Design of Microstrip Polygon Shaped Patch Antenna for IoT Applications

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Abstract. A Microstrip polygon shaped patch antenna is proposed in this work for Internet of Things (IoT) application. The antenna has multiband response at 2.39 GHz, 4.39 GHz, 5.8 GHz and 6.56 GHz with bandwidth of 230 MHz, 380 MHz, 390 MHz and 350 MHz respectively. The partial ground structure is developed for bandwidth enhancement of the proposed model. The FR4 material is selected as the substrate of the antenna. The antenna operates over the frequency ranges of Bluetooth and WiFi as well as RF Devices and Radio Location applications.

Keywords: Microstrip polygon shaped patch antenna · Partial ground structure Bluetooth · WiFi · RF devices · Radio location · Internet of Things (IoT)

1 Introduction

Internet of Things (IoT) is an emerging sprawling set of technology. The working frame of IoT consists of network connected devices which is embedded in the physical environment. The advantage of IoT simply improves some existing process or enables new scenario which was not previously reliable. The sensors, actuators and software together bring the IoT in to reality. Each component which can be accessed through IoT is identified by a unique IP address [1, 2]. The interconnection between the devices to the host and vice versa is done by various wireless communication modules like WiFi, WiMax, Bluetooth etc.

For a smart scenario, the combination of more than one wireless communication technology is required. So the antenna that used for IoT applications should be a multiband antenna and the resonant frequencies should be in the ranges of prerequisite frequency bands. The IoT module prefers the compact size for the components, so that the power consumption and memory of the devices should be reduced [3, 4]. As well as the low rate of data transfer is currently possible through this virtual communication. Hence the antennas that required having the limits of bandwidth less than 1 GHz. Thus the requirements of the antenna that using in IoT technology is should have multiband response and bandwidth less than 1 GHz.

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2 Antenna Design

The designed antenna should be fabricated on a grounded substrate of FR4 material, which has the dielectric constant of 4.4. The Microstrip line feeding mechanism is selected for the feeding of the antenna. The analysis of the antenna for the prerequisite resonant frequencies is gradually emerged from the simple circular shaped Microstrip patch antenna (CSMPA). The calculation of the dimensions of the CSMPA is done by using the following equations.

$$F = \frac{8.791 \times 10^9}{f_r \sqrt{\varepsilon_r}} \tag{1}$$

$$a = \frac{F}{\left\{1 + \frac{2h}{\pi F \varepsilon_r}\left(ln\left(\frac{\pi F}{2h}\right) + 1.7726\right)\right\}^{0.5}} \tag{2}$$

$$a_e = a\left\{1 + \frac{2h}{\pi \varepsilon_r a}\left[ln\left(\frac{\pi a}{2h}\right) + 1.7726\right]\right\}^{0.5} \tag{3}$$

$$\varepsilon_{reff} = \frac{1}{2}(\varepsilon_r + 1) + \frac{1}{4}\left(\frac{\varepsilon_r - 1}{\sqrt{1 + \frac{12h}{a}}}\right) \tag{4}$$

The parameter f_r is the resonant frequency, ε_r is the dielectric constant, h is the substrate height and a is the radius of the CSMPA. ε_{reff} is the effective dielectric constant and a_e is the effective radius of the CSMPA [5]. Since the surface area of microstrip patch antenna is inversely proportional to the resonant frequency. Thus for a defined area, there should be a fixed resonant frequency. So for a particular resonant frequency response can be obtained by changing the planar geometrical shapes of the antenna which shares same equivalent surface area. A Hexagonal shaped Microstrip patch antenna (HSMPA) is evolved from the CSMPA by this equal area concept.

$$\pi a_e^2 = \frac{3\sqrt{3}}{2} a_h^2 \tag{5}$$

Where a_h is the side length of the HSMPA. Then the proposed polygonal shape is introduced as the combinations of six rectangles with a single hexagon. The area of the HSMPA is made to the equivalent of sum of area of six rectangles and the area of single hexagon.

$$A_H = A_h + A_r \tag{6}$$

A_H is the area of HSMPA and A_h and A_r are the area of single hexagon and six rectangles respectively in the proposed structure. The evolution of the proposed Microstrip polygonal shaped patch antenna from the CSMPA is given in the following figures.

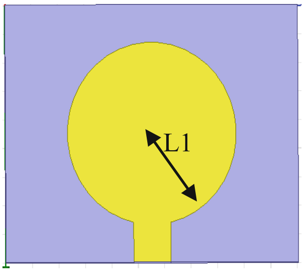

Fig. 1. The circular shaped microstrip patch antenna with L1 = 15.94 mm

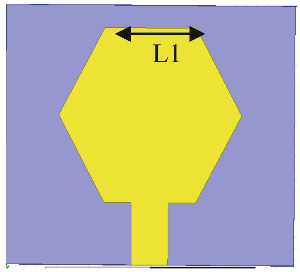

Fig. 2. The hexagonal shaped MPA with L1 = 17.5 mm

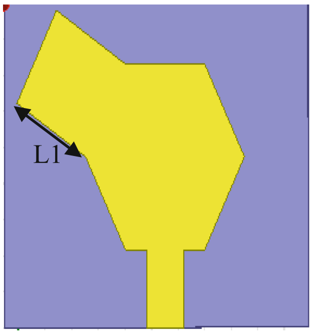

Fig. 3. The derived geometry of the MPA with L1 = 14.9 mm

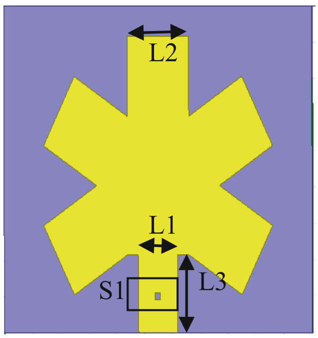

Fig. 4. The proposed antenna structure

The substrate dimension of the Microstrip patch antenna is 45 mm × 55 mm 1.6 mm. The Figs. 1, 2, 3 and 4 gives the gradual development of the proposed antenna for same equivalent area. Figure 1 represents CSMPA is considered the basic antenna structure for the evolved antenna. The HSMPA in the Fig. 2 has the same equivalent surface area of CSMPA. The prior stage of the proposed antenna structure is given in Fig. 3 and the proposed antenna with slotted structure for gain enhancement [6, 7] is shown in Fig. 4 (Table 1).

Table 1. Dimensions of the proposed antenna (mm)

L1	L2	L3	S1
7	11	10.8	1 × 1

The modified ground structure is also introduced in the proposed antenna which is shown in the following figure (Fig. 5).

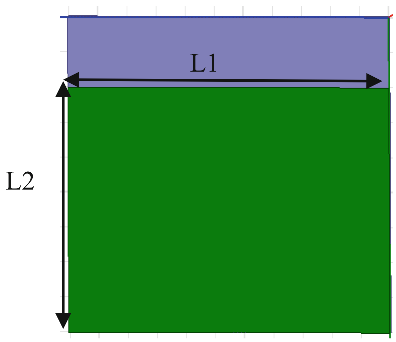

Fig. 5. The partial ground structure of the proposed antenna With L1 = 55 mm and L2 = 35

The partial ground structure in the proposed antenna gives improved impedance bandwidth as well as reflection coefficient due to the disturbance in the distribution of surface waves in the substrate of the antenna.

3 Simulation Results and Discussion

The simulated results of the each stages of the antenna is discussing here. The change in the resonant frequencies and the reflection coefficient of each stage of the antenna is shown in the given figure (Fig. 6).

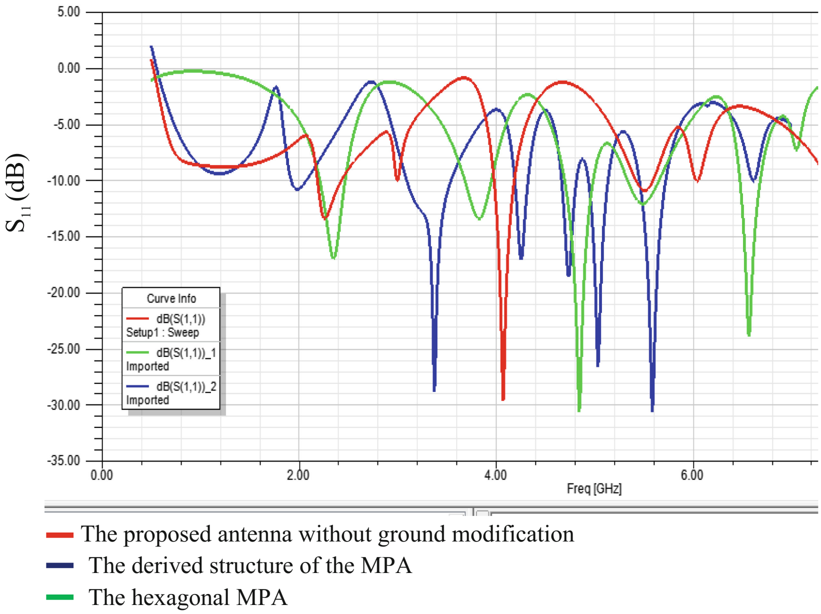

Fig. 6. The S parameter of the antenna

The simulated results of the reflection coefficient of the each stage of the antenna gives the changes in the resonant frequencies according to the geometry. The tuning of the resonant frequency in to the prerequisite frequencies is done by the each evolvement stage of the proposed antenna (Fig. 7).

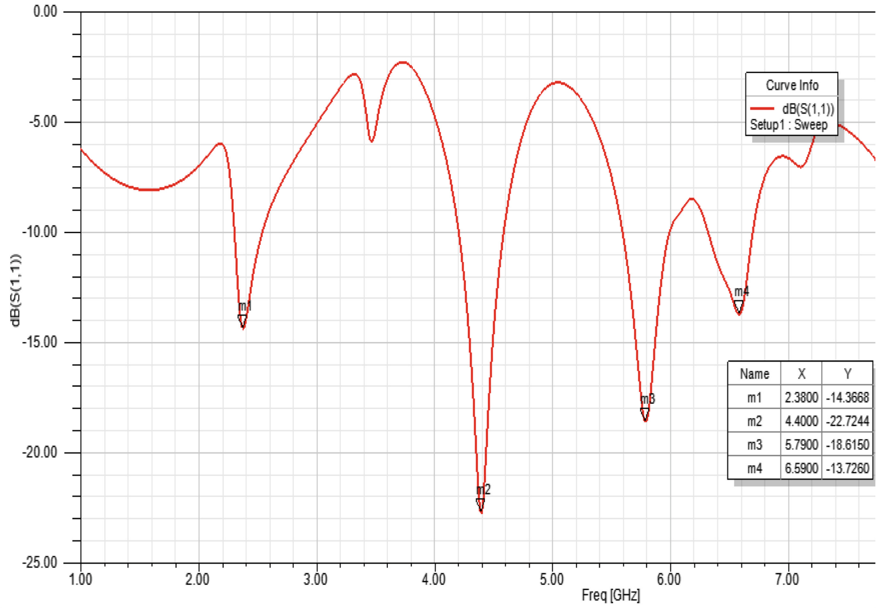

Fig. 7. The S parameter of the microstrip polygon shaped patch antenna with partial ground structure.

After the introduction of the partial ground structure the antenna performance is improved as the resonant frequencies obtained at 2.39 GHz, 4.39 GHz, 5.8 GHz and 6.56 GHz. The antenna is working in the ranges of Bluetooth and WiFi is obtained with relevant reflection coefficient (Fig. 8).

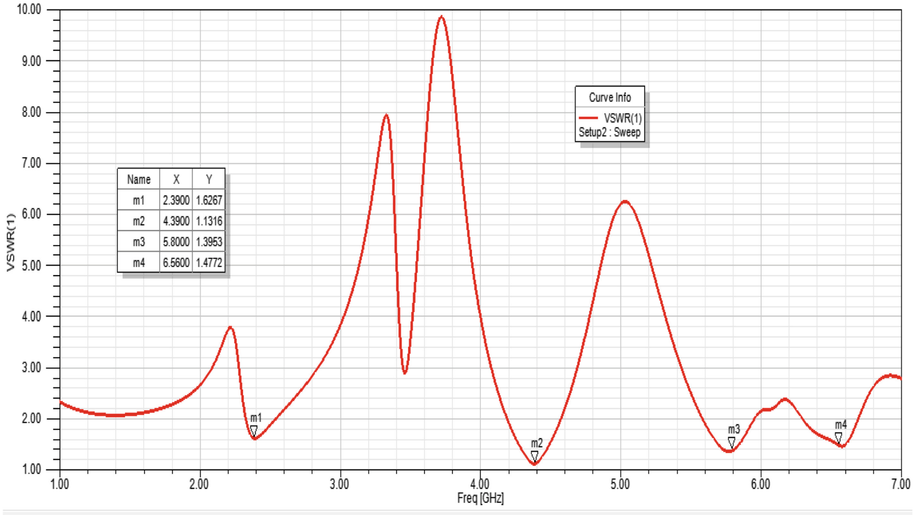

Fig. 8. The VSWR plot of the proposed antenna

The VSWR values of the respective resonant frequencies are simulated as less than 2 which indicate that perfect impedance matching at the simulated resonant frequencies.

The 2-D radiation pattern of the antenna is simulated with the values of azimuthal angle (phi) at zero and 90° respectively is given in Figs. 9 and 10.

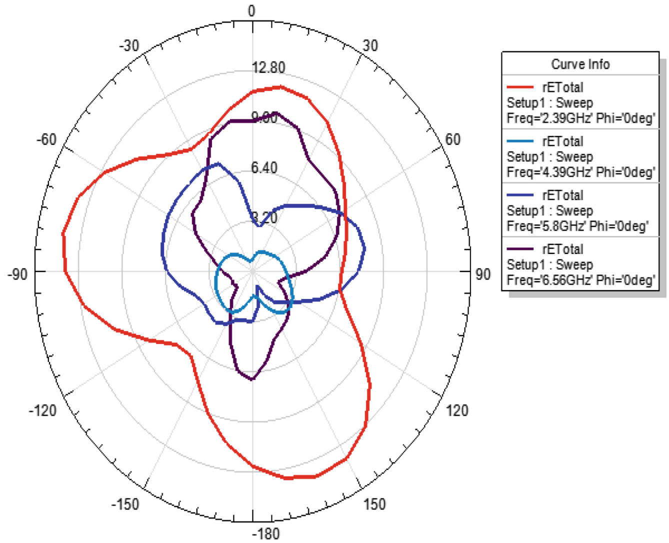

Fig. 9. The radiation pattern of the antenna at phi is 0°

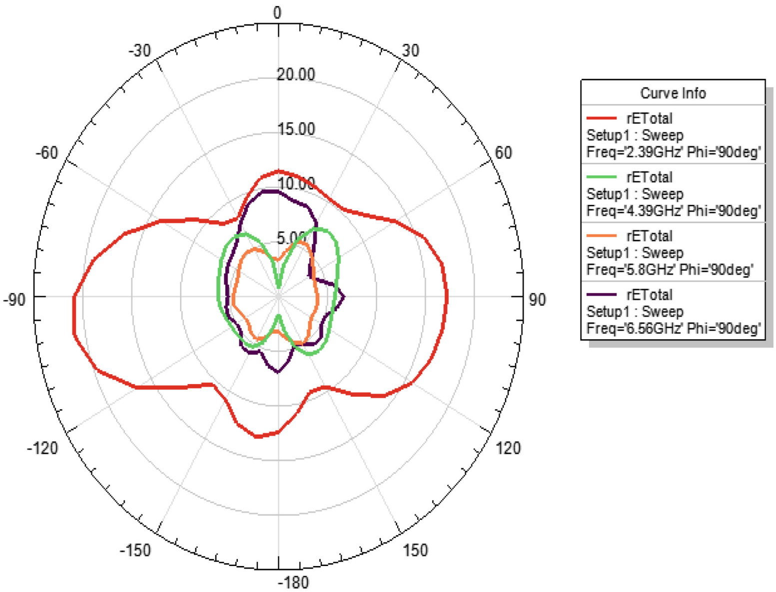

Fig. 10. The radiation pattern of the antenna phi is 90°

The simulated gain result of the proposed antenna at each resonant frequency is given in the figures from Figs. 11, 12, 13 and 14. These results show that the maximum gain of the antenna is obtained 11.3 dBi at 2.39 GHz.

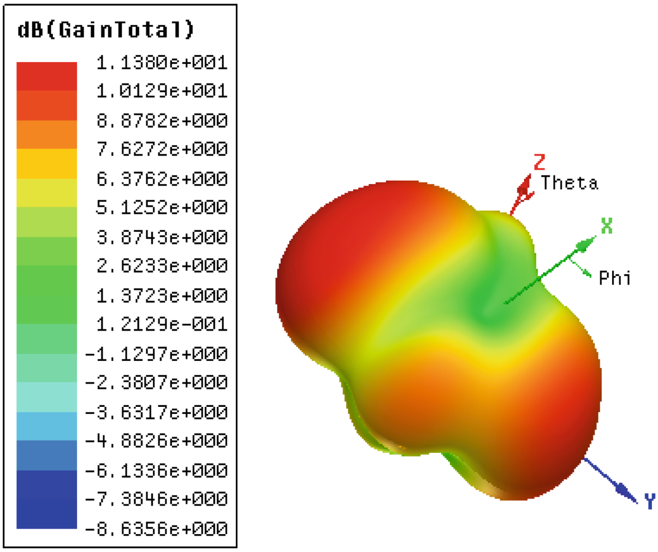

Fig. 11. The 3-D plot of gain of the antenna at 2.39 GHz

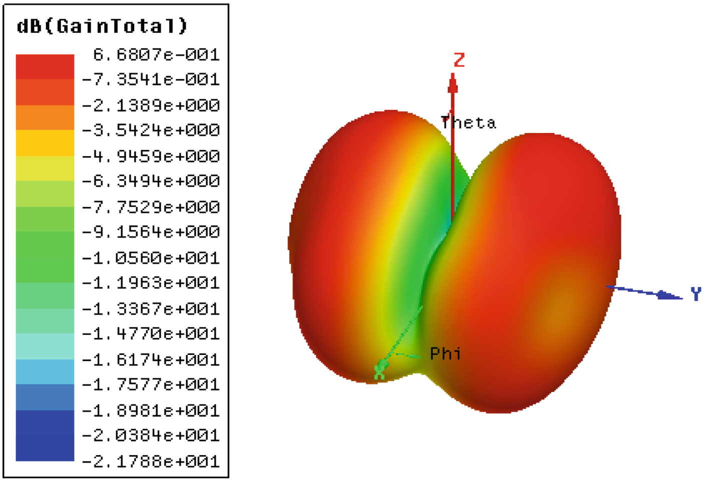

Fig. 12. The 3-D plot of gain of the antenna at 4.39 GHz

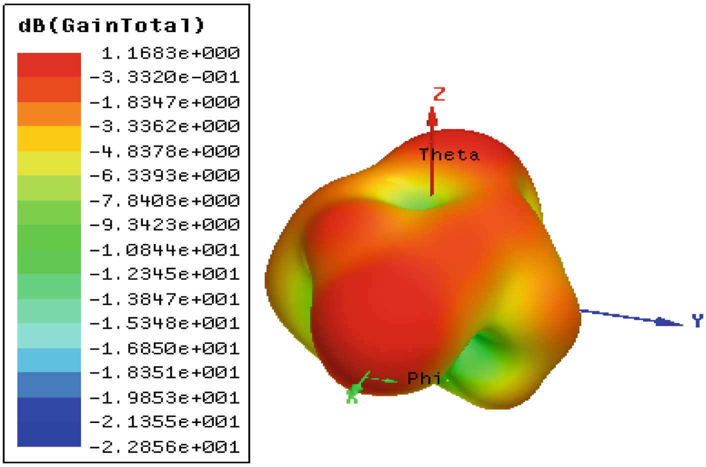

Fig. 13. Gain of the antenna at 5.8 GHz

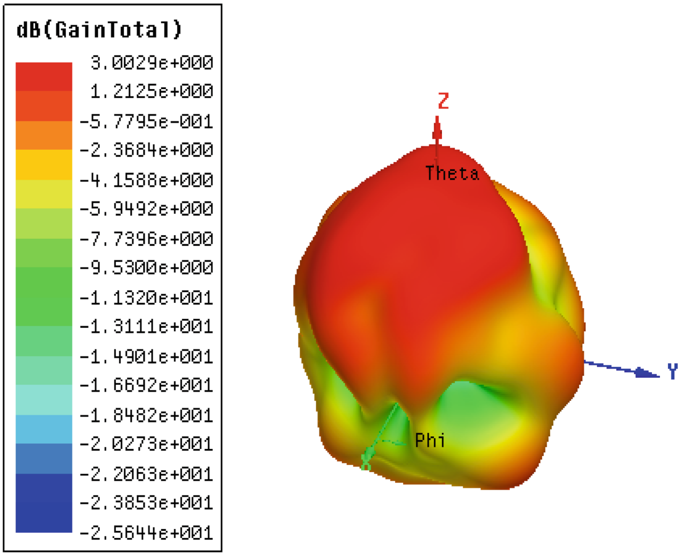

Fig. 14. The gain of the antenna at 6.56 GHz

4 Conclusion

A Microstrip polygon shaped patch antenna is for IoT application is introduced in this work. The resulted multiband antenna is having resonant frequencies at 2.39 GHz, 4.39 GHz, 5.8 GHz and 6.56 GHz with impedance bandwidth of 230 MHz, 380 MHz, 390 MHz and 350 MHz respectively. The maximum gain of the antenna is 11.3 dBi at 2.39 GHz is also obtained. The antenna operates over the frequency ranges of Bluetooth and WiFi as well as the application extends in the ranges of RF Devices and Radio Location.

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