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5.8 GHz BAND Wi-Fi AND IoT APPLICATIONS ANTENNA DESIGN

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ABSTRACT

Due to the increase in internet-connected devices in daily life, the compact embedded wireless device becomes necessary to meet multiple frequency-based applications on a common platform. Reconfigurability is a good solution for improving device utility in many technical interfaces. Wireless compatibility between different devices over the Internet reveals the importance of the antenna unit. Internet of Things (IoT) based applications requires integration with wireless communication technologies to obtain application data. In this study, a meander-shaped microstrip patch antenna in the 5.8 GHz band is proposed for use in IoT applications. The dimensions of the antenna are 40 x 15 x 1.6 mm^3. The antenna design consists of a full circle, a semicircle, and a meander line. In the antenna design, FR-4 has been used as the substrate material, and copper has been used as a conductor on the upper and lower surfaces. Performance parameters have been investigated in the proposed antenna design. In addition, a parametric study is presented to investigate the flexibility of the antenna. The results show that gain and yield can be improved by adjusting the dimensions of the rectangular ground plane. As a result of the improvements, the terminated antenna, return loss below -20 dB in the 5.8 GHz band, 700 MHz wide operating band, 4.35 dBi realized gain, 5.3 dBi directivity, -0.9188 dB radiation efficiency and -0.9445 dB total efficiency have been obtained. In addition, the proposed antenna also operates in the 4.5 GHz, 7 GHz, and 8.5 GHz bands as multi-band.

Keywords: Internet of Things (IoT), Microstrip Antenna, Antenna Gain, Return Loss, Multiband

1. INTRODUCTION

Wireless communication technology is in high demand nowadays. It has also necessitated the use of more than one wireless technology (Vinodha and Raghavan 2017). This is where the Internet of Things (IoT) enters the picture. The Internet of Things (IoT) is the integration of people, processes, and technology using connectable objects and sensors. It allows communication between the virtual and physical worlds (Vikram 2016). Internet of Things (IoT) applications encompass significant developments in computer networking, microelectronics, and modern communication systems. This technology allows physical sensing and working items to be remotely controlled via the internet. These devices must be compact, cost-effective, and energy-efficient to operate in many bands for LTE, WLAN, WiMAX, and ZigBee. Any of these wireless communication technologies can be used to connect IoT devices. The extent of the Internet of Things (IoT) operating on these bands is expanding daily. As this trend continues, there will be greater demand for smaller devices as well as improved antenna modules. Sensors in conjunction with any of the wireless communication technologies enable IoT to be realized. Sensors can be embedded in IoT devices based on the application (Lazarescu 2013). With the miniaturization of embedded systems, smart cities, smart health, smart factories, and environmental monitoring are becoming a reality. In these circumstances, multiple modules can be coupled in these compact devices to boost efficiency, dependability, and longevity (Mukhopadhyay and Suryadevara 2014, Acharjya, Geetha et al. 2017). Existing wireless components (6, 7, 8, 9, 10) will inevitably be replaced by components compatible with developing technological improvements in the coming days, given the rapid technical progress in microwave and millimeter-wave component technologies.

In Section 2, the design parameters of the proposed antenna model are presented. In Section 3, the results obtained from the proposed antenna model are given in detail. In Section 4, the comparison of the proposed antenna with other antennas in the literature is discussed. In the 5th section, there are conclusion comments about the study.

2. MATERIALS AND METHOD

In this section, information is given about the design parameters and development process of the proposed 5.8 GHz band Wi-Fi and IoT applications. In addition, information and comparison of the proposed antenna design about different antenna designs made in the literature is presented.

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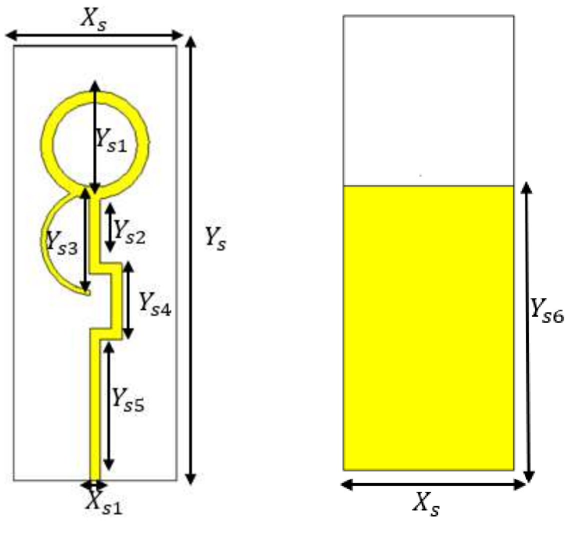
A planar multi-standard MIMO antenna has been developed for IoT applications (Jha, Bukhari et al. 2018). A loop antenna operating in three standards (GSM 900, GSM 1800 and Bluetooth Low Energy) has been developed for biotelemetry IoT applications (Damis, Khalid et al. 2018). A dual-band modified Sierpinski triangle fractal antenna has been developed for Wi-Fi applications (Zeybek and ElMahgoub 2018). A semicircular multiband asymmetric coplanar feeder antenna has been developed for IoT applications (Labade, Tambe et al. 2017). Again, a dual-band C-slot microstrip antenna design has been developed to be used in Wi-Fi and WiMax applications (Yassin, Saeed et al. 2014). A MIMO antenna design consisting of a double polarized 8x8 antenna array has been developed for outdoor Wi-Fi access points (Stavrou, Litschke et al. 2014). A multi-band MIMO antenna design has been developed for use in 5G mobile phones, WLAN, WiMax and 5.8-6 GHz Wi-Fi applications (Mathur, Augustine et al. 2021). In wireless communication systems, MIMO antenna design has been developed in the ISM (Industrial, Scientific and Medical) band (Baytöre, Palandöken et al. 2015). An antenna design has been developed to cover the 5.8 GHz band for Wi-Fi application and between 6 GHz and 8 GHz for 5G mobile applications, with a hexagonal shape and surrounded by five hexagonal metamaterials (Orugu, Nesasudha et al. 2021). In order to reduce the size of the compact printed inverted F-shaped MIMO antenna design operating at 5.8 GHz for Wi-Fi applications, the antenna design was developed using a short-circuited fractal-shaped patch at one working end (Pan, Zhang et al. 2016).

2.1 Meander Shaped 5.8 GHz Microstrip Patch Antenna Design

The proposed antenna design is made of two-sided monolayer substrate material. On the upper surface, there is a patch structure with a full circle, a semi-circle and a meander-shaped slit, and on the lower surface there is a rectangular soil structure whose dimensions are smaller than the substrate material. The proposed antenna design and the parameters that make up the design are presented in Figure 1 in detail.



(a) (b)

Figure 1. Proposed antenna design; a) upper and b) lower surfaces of the antenna

In the antenna design, FR-4 (dielectric constant is 4.3, loss tangent value is 0.02) substrate material with a thickness of 1.6 mm was used. Copper is used as a conductor on the upper and lower surfaces. The dimensions of the antenna are 15 mm x 40 mm. Antenna design parameters are presented in detail in Table 1. In the proposed antenna design, a split port is used perpendicular to the upper surface and the ground plane.

Table 1. Design parameters of the proposed antenna model (in mm)

X_s	Y_s	X_{s1}	Y_{s1}	Y_{s2}	Y_{s3}	Y_{s4}	Y_{s5}	Y_{s6}
15	40	2	5	6	8.7	7	13	25

The return loss of the proposed antenna in Figure 2 at 5.8 GHz was measured as -22.8 dB. On the other hand, return loss values of -23.4 dB, -18.9 dB and -37 dB were obtained at 4.5 GHz, 7.1 GHz and 8.7 GHz resonance frequencies, respectively.

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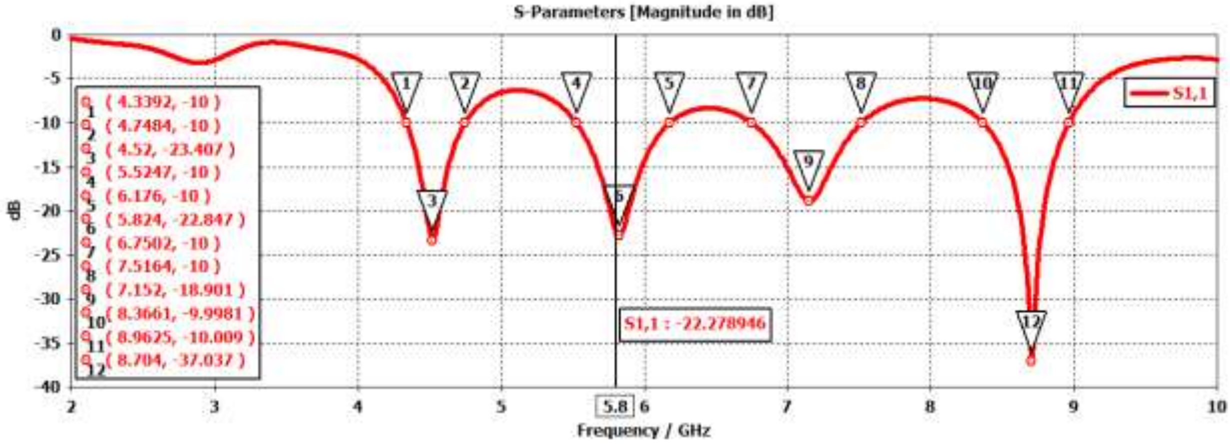

Figure 2. Return loss of the proposed antenna

Figure 3 shows the gain value of the proposed antenna at 5.8 GHz. The gain obtained at 5.8 GHz was obtained as 4.35 dBi.

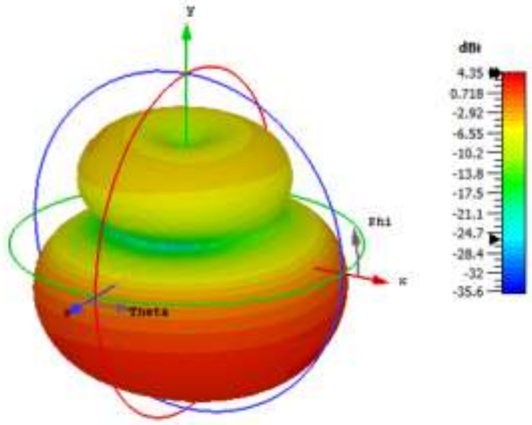

Figure 3. 3D gain representation of the proposed antenna as a result of simulation

2.2 Parameter Study of Proposed Antenna

Parametric analysis of different Y_{s6} lengths, which are reduced from 40 mm to 25 mm, of the conductive material in the ground plane has been made. In the analysis, the antenna does not work in the desired frequency band in the ground plane with 40 mm, 35 mm and 30 mm lengths. The return loss of the antenna remained above -10 dB in the first three analyzes and the gain values were measured as -6.51 dBi, -8.25 dBi and 0.322 dBi, respectively. In the parametric analysis obtained, the best result has been obtained at 25mm, and the return loss at 5.8 GHz was -22.3 dB, and the gain was 4.35 dBi.

In Figure 4, the return loss parameters formed as a result of the simulation of the parametric analysis obtained with different Y_{s6} lengths is presented.

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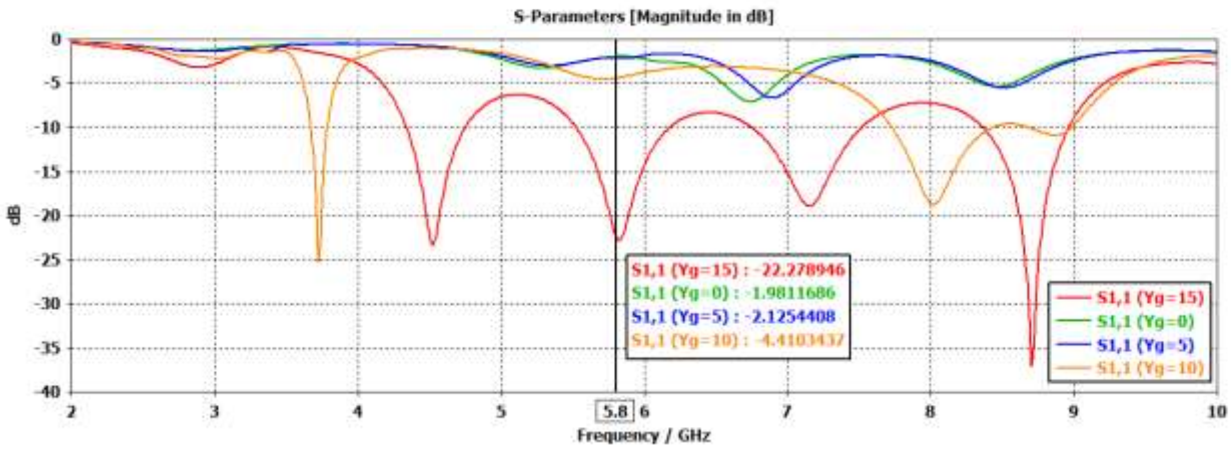

Figure 4. Return loss data obtained as a result of parametric analysis of different Y_{s6} lengths

3. Results

In this study, although the bandwidth of the proposed antenna is high, it works as multi-band. The frequency values at which it resonates were obtained as 4.5 GHz, 5.8 GHz, 7.1 GHz and 8.7 GHz. S11 parameters and gain values were measured as -23.34 dB, -22.3 dB, -18.9 dB, -36.67 dB and 3.1 dBi, 4.35 dBi, 2.32 dBi and 2.18 dBi, respectively.

4. DISCUSSION

Table 2 shows the comparison of the proposed antenna with the existing studies in the literature. Many researchers have presented parametric and measurement results for different applications at different resonance frequencies. In comparison, it can be seen from the table that the proposed antenna mostly has a smaller size than other antenna sizes, but its gain is higher than the others.

Table 2. Comparison of the proposed antenna with other studies in the literature

Reference	Antenna Size (mm^2)	Operating Frequency (GHz)	Operating Bandwidth (%)	Gain (dBi)
(Jha, Bukhari et al. 2018)	120 x 65	5.6	54.92	1.68
(Srivastava, Saurabh et al. 2019)	100 x 40	4.68	68.3	5.03
(Kuo and Wong 2003)	70 x 50	5.35	20	1.5
(Wu, Hsiao et al. 2004)	75 x 75	5.8	33.8	3.7
(Naidu, Kumar et al. 2019)	10 x 19	5.5	15	1.8
(Liu, Xu et al. 2018)	12.5 x 13	5	12	1.55
Proposed Antenna	15x40	5.8	65	4.35

5. CONCLUSION

Applying antenna as wireless sensor technology is one of the advantages of IoT applications. In this study, microstrip patch antenna design is presented for use in Wi-Fi and IoT based applications in the 5.8 GHz band. The performance parameters of a full circle, half circle and meander shaped microstrip patch antenna on the upper surface are examined and presented. The parametric analysis of the ground plane and the semicircle was also examined and the final antenna design was determined based on the best results.

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