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Size Reduction and Gain Enhancement of a Microstrip Antenna using Partially Defected Ground Structure and Circular/Cross Slots

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ABSTRACT

Microwave engineers have been known to designedly created defects in the shape of carved out patterns on the ground plane of microstrip circuits and transmission lines for a long time, although their implementations to the antennas are comparatively new. The term Defected Ground Structure (DGS), precisely means a single or finite number of defects. At the beginning, DGS was employed underneath printed feed lines to suppress higher harmonics. Then DGS was directly integrated with antennas to improve the radiation characteristics, gain and to suppress mutual coupling between adjacent elements. Since then, the DGS techniques have been explored extensively and have led to many possible applications in the communication industry. The objective of this paper is to design and investigate microstrip patch antenna that operates at 2.4 GHz for Wireless Local Area Network WLAN IEEE 802.11b/g/n, ,Zigbee, Wireless HART, Bluetooth and several proprietary technologies that operate in the 2.4 GHz band. The design of the proposed antenna involves using partially Defected Ground Structure and circular/cross slots and compare it to the traditional microstrip patch antenna. The results show improvement in both the gain of 3.45 dB and the S11 response of -22.3 dB along with reduction in the overall dimensions of the antenna. As a conclusion, the performance of the antenna has been improved through the incorporation with the DGS and slots structures regarding the S11 response and the gain. The proposed antenna become more compact. Finally, the radiation pattern of proposed antenna has remained directional in spite of adding slots on the ground plane.

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1. INTRODUCTION

In the wireless technology industry, there have been important development through the last decade, that determines the accessibility of efficient hardware that can be used at high data-rates and at low signal powers. Microwave designers have been working on developing the RF devices to meet the requirements. Since the actual realization of artificially engineered metamaterials in the beginning of 21st century, Different unprecedented methods have been tested to enhance the performance of printed antennas [1].

The Defected Ground Structure (DGS) approach is a newly progressing technique for designing low profile antennas such as microstrip and dielectric resonator antennas. The DGS can be considered as Electromagnetic Band Gap (EBG) structure but easier [2], from which it developed. It shows a band-stop property and its area of application includes microstrip transmission lines and circuits. Kim and Park [3] suggested and utilized the term 'DGS' in characterizing a single unit of dumbbell-shaped defect. Its evolution is completely explored in [4]. In addition to moderen books [5], [6] have discussed the topic of using the DGS in antenna design dumbbell-shaped DGSs were applied to design a filter [7], [8] then different forms were tested to characterize many microwave circuits such as filters [9], [10], rat race couplers [11], branch line couplers and Wilkinson power dividers [12], [13].

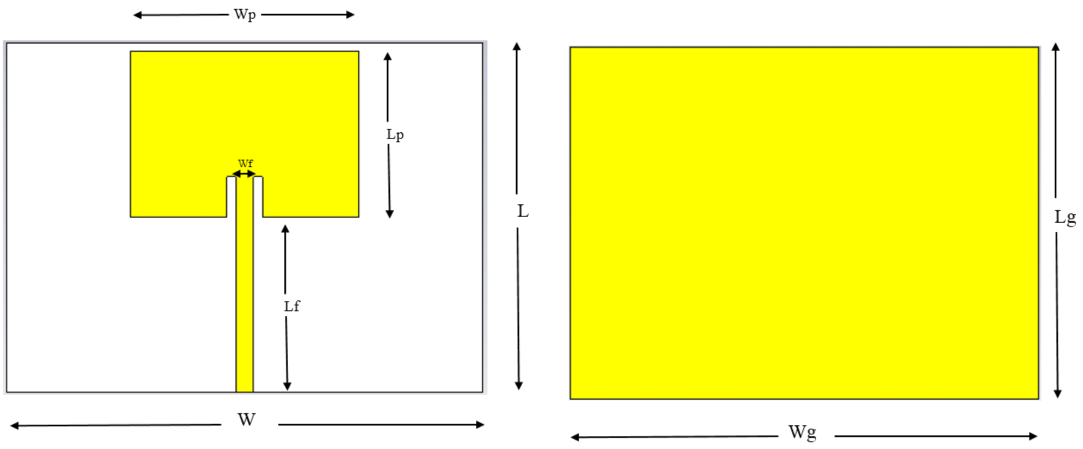
The DGS was incorporated with a microstrip radiator [14] to enhance its radiation characteristics. A series of realizations the potential of using DGS technology to address various printed antenna issues. This mechanism has grown among antenna designers and then used in monopole UWB antennas [15], Planar Inverted ‘F’ Antenna (PIFA) antennas for mobile handsets [16], microstrip antennas for WiMAX applications [17], dielectric resonators [18], phased arrays [19], etc.

In this paper, an microstrip antenna with a more compact size and wider bandwidth is proposed. The configuration of the traditional antenna, with dimensions of 60*80*1.6 mm^3 is designed, both antennas were explained in detail including the new structure. The comparison in term of size and configuration of the reference and the new proposed antenna is demonstrated. In this work, the size, return loss, radiation pattern, and gain characteristics are improved.

2. ANTENNA DESIGN

2.1. Design of a rectangular patch antenna

Figure 1 shows the top and bottom views of the traditional rectangular microstrip patch antenna which is designed by using low cost FR4 material having dielectric constant ε_r= 4.3 and thickness h=1.6 mm. The traditional microstrip antenna is designed for 2.4 GHz with overall dimensions of L = 60 mm and W = 80 mm. The patch dimensions L_p = 28.6 mm and W_p = 38.4 mm fed by a 50Ω center fed microstrip line feed having dimensions Lf = 30 mm and W_f = 3 mm. The length L_g = 60 mm and W_g = 80 mm of the ground plane of the antenna.



(a) (b)

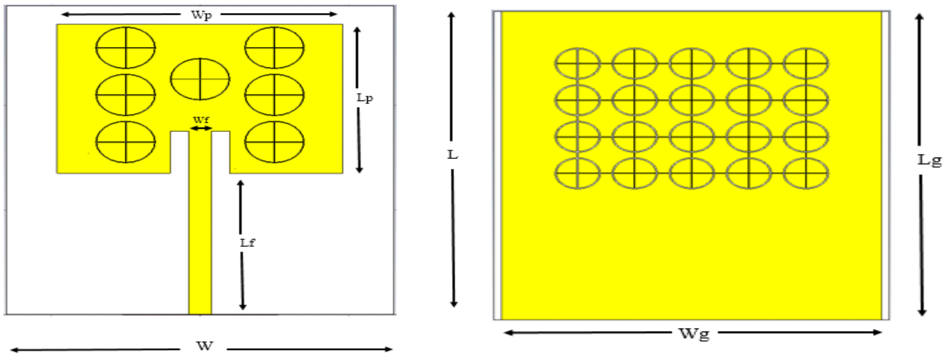
Figure 1. The top and bottom view of traditional rectangular patch antenna

2.2. Design of the proposed DGS/slotted rectangular patch antenna

Figure 2 shows the top and bottom views of proposed DGS/slotted rectangular antenna. The desired frequency of 2.4 GHz is kept with decrement in the overall dimensions of the antenna. The dimensions of the proposed antenna are L= 59 mm and W = 52 mm with shorter feeder Lf = 27 mm and Wf = 3 mm. The length and width of the ground plane of the antenna are Lg = 59 mm and Wg = 50 mm.

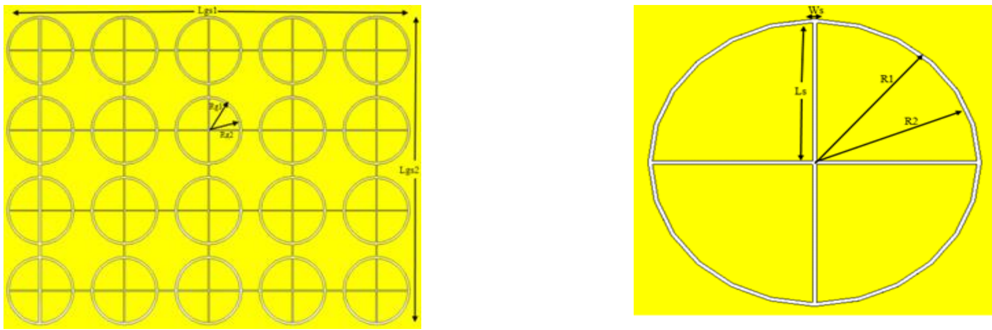
The study is carried out by curving three slots on each side and one in the middle of the radiating patch. Each slot carries the same dimensions of the others and consists of a circle with outer radius R1 = 4 mm and inner radius R2 = 3.9 mm. Combined with the circle slot, two crossed strip lines of width Ws = 0.1 mm and length Ls within the circumference of the circle are added.

On the other hand, On the ground patch of the antenna the DGS is applied by inserting also circular slots with dimensions Rg1 = 3 mm and Rg2 = 2.8 mm. Along with crossed thin lines of width of 0.1 mm for both lines and length Lgs1 = 36 mm, Lgs2 = 27 mm for the horizontal, vertical line respectively. Figure 3 shows a closer view of the DGS/slots on the upper and lower planes.



(a) (b)

Figure 2. The top and bottom view of DGS/slotted patch antenna



(a) (b)

Figure 3. Slots view on the lower and upper planes of the DGS/slotted patch antenna

3. RESULTS AND DISCUSSION

After the optimization of the antenna's different parameters, the antenna is simulated using CST Microwave Studio. The following parameters are discussed:

3.1. Return Loss of the conventional and proposed antenna

Figure 4 shows the computed *S*11 values for the metamaterial (DGS/slotted antenna) and conventional patch antenna. As shown, the conventional patch antenna has a relatively small return loss of -12.4 dB at 2.448 GHz (Assuming -10dB return loss level as an acceptable RL), while the proposed antenna has improved return loss -10 dB bandwidth of value -22.3 dB at -10 dB RL reference level.

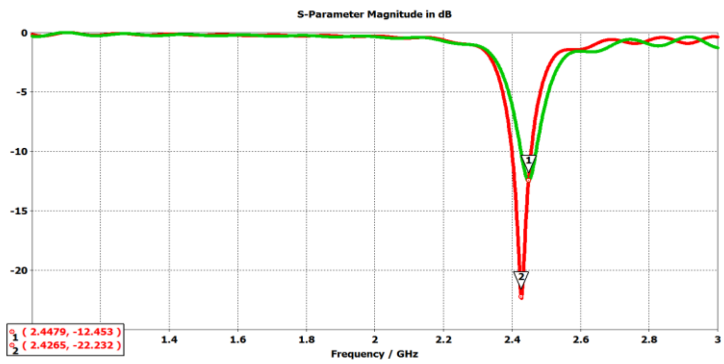
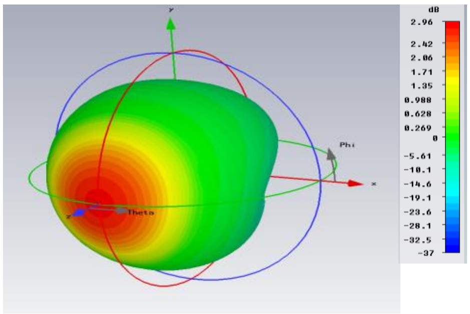


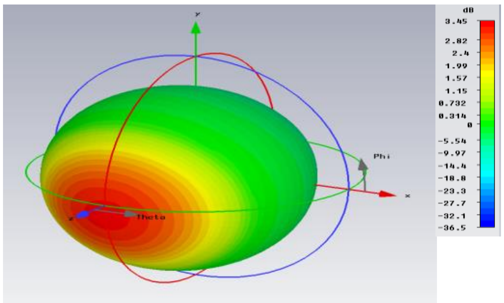
Figure 4. The simulated return loss of the proposed and traditional patch antennas

3.2. Gain of the conventional and proposed antenna

Antenna gains are simulated at the resonant frequencies as shown in Figure 5. The antenna gain of the conventional antenna is 2.96 dB, while for the proposed antenna is 3.45 dB. Comparing between the two values, there has been improved.



(a)



(b)

Figure 5. The simulated gain (a) the traditional antenna (b) DGS/slotted patch antennas

3.3. Radiation Pattern of the conventional and proposed antenna

Figure 6 shows the radiation pattern of microstrip antenna with and without DGS/slots in *E*-plane. While the radiation pattern of microstrip antenna with and without DGS/slots in *H*-plane is shown in Figure 7. The 3 dB beamwidth in *E*-plane becomes less by 2^o from 89^o to 87^o and also in *H*-plane, and the main lobe shifts from 0 to 5^o.

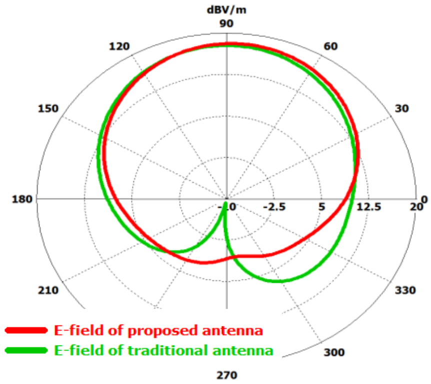


Figure 6. Simulated radiation pattern in *E*-plane

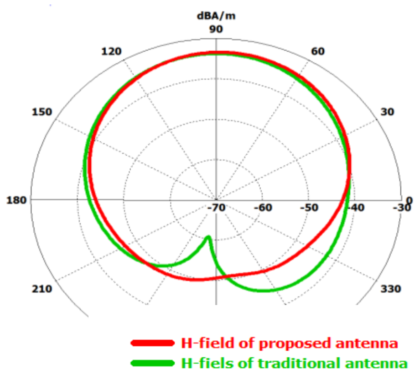


Figure 7. Simulated radiation pattern in *H*-plane

A comparison of various papers on the microstrip patch antenna is shown below in a tabulation. Where the overall dimension of the proposed antennas smaller than the antenna in these papers. Therefore, the proposed DGS antenna is compact when compared to other antenna designs.

Table 1. Comparison of overall dimension of the proposed antenna and other antenna types for Wireless applications at 2.4 GHz

Title	Frequency with return loss	Size
proposed Antenna Using Partially Defected Ground Structure and Circular/Cross Slots	RL of -22.3 dB at 2.448 GHz	59x52 mm^2
Design of a Microstrip Antenna for Wireless Communication [20]	RL of -20 dB at 2.4 GHz	118x134mm^2
Design of Wideband Microstrip Patch Antenna [21]	RL of -16.8 dB at 2.448 GHz	60x55 mm^2
Design of H And T-Slotted Microstrip Patch Antennas [22]	RL of -22 dB at 2.15 GHz	60*60 mm^2

4. CONCLUSION

The conclusion of this paper is the performance of an antenna can be observed through the simulation. The simulation results are obtained by using CST Microwave Studio and acceptable result in performances can be obviously noticed. The proposed antenna which is DGS and Slot microstrip patch antenna is radiated within the Wireless LAN band of 2.4 GHz. The return loss is observed of -22.3 dB at the resonant frequency of 2.448 GHz and can be applied in different Wireless LAN applications. Finally, the main objectives in this paper have been achieved which is the performance of the antenna has been improved through the incorporation with the DGS and slots structures regarding the S11 response. The radiation pattern of proposed antenna has remained directional in spite of adding slots on the ground plane. The gain of the proposed antenna compared to the typical microstrip antenna has improved; the size is reduced by 33.1% compared to the microstrip antenna without the DGS. Thereby, the proposed antenna become more compact.

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