Theoretical Analysis of Defected Ground Multiband Rectangular Shape Microstrip Patch Antenna

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Abstract This research work presented and implemented a rectangular microstrip patched antenna executed at 2.4 GHz. The proposed antenna designed with defected ground structure. A 0.8-mm-thickness FR4 substrate material with size 60 mm × 60 mm and permittivity of 4.4 was utilized for the proposed antenna design. HFSS software was utilized for the simulation. The proposed antenna resonates at 2.4 GHz. The performance of the antenna was analyzed by changing the feed position.

Keywords Microstrip · Antenna · Multiband and defected ground

1 Introduction

Microstrip patch antennas (MPAs) have gained much attention in modern-day wireless communication technology or ultra-wideband (UWB) applications owing to their significant attributes say, thin profile together with lightweight, low-cost and can also be used on any host surfaces. MPA has limitations such as limited bandwidth along with lower gain and also poor efficacy [1]. Thus, there is a great need for designing multiband antenna solely for the purpose of diminishing the number of antenna's embedded in device by a single antenna amalgamating numerous applications frequency band [2, 3]. Several methods were presented in the past to achieve multiband with notches along with slots. A lot of papers on multiband antennas were offered in the literature. In [4], a range of papers are presented in the literature where numerous methodologies are used to accomplish improved radiation

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pattern, UWB, and also current distribution over the radiating elements that include coplanar waveguide fed monopole antenna utilizing a defected substrate rhombus strip bounded annular ring antenna resulting from microstrip feedline using DGS [5]. Constructing slots on the patch might also be an easy approach for designing a multiband microstrip antenna [6]. The antenna should provide for a way to minimize the substrate size in order for the antenna size to be minimized [7]. A significant amount of miniaturization has been made possible by careful and meticulous investigation of slot insertion in patch and ground of MSA antenna [9], and the patch and ground plane are shorted for the further size reduction [10–15].

This research work presented proposed antenna design resonates at 2.4 GHz. The performance of the antenna was analyzed by changing the feed position. Parameters are simulated using AN SOFT HFSS v.l3.

2 Antenna Design

Various designs for a variety of shapes small-size and wide-bandwidth of microstrip antennas are design through HFSS software. In the design process of the flat surface comprising of an infinite together with a finite ground plane, back lobes are offered for the ground plane. The blueprint structure could be executed on the infinite ground plane. An accurate value is required to plot the full structure. The value could be allotted onto three axes. The structures shape can be adjusted by altering the position value. Once the antenna design is complete, the next step is to allocate frequency sweep for the actual frequency range. If we want to utilize the antenna for specific application, the corresponding return loss along with VSWR together with radiation pattern can be acquired. For optimum antenna performance, a thick dielectric substrate with low dielectric constant is appropriate.

This offers better efficacy, greater bandwidth and also improved radiation. The elementary microstrip patch antenna is a strip conductor of size $L \times W$ and thickness hacked by aground plane. The substrate thickness is lesser on compared to the wavelength. While designing an antenna, rotation of the axis along different directions offers various antenna structures. These could be appraised using high-frequency structure simulator software (Table 1).

1. **Width of the Patch**

$$W = \frac{C}{2f_r\sqrt{\frac{2}{\varepsilon_r+1}}} \tag{1}$$

C Free space velocity of light.
f_r Resonating frequency.
ε_r Relative permittivity of substrate.

Table 1 Comparison with previously designed-type antennas

References	Dimension	Frequency of operation (GHz)	Gain (dB)	Feeding method	Substrate
[8]	52 × 58	$F1 = 1.87$	4	Coaxial feed	FR4
		$F2 = 2.25$	4.56		
		$F3 = 4.8$	5		
[7]	33.47 × 29.14 × 1	$F1 = 1.48$	4.11	Coaxial feed	Polyester
		$F2 = 2.24$	4.88		
		$F3 = 3.84$	6.47		
Proposed	60 × 60 × 1.5	$F1 = 8.7$	5.17	Microstrip line	FR4
		$F2 = 12.3$	3.16		
		$F3 = 14.6$	7.44		
		$F4 = 16.1$	11.22		

2. **Effective Length**

$$L_{\text{eff}} = \frac{C}{2f_r\sqrt{\frac{2}{\varepsilon_r+1}}} \tag{2}$$

3. **Effective Dielectric Constant**

$$\varepsilon_{\text{reff}} = \frac{(\varepsilon_r + 1)}{2} + \frac{(\varepsilon_r - 1)}{2}\left[1 + 12\frac{W}{h}\right]^{-\frac{1}{2}} \tag{3}$$

4. **Patch Length Extension**

$$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon_{\text{reff}} + 1)\left(\frac{w}{h} + 0.264\right)}{(\varepsilon_{\text{reff}} - 0.258)\left(\frac{w}{h} + 0.8\right)} \tag{4}$$

5. **Length of the Patch**

$$L = L_{\text{eff}} - 2\Delta L \tag{5}$$

6. **Width of the Substrate**

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

7. **Length of the Substrate**

$$Wg = 6h + W \tag{7}$$

3 Geometry of the Antenna

Figure 1 gives an illustration of the rectangular-shaped microstrip patch antenna geometry. The substrate size is 60 mm × 60 mm and 1.5 mm thick. The patch is presented in a rectangular shape with an effective size of 35 mm × 18 mm. The antenna utilizes a microstrip line feeding method (Tables 2 and 3).

4 Result and Discussion

Simulation was executed utilizing HFSS Software. Subsequent sections offer the simulation result of the proposed antenna design (Fig. 2; Table 4).

5 Conclusion

A square-shaped antenna with defected ground structure was proposed and implemented. The suggested antenna's functional characteristics say, return loss together with its SWR along with the radiation pattern were examined. The designed antenna is resonating at 2.4 GHz. The proposed antenna's size is 60 mm × 60 mm. The offered antenna's size is small and meets the requirement.

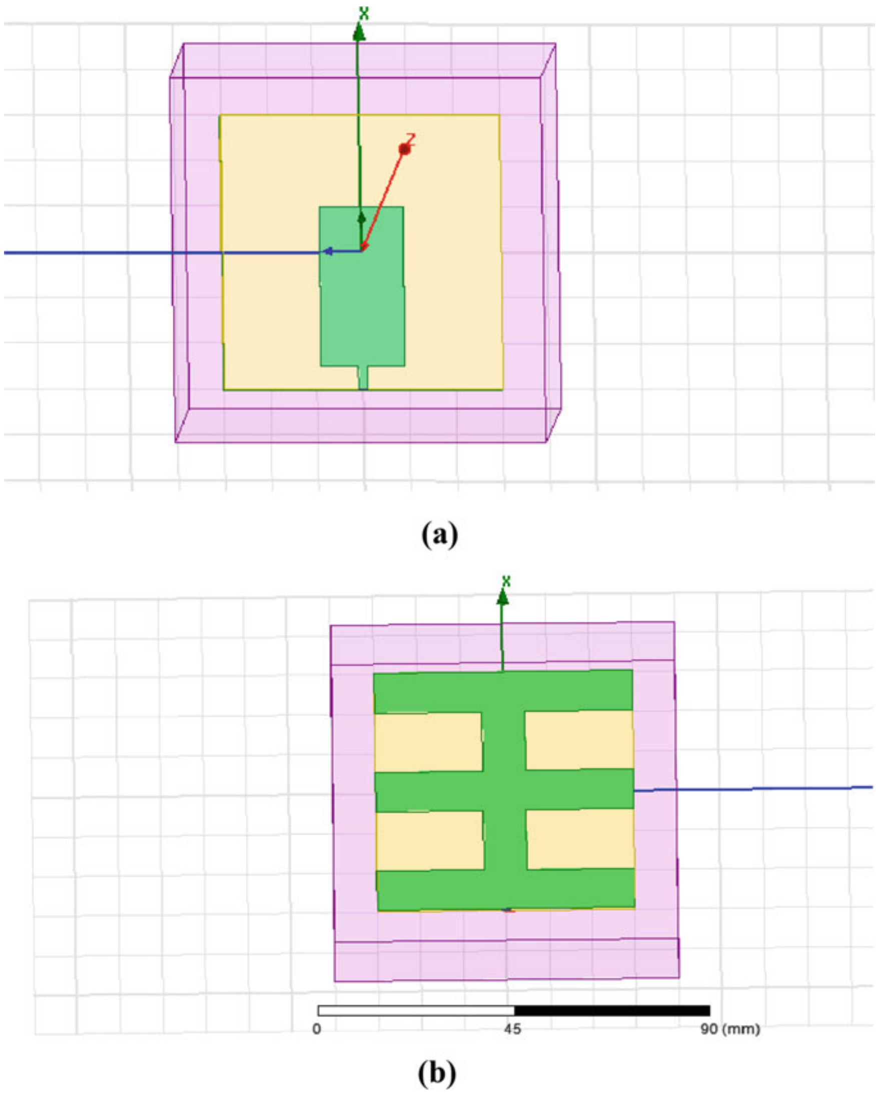


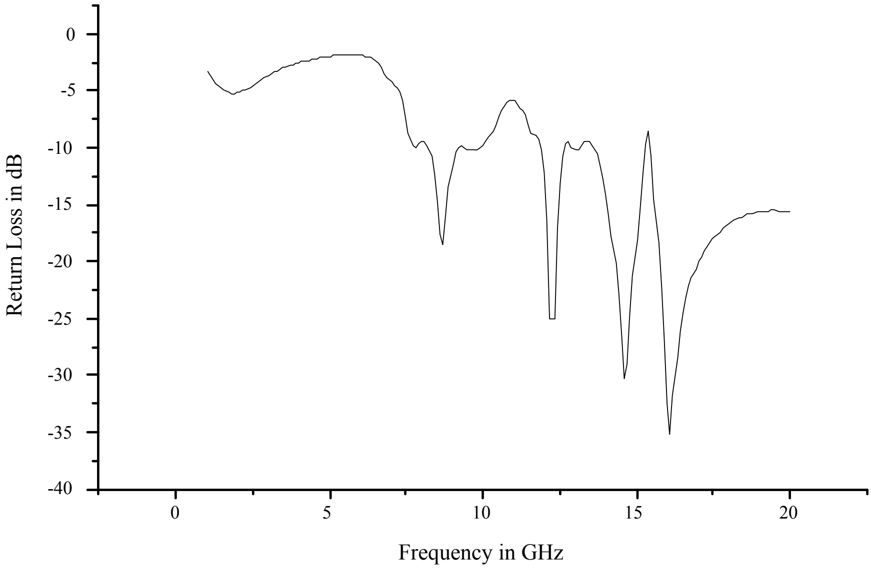
Fig. 1 **a** Rectangular-shaped microstrip patch antenna. **b** Ground defected structure

Table 2 Structural details of microstrip patch antenna

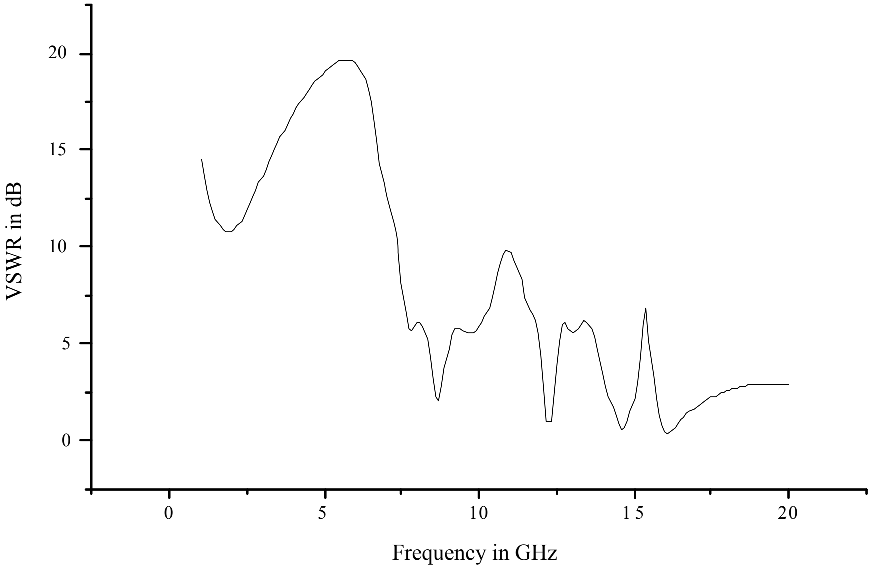
S. No.	Parameters	Value (mm)
1	Substrate width	60
2	Substrate length	60
3	Thickness of the substrate	1.5
4	Patch width	18
5	Patch length	35
6	Feed width	2
7	Ground width	60
8	Ground length	−60

Table 3 Structural details of different slot length and width

S. No.	Parameters	SLOT 1	SLOT 2	SLOT 3	SLOT 4
1	Slot width (mm)	10	−10	10	10
2	Slot length (mm)	−60	−60	−25	25



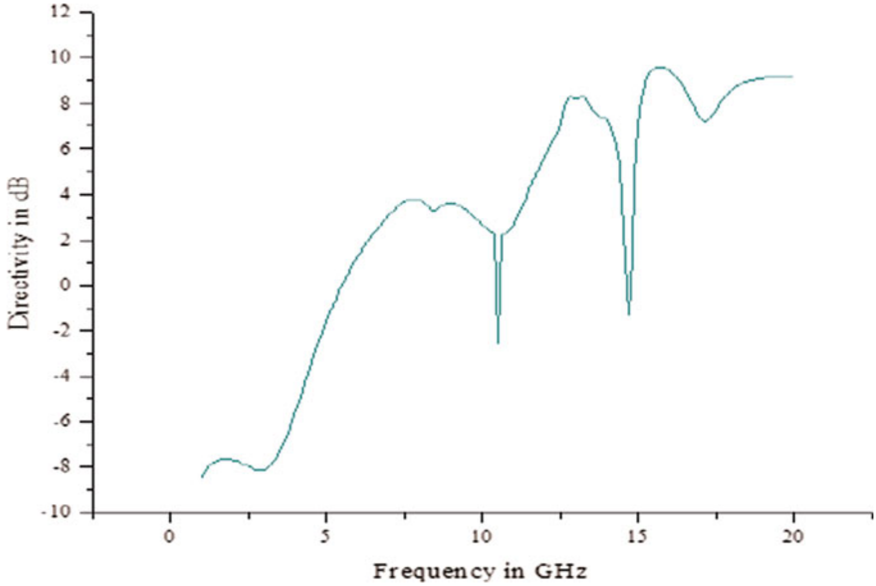
(a)



(b)

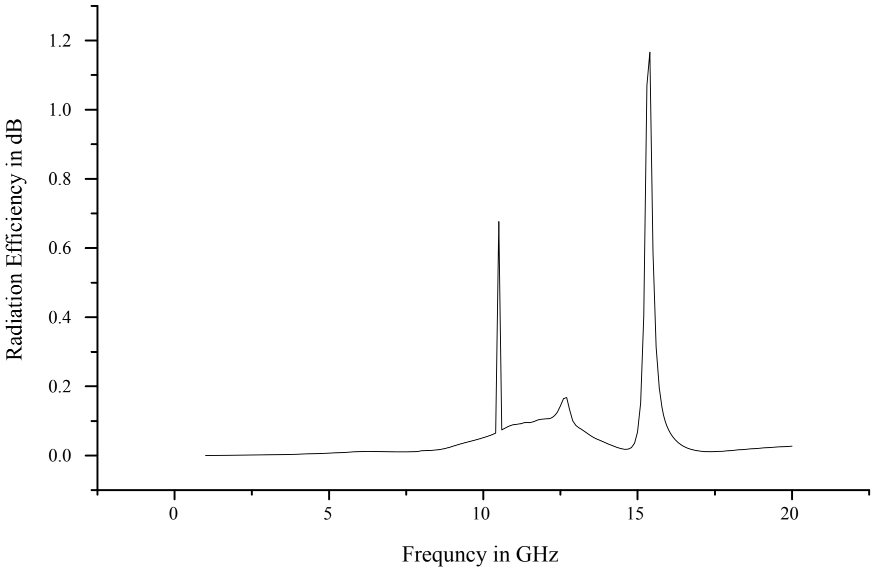
Fig. 2 **a** Return loss of rectangular shape microstrip patch antenna. **b** VSWR of rectangular shape microstrip patch antenna. **c** Gain of rectangular shape microstrip patch antenna. **d** Directivity of rectangular shape microstrip patch antenna. **e** Radiation efficiency of rectangular shape microstrip patch antenna. **f** Impedance of rectangular shape microstrip patch antenna. **g** Radiation pattern at frequency 8.7 GHz. **h** Radiation pattern at frequency 12.3 GHz. **i** Radiation pattern at frequency 14.6 GHz. **j** Radiation pattern at frequency 16.1 GHz

(c)



(d)

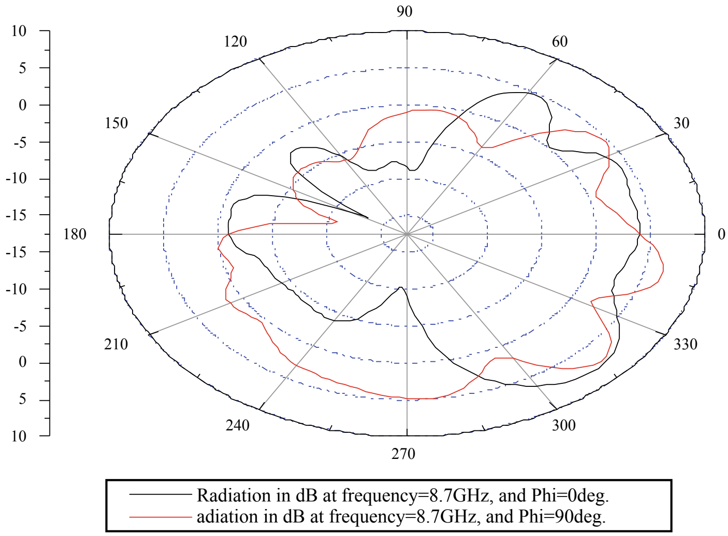
Fig. 2 (continued)



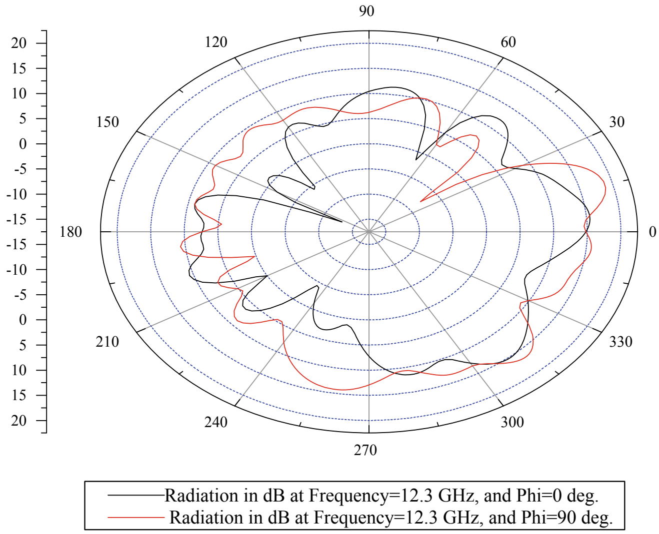
(e)

(f)

Fig. 2 (continued)

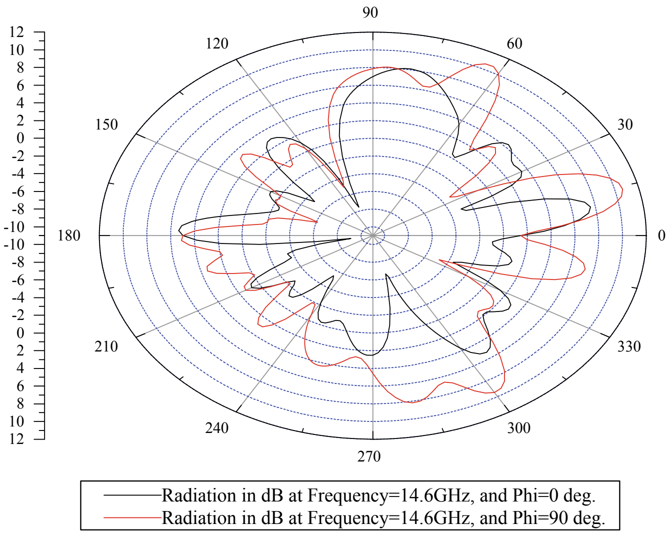


(g)

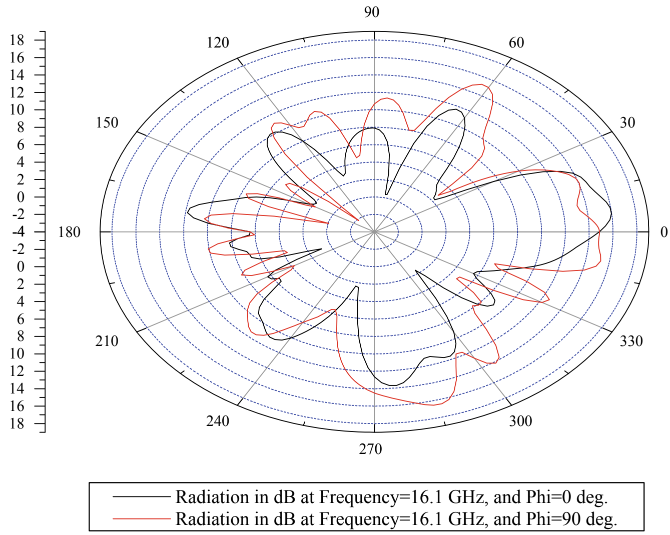


(h)

Fig. 2 (continued)



(i)



(j)

Fig. 2 (continued)

Table 4 Summary of the simulation results

Frequency of operation (GHz)	Return loss	Gain	Directivity	VSWR	Impedance in 20 dB
8.7	−18.467	5.179	6.6337	2.0824	33.1481
12.3	−24.975	3.161	5.0821	0.9807	34.1448
14.6	−30.223	7.441	8.2649	0.5356	33.5804
16.1	−35.244	11.226	19.6584	0.3004	33.8898

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