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Research Article

# Compact Defected Ground Structure Microstrip Patch Antenna for Wi-Fi Applications

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Abstract: In recent years microstrip patch antennas having minute size is an exciting topic for many researchers and design engineers. In this paper a novel miniaturized microstrip patch antenna for Wi-Fi applications is proposed. The concept of defected ground plane (DGS) is used for achieving miniaturization. The prototype is designed and analyzed by CST Microwave Studio. Low cost FR-4 substrate having thickness of 0.8 mm is used for the design of the antenna. The antenna is having compact size of 16 × 17 mm$^2$. The simulated results demonstrate that the antenna has bandwidth of 2.02% (49 MHz) with -41.46 dB reflection coefficient at resonating frequency. The antenna has bidirectional radiation pattern. The proposed design provides a size reduction of 75.46% in comparison to conventional patch. The proposed antenna is having compact size and is low cost which makes it a suitable candidate for 2.4 GHz Wi-Fi band.

*Keywords: Wi-Fi; microstrip antenna; DGS; miniaturization; slot*

## I. Introduction

Wireless technology has developed rapidly in recent years, making cellular communication more advanced than ever [1]. It has revolutionized our lives, our jobs, and how we interact with one another. When it comes to wireless communication, an antenna plays a vital role. Due to the stringent requirements of modern communication systems, miniaturized antennas have become increasingly popular [2]. Due to their complexity and restrictions, designing a compact antenna becomes a crucial task for scientists and researchers [3]. Recent years have seen an increase in the use of microstrip patch antennas due to their low cost, light weight, inexpensive and easy manufacturing using printed circuit boards [4-5].

In [5] authors presented a detailed review of topology- and material-based methods for miniaturization of antenna. The topology-based miniaturization techniques include the defected ground structure. Microstrip antennas that integrate defected ground structures (DGS) have become increasingly popular thanks to their simple structural designs and ease of imprinting on microstrip substrates [6].

Slot on the patch affects the input impedance matching and degrade pattern purity. It can be prevented by employing slots on the ground plane known as defected ground structure (DGS). In comparison to slot on the patch DGS provides better results in terms of frequency and cross-polar (XP) level [7]. As a result of the modification to the ground plane, a discontinuity has occurred in the ground plane, which has caused the primary radiator's electric current to reroute along the ground's conducting surface, thus increasing the ground plane's electrical length [5, 8]. In addition to reduce the antenna size DGS is integrated in patch antenna for various applications like harmonic suppression, cross-polarization reduction [9] and mutual coupling reduction [10].

Each DGS shape has its own characteristics and creates effect on the performance of the device according to its geometry and size. Effective capacitance and effective inductance of the model are changed by embedding the slots on the ground plane, resulting in shifting of resonance frequency to its lower side. Thus, compactness is achieved by using DGS [11].

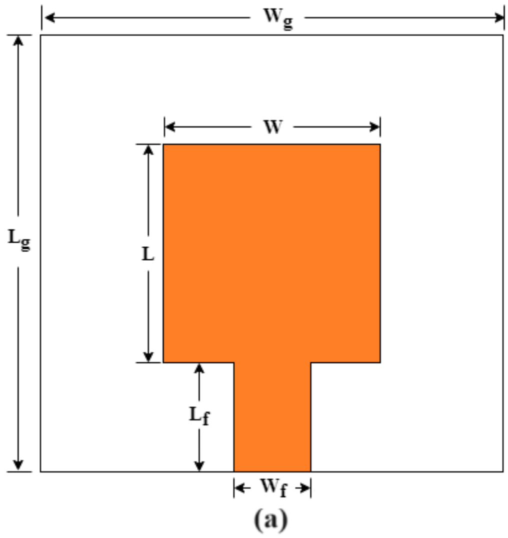
By introducing DGS antenna resonance frequency is shifted from 5.7 GHz to 3 GHz resulting in size reduction up to 50% [10]. For lower GNSS, WiMAX, C-band and WLAN systems a compact multiband antenna utilizing slot in the radiating patch and the ground plane is addressed in [12]. A miniaturized quadband heart-shaped planar monopole antenna (QHPMA) by using the combination of the DGS, and the metallic vias is presented in [13]. For LoRa application at 868 MHz an inset fed miniaturized antenna with defected ground plane is proposed [14]. Here linearly polarized waves are generated. Using defected ground structure, a miniaturized microstrip patch antenna array is demonstrated in [15], for S band at 2.2 GHz with size reduction up to 83% in comparison to conventional patch antenna. A circularly polarized triple band microstrip fed simple square slot antenna is presented in [16] for S-band and C-band.

Based on the literature presented above, it is evident that by using the concept of defected ground plane miniaturized microstrip patch antennas have been designed for various different wireless applications, these antennas can be single band, multi band antennas or they can be reconfigurable one. The main purpose of this work is to design and analyse a miniaturized microstrip patch antenna with defect in the ground plane. A novel shape of DGS is proposed which results in the antenna to operate at 2.4 GHz Wi-Fi band. CST microwave studio [17] is used for the design and analysis of the proposed antenna.

The rest of the paper is organized as follows. In section II the methodology for the designing of the proposed miniature antenna loaded with DGS is discussed. Section III deals with the discussion of simulation results. Finally, section IV concludes the paper.

## II. Design Methodology

The main purpose of this work is to design a compact antenna for Wi-Fi applications using DGS method. This section describes the design methodology of the proposed antenna. The geometry of the proposed antenna is shown in **Fig.1**. As shown modifications are done in the ground plane which results in the discontinuity in the ground surface current path. The defect in the ground plane alters the electrical length of the ground plane and the antenna starts resonating at lower resonant frequency.



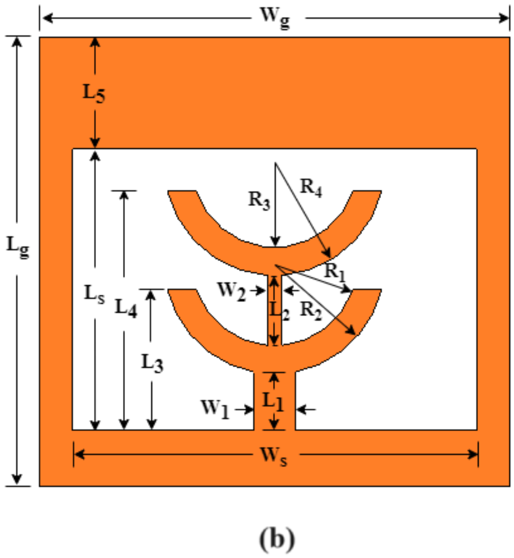




***Figure 1.*** *Antenna geometry (a) front view and (b) back view.*

As shown in **Fig.1** the top layer of the antenna consists of square radiating patch and the ground plane is having defected structure. The square patch is fed with 50 Ω microstrip feed-line. The antenna is printed on low cost FR-4 substrate having thickness

***Table 1.*** *Dimensions of the proposed antenna (mm).*

| *Parameter* | *Value* | *Parameter* | *Value* | *Parameter* | *Value* | *Parameter* | *Value* |
|---|---|---|---|---|---|---|---|
| $L_g$ | 16 | $L_f$ | 4 | $L_2$ | 2.5 | $W_2$ | 0.5 |
| $W_g$ | 17 | $W_f$ | 3 | $L_3$ | 5 | $R_1$ | 3 |
| $H_s$ | 0.8 | $L_s$ | 10 | $L_4$ | 8.5 | $R_2$ | 4 |
| L | 8 | $W_s$ | 14.6 | $L_5$ | 4 | $R_3$ | 3 |
| W | 8 | $L_1$ | 2 | $W_1$ | 1.5 | $R_4$ | 4 |

of 0.8 mm, dielectric constant of 4.4 and loss tangent of 0.02. The overall size of the antenna is $L_g \times W_g \times H_s = 16 \times 17 \times 0.8$ mm$^3$. The optimized design parameters of the proposed antenna are listed in Table 1. The size reduction achieved is 75.46% in comparison to conventional patch. With the proposed design, we aim to create a compact, low cost antenna for Wi-Fi applications. The design strategy was to keep the reflection coefficient ($S_{11}$) of less than -10 dB.

## III. Results and Discussions

To study the performance of the proposed microstrip patch antenna, the antenna prototype is designed, simulated, and analyzed using CST microwave studio.

In order to understand the influence of the various design parameters on the resonant frequency of the antenna parametric analysis is necessary. Parametric analysis is performed by varying one parameter at a time and keeping other as constant. The vital parameters selected for analysis are $W_1$ and $W_2$.

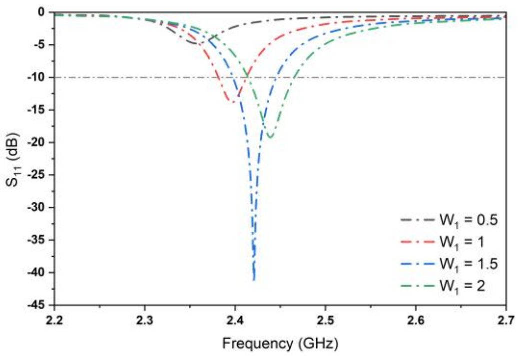



***Figure 2.*** *Effect of variation in $W_1$ on the reflection coefficient ($S_{11}$).*

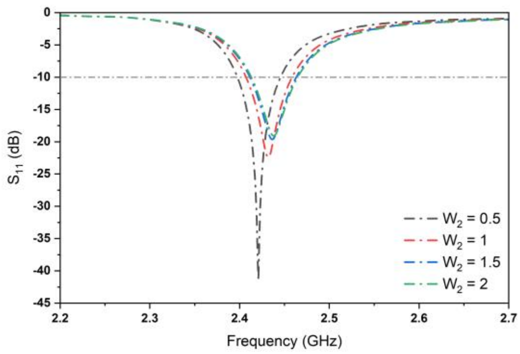



***Figure 3.*** *Effect of variation in $W_2$ on the reflection coefficient ($S_{11}$).*

The effect of width $W_1$ on the performance of the antenna is studied first. The width $W_2$ is kept constant at 0.5 mm and the width $W_1$ is varied from 0.5 mm to 2 mm in suitable steps. The effect of variation in $W_1$ on the reflection coefficient is shown in **Fig.2**. As can be seen from the figure as the width $W_1$ increases, the resonant frequency increases significantly. When $W_1$ equals to 1.5 mm the antenna resonates at 2.42 GHz with reflection coefficient equals -41.46 dB.

**Fig.3** shows the effect of variation on the reflection coefficient for different values of $W_2$ keeping $W_1$ constant at 1.5 mm. The width $W_2$ is varied from 0.5 mm to 2 mm in suitable steps. As the value of $W_2$ increases, the frequency shifts from 2.42 GHz to 2.44 GHz with reduction in reflection coefficient from -41.46 dB to -19.09 dB.

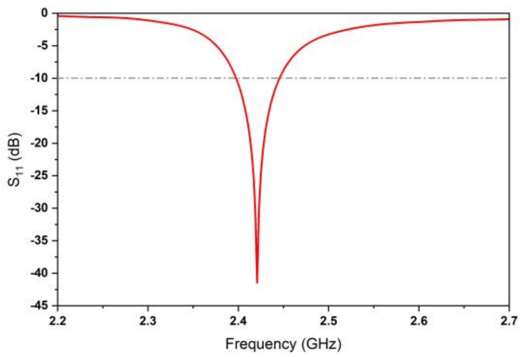



***Figure 4.*** *Simulated reflection coefficient ($S_{11}$) of the proposed antenna.*

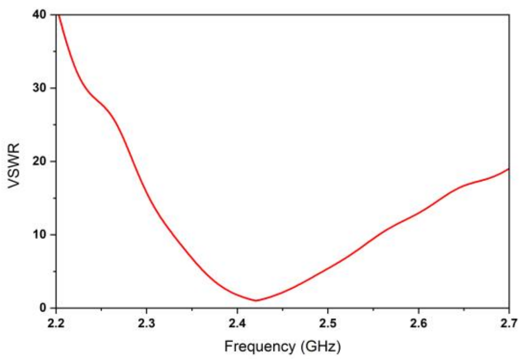



***Figure 5.*** *Simulated VSWR of the proposed antenna.*

**Fig.4** shows the reflection coefficient of the proposed antenna. The simulated results show that the antenna resonate at 2.42 GHz with reflection coefficient ($S_{11}$) of -41.46 dB and has bandwidth of 2.02% (2.397-2.446 GHz). For efficient performance of the antenna the value of VSWR should be between 1 and 2. The VSWR plot is shown in **Fig.5**. At the operating frequency the antenna has VSWR value of 1.01.

The simulated normalized radiation patterns of the proposed patch antenna including the co-polarization and cross-polarization in the H-plane ($\phi = 0$) and E-plane ($\phi = 90$) are shown in **Fig.6**. The proposed antenna produces almost symmetrical

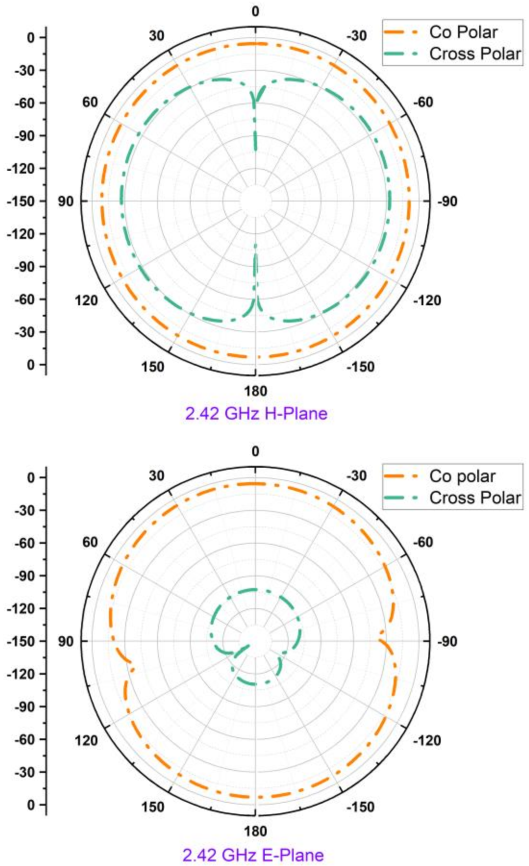



***Figure 6.*** *Simulated normalized radiation patterns of the proposed antenna.*

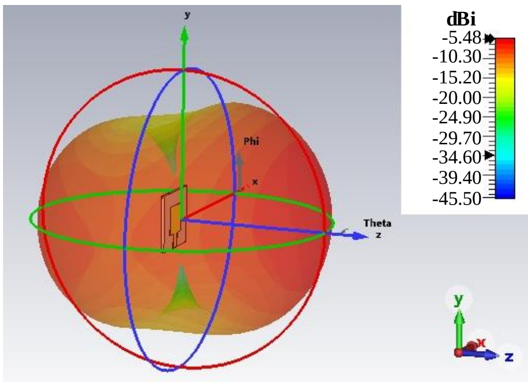



***Figure 7.*** *Simulated 3D radiation pattern of the proposed antenna.*

radiation pattern having bidirectional nature. In the proposed design the E-plane and H-plane cross-polarization levels are lower than that of the co-polarization levels. The 3D radiation pattern of the proposed antenna at 2.42 GHz is shown in **Fig. 7**. The simulated gain of the antenna is -5.48 dBi.

For further analysis, we have investigated surface current impact on the performance of the antenna. **Fig.8** shows the average surface current distribution on both the patch and the ground plane of the proposed antenna. As can be seen in figure the intensity of current on the defected ground plane is very high in comparison to the patch. The figure also shows the current path on the top surface is along the microstrip line to the edges of the square patch and then the current shifts to the ground plane from the top of the DGS towards its bottom completing its path. In this way the DGS affects the ground plane's electrical length and the antenna is able to radiate at lower frequency.


***Figure 8.*** *Current distribution of patch antenna with DGS, (a) front view, (b) back view.*

## IV. Conclusion

A miniaturized microstrip patch antenna fed by microstrip feed line is proposed. Modifications are done on the ground plane to achieve the miniature size. The antenna operates at 2.42 GHz with reflection coefficient of -41.46 dB. Detailed analysis is carried out to investigate the effect of vital parameters on the design of antenna. The design provides substantial reduction in size as compared to a typical microstrip patch antenna operating at the same frequency. The antenna is having miniature size to be installed in communication systems where available space is a major issue.

### AUTHOR CONTRIBUTIONS

**D. Sakle**: Conceptualization, Theoretical analysis, Antenna simulation, Writing, Review and editing.

**M. Deshmukh**: Supervision, Review and editing.

### Disclosure Statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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