



Parasitic Rectangular Patch Antenna with Variable Shape Ground Plane for Satellite and Defence Communication

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Abstract

This paper represents a simple parasitic rectangular patch antenna with variable shape ground plane, the ground plane is partial with slots on the upper part (connected to port) with circular parasitic elements. Designed of the proposed antenna on an FR-4 substrate material with permittivity 4.3 and 0.025 loss tangent and has dimensions of $20*20*1.5$ mm³. The impedance bandwidth of the proposed antenna is 145% (3.52GHz – 19.1GHz). The peak gain and radiation efficiency of the proposed antenna are 8.2 dB and 81% respectively in the proposed band of operation. The radiation pattern of the proposed antenna is stable for lower order frequency band with the fulfillment of omnidirectional characteristics. Due to simplicity and compactness, the proposed antenna is suitable for satellite communication (3-6 GHz and 7-9 GHz), defence communication applications and it covers 8-12 GHz (X-band). The proposed antenna details are described and simulated results are elaborated.

1. Introduction

Designing of compact antenna with large frequency range is very difficult, the rectangular patch antenna with the variable ground plane is highly considerable for X-band or satellite communication. Miniaturized dual broadband printed slot antenna with parasitic slot and patch showing dual band operates from 2.4 to 6.1 GHz and 9.4 to 13.8 GHz [1]. Bandwidth enhancement is achieved by the introduction of a curved slot in the patch [2]. A printed wide-slot antenna is with the parasitic patch is used for bandwidth enhancement [3]. Printed microstrip slot antennas are widely used in various communication systems because wide-slot antennas have two orthogonal resonance modes, which are merged to create a wide impedance bandwidth [4]. A simple microstrip patch antenna is designed on an FR4 material to achieve 2.4 GHz frequency [5]. An inset fed rectangular microstrip patch antenna is simulated for achieving WLAN frequency [6]. By designing a rectangular microstrip patch antenna, 2.4 GHz frequency is reported [7]. Bandwidth enhancement is obtained by the rotated square wide slot. A printed wide-slot antenna with the rotated slot is proposed for bandwidth enhancement in [8]. Ultra-wideband applications have been reported by excitation of higher order resonance on

the introduction of a U-shaped slit in the partial ground plane and rectangular parasitic patches adjacent to the microstrip line [9]. Recently a compact planar antenna with a stair-shaped ground plane with broadband characteristics has been reported [10]. By adding a folded strip in the planar monopole antenna, dual UWB band characteristics have been reported [11]. By the introduction of the X-shaped slit in the circular patch with T-shaped structure in the partial ground plane, the wideband behaviour of antennas has been reported [12]. Cutting rectangular, U-shaped, slots for obtaining broadband behaviour have been proposed [13].

In this paper, a rectangular patch with the variable ground plane is proposed. The gain of the antenna is very high 8.2 (dB). The optimum size of the proposed antenna is $20*20*1.5$ mm³. The proposed antenna shows a stable radiation pattern at lower frequency order 4.2 GHz and quasi-stable radiation pattern at higher order frequency range 17.3 GHz.

2. Antenna Design

A compact rectangular patch antenna has a small in size of $20*20*1.5$ mm³ with ϵ_r of 4.3, μ of 1 and loss tangent of 0.025. The microstrip line of the proposed antenna has a resistance of 50Ω . Geometrical configuration and the exact parameter of the proposed antenna as shown in Fig. 1. (All values are in mm).

Patch and microstrip are printed on one side of the substrate and the various slots are created on the ground plane on the other side of the substrate. Parasitic in the shape of rectangles has been introduced on both the sides of the antenna. The lower order resonance is achieved by adding circular parasitic element. The electrical size of the antenna is increased due to by adding parasitic slots in both sides of the proposed antenna as a result resonance are excited at lower order frequency band. The antenna resonates in a single band of frequency ranging from 3.5 to 19.1 GHz. The partial ground plane created has not only reduced the resonant frequency to a lower range but also created dual bands. Further enhancement of the bandwidth is observed by cutting 2 slots on the upper part of the ground plane. Finally, parasitic elements on the ground, as well as front plane, are introduced symmetrically. The proposed antenna is simulated using CST microwave studio.

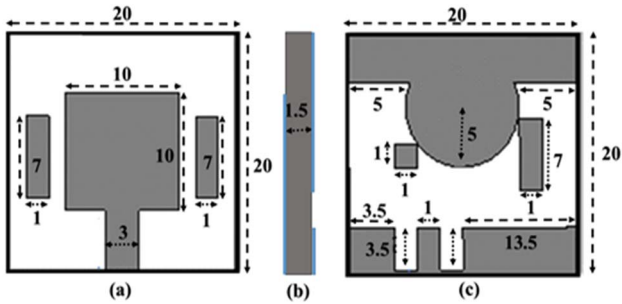


Figure 1. Geometry configuration and parameters of proposed antenna. (a) Front view (b) side view. (c) Back view (ground plane) (All values are in mm).

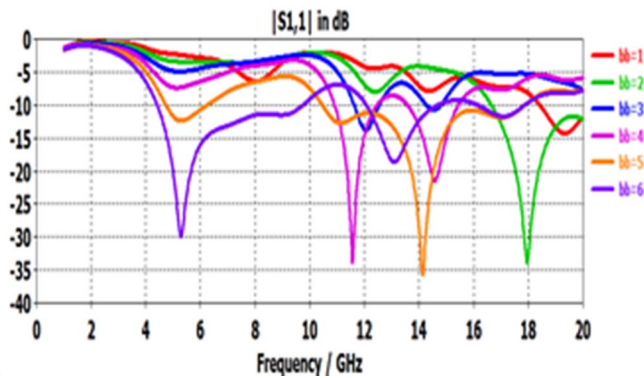


Figure 2. Simulated return loss of parametric operation on ground plane.

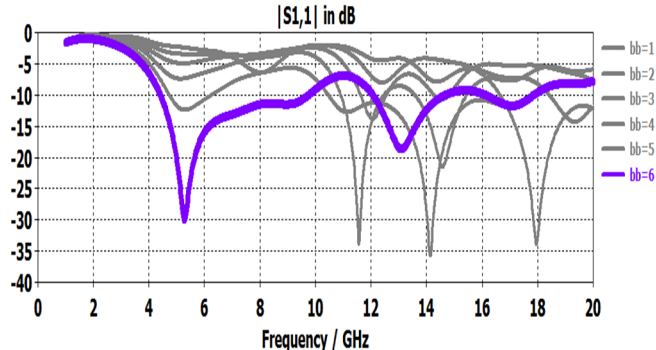


Figure 3. Simulated return loss of parametric operation on ground plane (bb=6 giving the most optimized result).

3. Parameter Study

In this section, steps are described in detail. A simple patch antenna was designed with the dimension of $20 \times 20 \times 1.5$ mm³ ($l=10$ mm; $b=10$ mm) and a patch of 10×10 mm ($l_p=5$ mm; $b_p=5$ mm) as shown in Fig 1. The material used is FR4 with permittivity 4.3 and 0.025 loss tangent. The first cut from the Centre and a parametric operation gave the optimized dimension as 20×12 (in mm); ($bb=6$ mm; $ll=10$ mm). The corresponding result is as shown in the Fig. 2. As it can be clearly seen from the next figure that a significant improvement was observed when a patch of dimension 20×12 (in mm) was created on the ground plane.

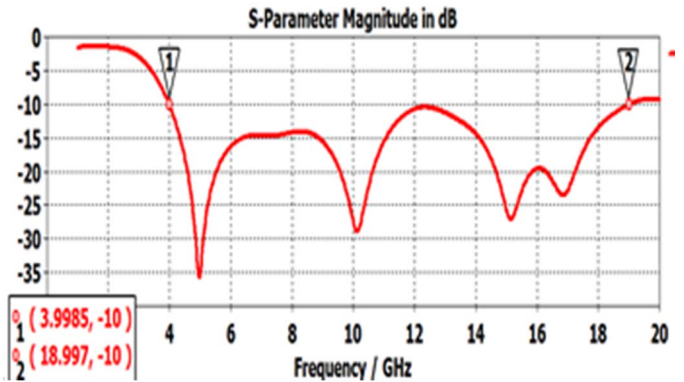


Figure 4. Simulated return loss of antenna on creating 2 rectangular slot.

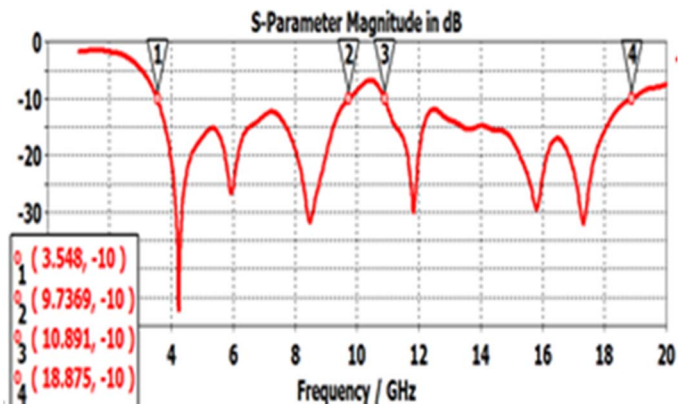


Figure 5. Simulated return loss of antenna on creating parasitic elements.

This is due to impedance matching at lower frequencies. Not only the antenna started resonating in the lower band but also the bandwidth increased. But it was observed that antenna was behaving as a dual-band antenna. To make it single band broadband, the frequency from 10-12 GHz had to resonate.

Slots of various dimensions were further created on the ground plane and it was observed that rectangular slots provide better impedance matching and it started to resonate at a wider range. 2 slots of dimension 1×3.5 (mm) were then cut. The result was obtained as shown in Fig.4.

On adding the slots, point 1 from Fig.4. Has started resonating from 3.99 GHz and the range of frequency from 9.75 to 12.08 GHz has also started to resonate. To further improvise it parasitic elements were added not just adjacent to the patch but on the ground plane as well. A circular patch was then added and the obtained result is shown in Fig.5.

To make the antenna resonate from 9.7 to 10.89 GHz and hence make it a single broadband, dimensions of all the patches were optimized.

Similar shaped patches were added first but on decreasing the length of one of the patches on the ground plane, better result were obtained. The graph due to that patch is shown in Fig.6. In the next section, various results obtained after simulation are described and elaborated.

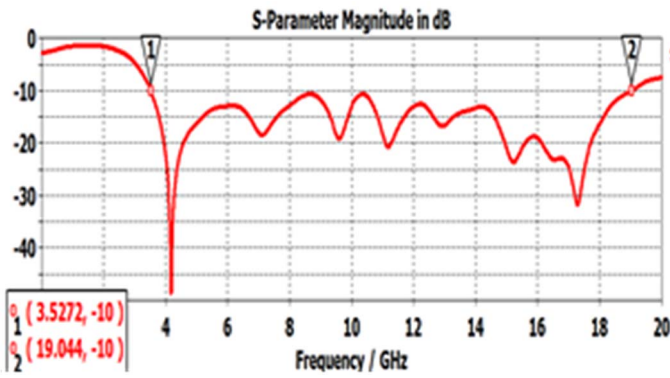


Figure 6. Simulated return loss of proposed antenna (final).

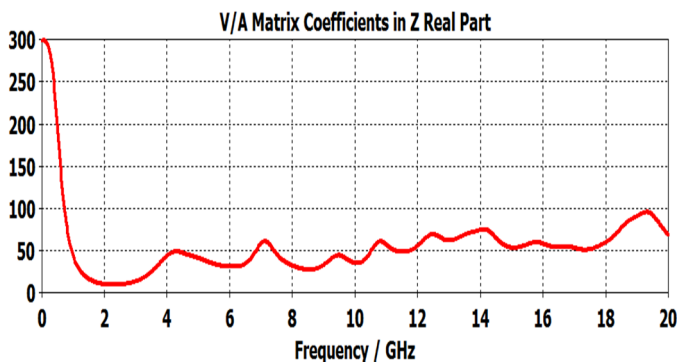


Figure 7. Simulated real part of Z-matrix for the proposed antenna.

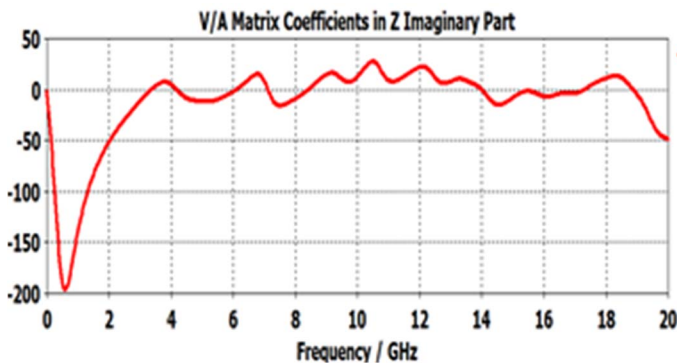


Figure 8. Simulated Imaginary part of Z-matrix for the proposed antenna.

4. Results

The proposed antenna has a compact size and resonating from 3.52 – 19.1 GHz is in good agreement with the various simulated plots. The real part of Z – matrix of the antenna is shown in Fig. 7. From the frequency range from 3.99 to 6.99 GHz the input impedance is below the 50 Ω line, due to some return losses and after that, the input impedance is normalized between 7 to 12 GHz, due to perfect matching. The input impedance is above the 50 Ω line, between the 12 to 19.1 GHz due to mismatching.

Fig. 8 shows the simulated imaginary part of the impedance curve, it has been observed that the proposed antenna behaves like inductive or capacitive during the frequency range of 3.99 to 8.6 GHz and after that purely inductive behavior is observed during 8.7 to 14 GHz.

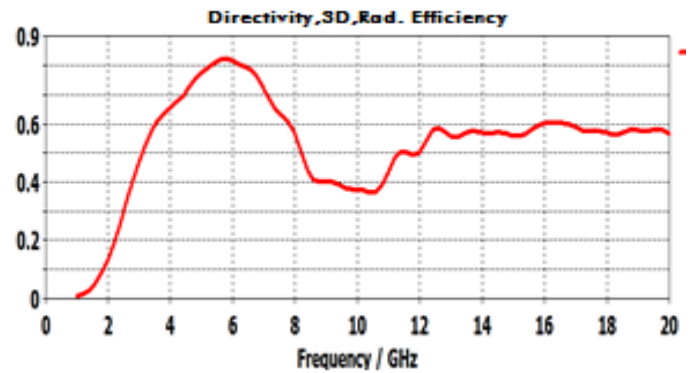


Figure 9. Simulated efficiency plot of the proposed antenna.

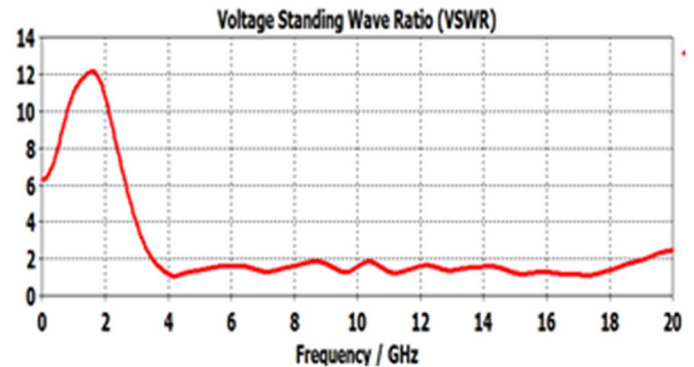


Figure 10. Simulated value of VSWR for the proposed antenna.

After 14 GHz some part is capacitive and inductive behavior observed. Fig. 9 shows the simulated radiation efficiency of the proposed antenna is about 81% Due to perfect matching.

Fig. 10. shows the simulated value of VSWR and it is observed that the voltage for the entire proposed frequency band the VSWR plot is below 2 that shows a good arrangement of the proposed antenna.

Fig. 11. The gain of the proposed antenna is reached at about 8.2 dB, the high gain is obtained because of increasing the electrical size of the antenna with the good arrangement of the partial ground plane with the parasitic slot.

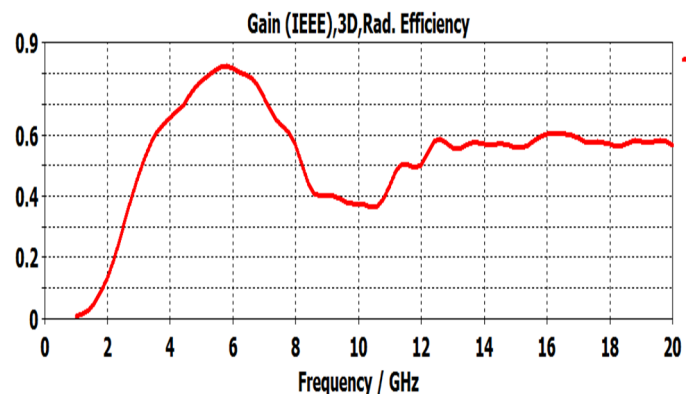


Figure 11. Simulated gain for the proposed antenna.

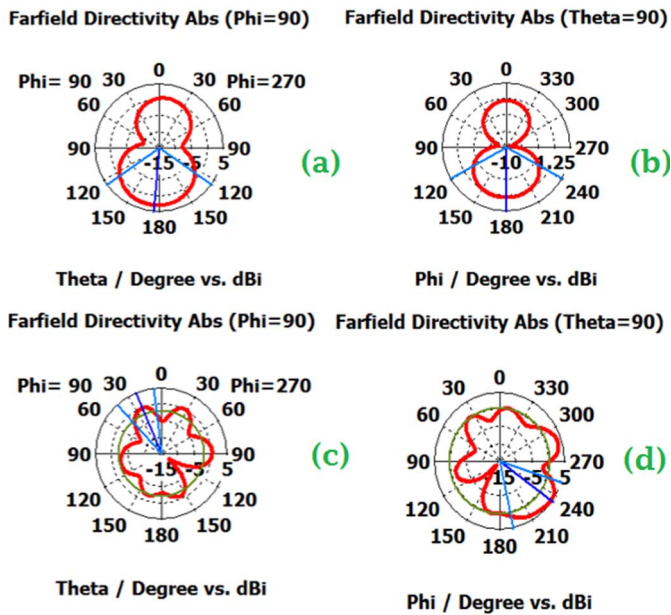


Figure 12. Stimulated radiation pattern of the proposed antenna (a) 4.2 GHz (phi) (b) 4.2 GHz (theta) (c) 17.3 GHz (phi) (d) 17.3 GHz (theta).

Fig. 12. Shows the simulated radiation pattern y-z plane ($\Phi=90^\circ$) and x-y plane ($\Phi=0^\circ$). The compact monopole antenna should be radiated omnidirectional path, stable omnidirectional H-plane and bidirectional E-plane radiation pattern are observed during 4.2 GHz band because radiations are contributed by both rectangular patch and variable shape ground plane. As the frequency is increased the losses increase due to this the unstable radiation pattern is observed at higher frequency band 17.3 GHz. It is observed that all the simulated graphs are in optimum result that fulfill the requirement of the proposed antenna.

5. Conclusion

A proposed compact rectangular antenna with variable shape ground plane has been proposed in this article. The proposed antenna has an overall size of $20 \times 20 \times 1.5$ cubic millimeter, and the structure has been simulated using (CST Microwave studio) a standard Finite integration technique (FIT) based commercial electromagnetic simulator. The total fractional bandwidth of the proposed is 145% (3.52GHz – 19.1GHz). The real part is normalized to 50Ω throughout the entire operational bandwidth. The behaviour of the proposed antenna is capacitive and inductive is observed by imaginary part throughout the entire bandwidth. The Peak gain of the antenna is 8.2 dB with the 81% of the radiation efficiency of the proposed antenna are in good agreement. Lower order stable radiation pattern fulfill the monopole requirement. As it can be clearly seen from the various graphs, the antenna is well suited for working in 3.52 to 19.1GHz range. A wide range of application is covered under this range. It covers 8-12 GHz (X- band) and it can be used in satellite

communication (3-6 GHz and 7-9 GHz) with defence communication applications.

6. References

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