High gain antenna at 915 MHz for off grid wireless networks

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ABSTRACT

This paper presents a high gain antenna for off-grid wireless networks at 915 MHz. The requirements for compact size and high gain antenna are needed in the industrial, scientific and medical (ISM) band for better performance and coverage. Hence, microstrip planar substrate is proposed to overcome the size challenges. The proposed antenna is designed based on rectangular patch with air gap technique. The proposed antenna is optimized using computer simulation technology software (CST) and fabricated on low profile FR-4 substrate. The measured performance agreed well with the simulated one. The reflection of less than -10 dB is obtained with high gain of 6.928 dB at desired frequency. Overall, this antenna can be a good candidate for the off-grid wireless network applications.

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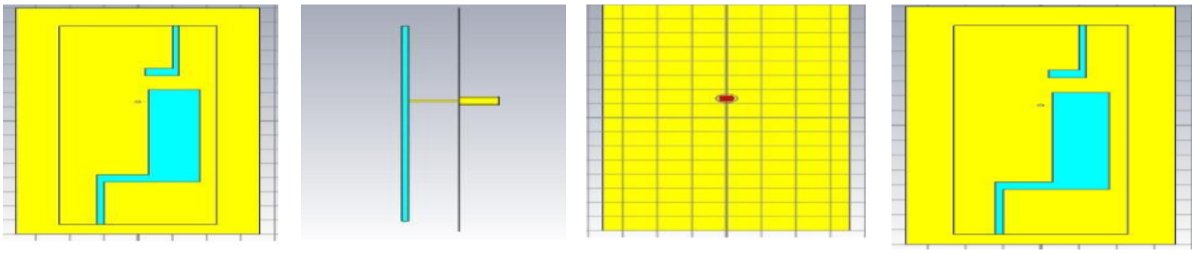
1. INTRODUCTION

The increasing needs for high gain antenna and compact size for industrial, scientific and medical (ISM) communication system are outlined as a requirement for better wireless network performance [1]. Various technologies for designing the antenna with compact size and high gain are introduced [2-4]. They are microstrip, waveguide, and substrate integrated waveguide (SIW). However, the waveguide technology and SIW are considered bulky and produce big size when it comes to the lower frequency. It is suitable for high frequency and millimeterwave applications [5-7]. Therefore, microstrip technology is preferred in the lower frequency due to the ability of having small size and can produce massive array. However, microstrip is not well known for its capability of producing high gain, since it uses dielectric material within the substrate which produces losses in the radiation part [8]. Therefore, there is a challenge to design a high gain antenna using microstrip technology at ISM band that has low profile, low loss, and compact size. Recent studies on microstrip antennas at ISM band, show a good performance as reported in [9-13]. It uses different techniques to achieve the compact size and high gain such as applying double layers of substrates as presented in [10]. Using rectangular or circular patch antennas [10, 11] has the benefit of increasing the gain and bandwidth as well.

Another technique of using air gap method is introduced in [12]. The antenna achieved a good gain of 5 dB and size reduction of 20%. However, the bandwidth is very narrow compared to the works presented in [9-11]. All these designs are proposed for on-grid communication. While the off-grid wireless network is indeed having the urgent of high antenna performance in terms of gain, bandwidth, and size [13-18]. In the case of any natural disasters or unable to communicate with the cell towers, the need to have reliable off-grid system as backbone is essential [19-25]. Therefore, the ISM band 915 MHz is proposed for off-grid communication devices in the case of coverage or communication off. This paper demonstrates a rectangular patch antenna with air gap technique based on microstrip technology at 915 MHz. The paper is divided as follow: section 2 presents the antenna design procedure. Section 3 discusses the findings and the analysis of the antenna performance. Section 4 concludes the finding and results.

2. MICROSTRIP PATCH ANTENNA: DESIGN PRINCIPLE

Figure 1 shows the proposed antenna strcutre. The proposed antenna is designed using FR4 substrate with dielectric constant of 4.3 and thickness of 1.6 mm. A rectangular patch is selected as antenna structure with dimensions of width, (W) and length, (L). The patch is design first to operate at 915 MHz.



(a) (b) (c) (d)

Figure 1. Front, right, back and perspective view of from 3D view of planar antenna

The calculations of the length, width and the value are found in [5]. The effective dielectric constant, of the substrate is given by width of patch, W [5]:

$$W = \frac{c}{2f\sqrt{(E_r+1)/2}} \tag{1}$$

Effective dielectric length, L_{eff} [5]:

$$L_{eff} = \frac{c}{2f\sqrt{eeff}} \tag{2}$$

The length of the antenna is can be calculated by using the following equations [5].

$$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon_{reff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{reff}-0.258)(\frac{W}{h}+0.8)} \tag{3}$$

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{w}\right]^{-1/2}, {}^{W}/_{h} > \tag{4}$$

Where h is the height of the substrate

As the dimensions of a patch are known. The length and width of a substrate is equal to that of the ground plane. For a ground layer, the length (L_g) and the width (W_g) are found based on the following equations [5, 6]:

$$L_g = 6h + L \tag{5}$$

$$W_g = 6h + W \tag{6}$$

To obtain optimal dimensions for the antenna, some parametric study has been done. The first parameter is to increase and decreases the length of the patch. At the beginning, the length of the patch is

110 mm which gives the frequency 2 GHz. By varying the length of the patch to achieve an optimal response at 915 MHz. Then the patch length of the antenna becomes 140 mm. At this length, the targeted frequency of 915 MHz is successfully achieved as shown in Figure 2. The second parameter is to vary the slot length to achive the desired gain at 915 MHz. This is can be clearly seen in Table 1. In summary, after the parametric study is used to obtain the optimum design dimentions. The final value of the antenna dimensions are shown in Table 2.

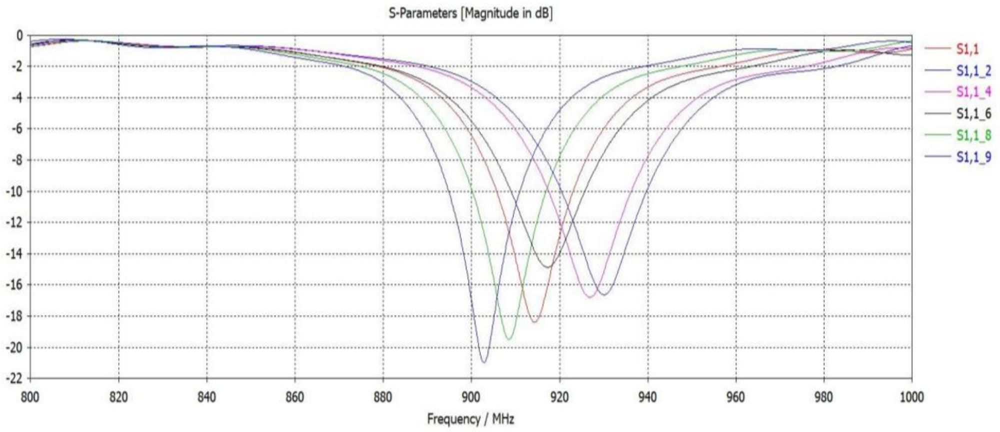


Figure 2. Return loss of patch at different lengths

Table 1. Effect of changing slot dimension

Length of slot (mm)	Gain (dB)
52	6.730
54	6.778
56	6.863
58	6.890
60	6.922
62	6.908

Table 2. The final parameters after optimization to antenna design

Parameters	Values (mm)
W	5
L	160
LS	140
Wu	3
Lu	60
HG	13

3. RESULTS AND DISCUSSION

CST software is used to simulate the proposed antenna at 915 MHz. The simulated parameters such as return loss, gain, directivity, VSWR. Figure 3 shows the simulated return loss at 915 MHz. A return loss of 18 dB is obtained at 915 MHz with bandwidth of 100 MHz. Figure 4 demonstrates the simulated radiation pattern in 2D and 3D structure and polar gain. It shows that the antenna generates the maximum gain of 6.928 dB along the bore side direction at 915 MHz.

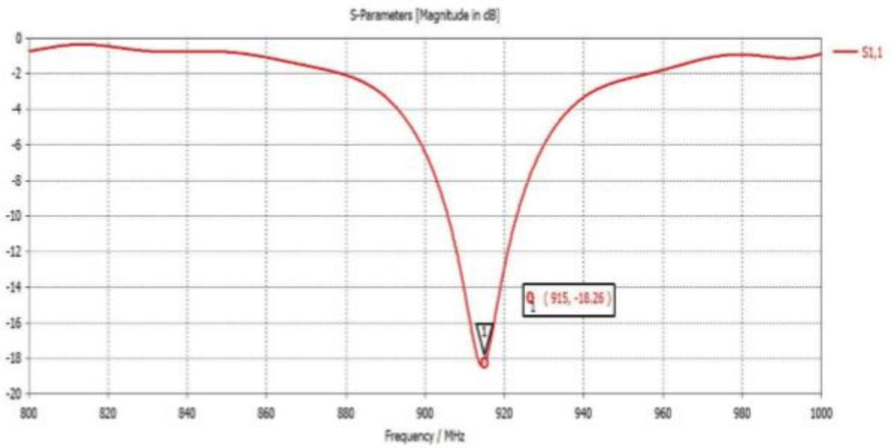
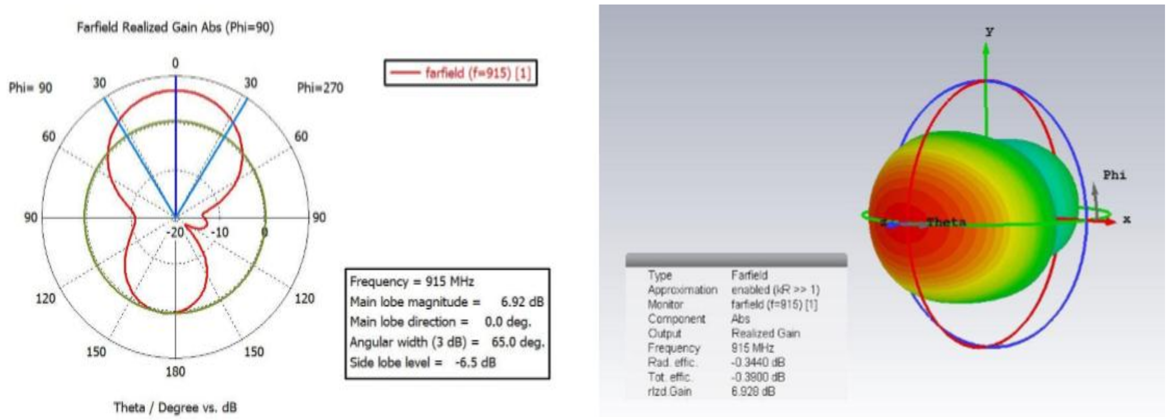


Figure 3. Return loss at frequency 915 MHz



(a) (b)

Figure 4. Radition pattern plots, (a) 2D Simulated beam width pattern and polar gain, (b) 3D plot of simulated radiation pattern

The proposed antenna is fabricated and measured using vector network analyzer (VNA) as shown in Figure 5. The measured antenna performance is slitlighly different compared to the simulated results. Figure 6 describes the measured return loss (S_{11}) which resonates at 915.6 MHz with return loss of 22.441 dB. At 915 MHz, a return loss of -14.68 dB. This loss of -3.8 dB is basically due to the fabrication tolerance or mimstch in the port excition. Figure 7 shows the measured radition pattern of E-Plane and H-plane at 915 MHz. It can be clearly noticed the disparences in the measured result with respect to the simulated one. This could be caused by the losses in the measurement cables or the mismatched at the port.

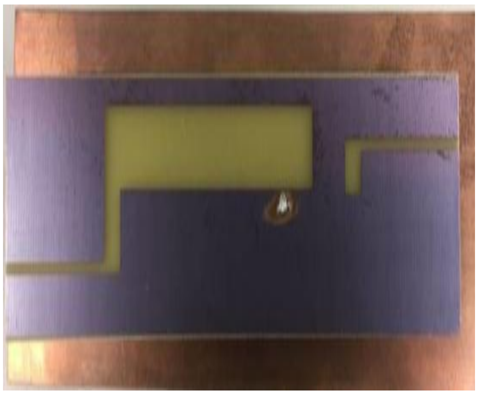


Figure 5. Fabricated antenna

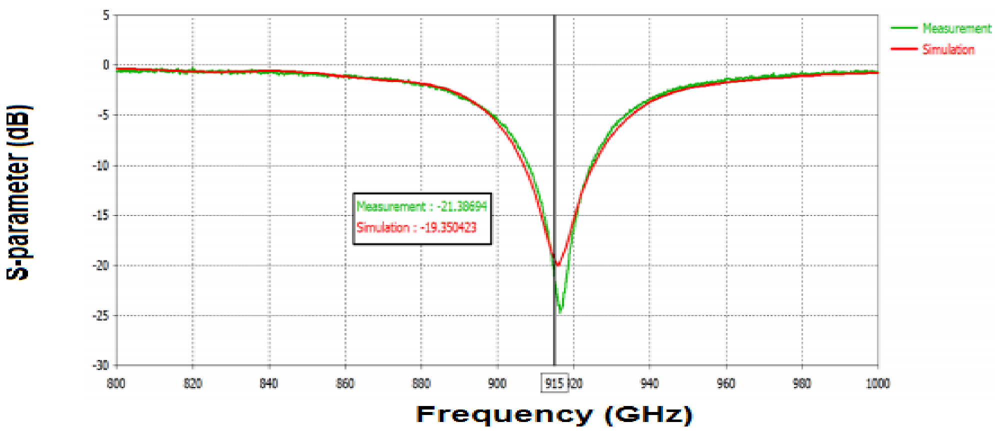
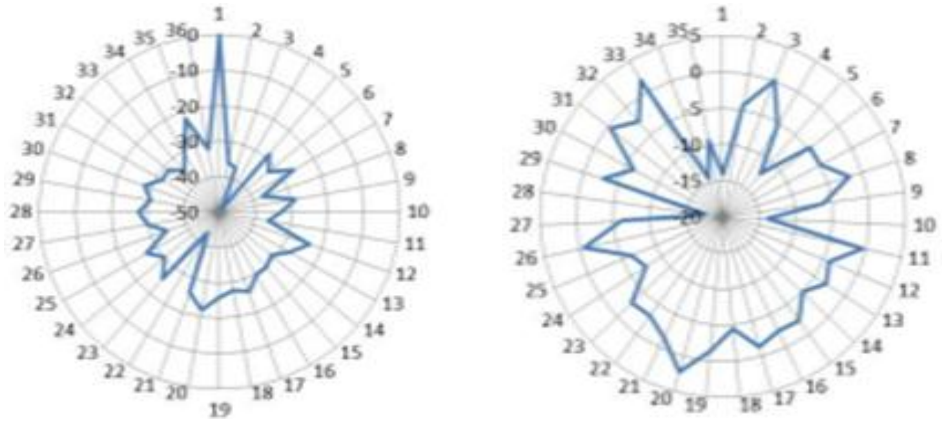


Figure 6. Measured S_{11} of the antenna prototype



(a) (b)

Figure 7. The measured radiation pattern of the antenna prototype

Table 3 shows the comparison of measurement and simulation results. The return loss in simulation is lower than in measurement. The simulation shows the return loss at frequency 915 MHz is -18.26 dB while in the measurement the return loss increases to -22.441 dB. The simulated gain of 6.928 dB at 915 MHz is and decrease to 5.044 dB in the measurement. These results could be due to a several factors such as soldering, environment and other factors.

Table 3. Comparision between simulated and measured results of the proposed antenna

Parameters	Simulation	Measurment
Frequecny (MHz)	915	915.6
Return Loss (dB)	18.28	22.44
Gain (dB)	6.928	5.044

4. CONCLUSION

This paper presented a new restangualr microstrip patch antenna at of 915 MHz. the designed antenna has implemented using air gap technique with slot line controlling the gain. The design is optimized using CST software and fabricated using low profile FR-4 substrate. The measured performance agreed well with simulated reults. A good return loss of 14.65 dB is btined at 915 MHz with a gain of 5.044 dB. The antenna has a small size fulfils the requirement of the modern wireless communication. Compact frequency micro-strip antennas have several advantages together with light-weight, low profile, and smaller size compared to alternative patch antennas.

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