniable fact of ever increasing demands for the wireless access, the world is looking for the proper utilization of sub-GHz band for the design of a proper antenna that fits in smaller devices and provides wider bandwidth [1]. On the other hand, the low gain of these high frequency bands is a critical challenge for the proposed 5G technology.

As demands grow so rapidly, the 5G technology is expected to provide ten times data traffic, 90% of the population for mobile broadband and 75% of the LTE coverage in 2021 which requires a huge development in wireless mobile communications. This is the main reason for considering the 5G as both evolutionary and revolutionary technology. Wireless communication started from Supporting only the analog voice in 1G to a variety of applications targeting billions of users [2] in 5G where connections are provided anytime and anywhere for anyone and anything, which is so called as Internet of Things (IoT). The corresponding characteristic requires more advanced antenna designs compared to the existing ones. Since using internet and wireless technologies have become a part of our daily life, IoT is literally would be an emerging technologies in a very near future.

Apparently, IoT applications are enabled by Tactile Internet concept which requires higher data rates with lower latency due to its multi-areas applications such as e-health, banking, transportation, smart cities and agriculture [3]. The intervention of the future system would be significantly improved by changing the deployment of the system architecture and obtaining the high gain and stable radiation characteristics over a large bandwidth level [4]. Generally, to fulfill the 5G antenna requirements a minimum antenna gain of 10dB and a wide bandwidth must be considered in the antenna design [5-7].Moreover, the slotting shape that can provide an equalized field between slots has an important role in antenna design for 5G applications. Antennas fulfilling these characteristics, are the ones compact in size which are able to integrate with other devices with acceptable radiation pattern while satisfying the impedance matching. Several antenna designs and solutions are already proposed in ,[4] in order to be compatible with these factors. On the other hand, the ultra wide-band is a revolutionary technology that covers the wide range of applications in communication. The Federal Communication

Commission (FCC) defined the Ultra wide-band as any technology that has a bandwidth of more than 500MHz. Due to the inverse relation between permittivity and the bandwidth, achieving the wider bandwidth is the biggest challenge in antenna design.

According to [1, 2, 4-7] the microstrip antennas are good candidates due to their compactness, lightweight and planar configuration. The major limitations of such antennas are their low gain, narrow bandwidth and operating in a single frequency; hence, several methods have been proposed to overcome these limits and improve the antennas' performance. Among these proposed methods, utilizing the thick substrate, impedance matching networks and multiple resonators are the most popular ones. However, mounting the parasitic patches on top of the main patch, restructuring the feed line to be more capacitive and designing the slots has been introduced to increase the impedance bandwidth and consequently increasing the performance of the antennas.

In this paper, the microstrip slot antenna with less complexity and ease of fabrication, operating at sub-GHz frequency bands is proposed. In the first step a single patch rectangular antenna is modified by introducing two slots to make a rook shape to the patch. In the second step, two semi ellipses on the both bottom edges of the patch are also protruded. This antenna can be easily fit into the handheld devices due to its compact size.

This paper is arranged as follows : Section 2 describes the proposed antenna for IoT; while Section 3 illustrates various simulation results and their discussions. Finally, the paper is concluded in Section 4.

2 Proposed antenna for IoT

The structure of the antenna and its configuration are illustrated in Fig. 1. The antenna is benefited of the compact size of 16×26mm^2 with a rook shaped radiating patch. The Rogers RT5880 (lossy) Substrate with a thickness of 0.6mm and a dielectric constant of 2.2 is used. The antenna is excited by a 50Ω microstrip feed line with the width of 2.4 mm and a length of 8 mm which is used for the antenna matching impedance adjustment. To improve the impedance matching, the feed line is tapered to be used as a transformer with size of 2.4×8mm^2.

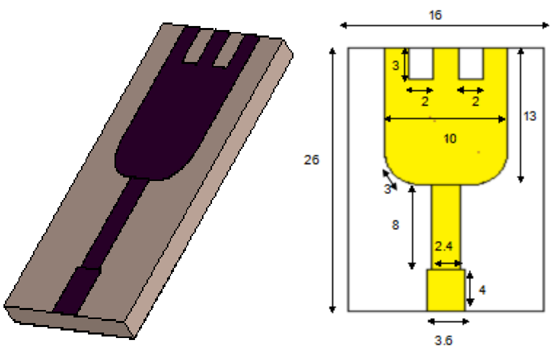

Fig.1. Geometry and dimensions of proposed antenna

The antenna is fed by a microstrip feed line in the x-z-plane in order to have an excitation mode of $TE^{x}_{\delta 11}$ where $(0 \prec \delta \prec 1)$. Accordingly, the resonant frequency of this mode in the x-direction is almost very small and can be neglected. In order to satisfy the impedance matching of 50Ω the location of feed line from the non-radiating edge is determined by

$$R_d = R_0 \cos^2\left(\frac{Y_0 \pi}{L}\right) \tag{1}$$

where R_d is the desired match impedance, R_0 is the input impedance of the proposed antenna at the edge, L is the length of patch and finally Y_0 is the distance from the edge corner [8]. The inset feed arrangement is considered using SMA connector associated with 50Ω feed line. since the feeding line had to be connected directly to the antenna, most of the energy would be reflected given that the antenna's characteristic impedance and the line's impedance of 50Ω [8]. It should be highlighted here that at high frequencies, the transmission line has a key role in antenna radiation as it is replaced by the lumped elements in low frequencies. Hence it is more easier to create a full passive network by using simple conductors.

In order to achieve simultaneous dual-band and a wider bandwidth, the slots on top of the patch and protruding semi ellipses on the bottom edges of the patch have been proposed. The semi ellipses etched in the edges affect as a trucked edge method for this high frequency patch and their dimensions have been proposed to be 3mm after several optimization process. On the other hand, since the thin patch of copper with the thickness of 0.035mm has been used, the space between the patch and the ground is so small which leads to an antenna with a high quality factor and consequently more energy is stored in the patch. The chosen dimensions and the operating frequency of the designed antenna makes it highly recommended to be used by IoT systems which are normally defined by small dimensions and long range communications [9].

3 Simulation results

The simulations of the proposed antenna are performed using Computer Simulation Technology (CST) Microwave Studio (CST MS 2014), a commercial software program which is based on Finite Integration Technique (FIT) that is equivalent to Finite Difference Time Domain (FDTD) method [10]. Hence, the optimal parameters are obtained due to this simulation. Since the rectangular patch is benefited by dominant modes of TM_{010} and TM_{001} therefore the dual band operation is achieved from the modified slot designed antenna.

The calculated reflection coefficients $|S_{11}|$ versus frequency of the proposed antenna is illustrated in Fig. 2. A reflection coefficient magnitude of -36dB is obtained at 8GHz frequency and a reflection coefficient magnitude of -18dB is obtained at 4GHz frequency.

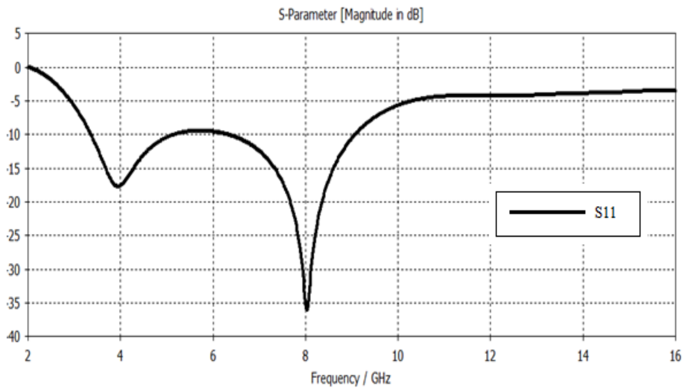

Fig. 2. Reflection coefficient versus frequency

The field directivity of the antenna is illustrated in Fig.3. As expected, antenna exhibits a broadside radiation pattern in both E and H plane which makes it a good candidate for the fifth generation of wireless communication that will transform the world to a connected smart platform [11] and thus enabling IoT applications.

Based on the simulation results, the main lobe magnitude of 3.39dB and the angular width or half power beam width of 104.6 degrees and the side lobe level of -20 dB have been obtained.

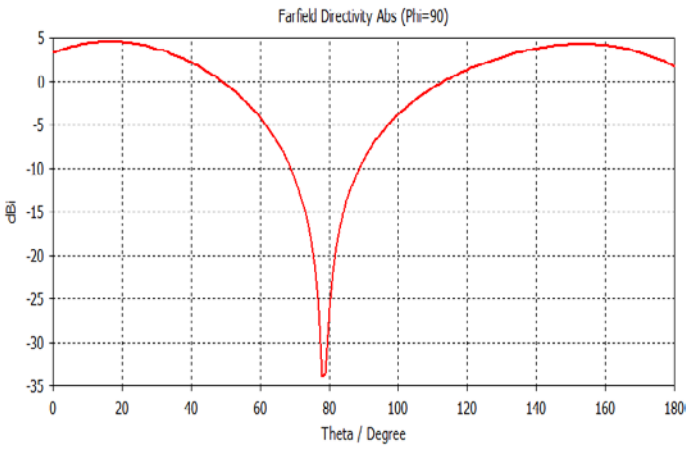

Fig. 3. Field directivity of antenna

According to the obtained results, a good agreement can be observed between simulated results and the theoretical facts. Moreover, the directivity of proposed antenna will make it a good candidate for the IoT applications. For the finite ground plane structure of the proposed antenna, the resonant frequency of 9.2 GHz with a gain of 4.42 dB, radiation efficiency of 69%, and a return loss of -31.2 dB have been obtained.

4 Conclusion

A rook shape dual band microstrip patch antenna has been proposed in this paper. The results show that the proposed antenna benefits of a thin structure, low weight, easy fabrication, and high radiation efficiency can make it a suitable candidate for 5G applications as it can be fitted to most devices. The antenna has a wide band operation with -36dB and -18dB reflection coefficient levels between 6.4GHz to 9 GHz and 3.5GHz to 5 GHz respectively . Many IoT applications tend to use the sub-GHz band in their operation and thus the proposed antenna gives an advantage of covering multiple frequencies in the sub-GHz band which makes it suitable for IoT devices.

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