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New Miniature Planar Microstrip Antenna Using DGS for ISM Applications

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Abstract

The aim of this paper is to use defected ground structures (DGS) in order to miniaturize a microstrip patch antenna. The DGS structure is integrated in the ground plane to improve the performance of the planar antenna, and shifted the resonance frequency from 5.8 GHz to 2.5 GHz, with a miniaturization up to 83%. The antenna is designed, optimized, and miniaturized by using the CST MW-studio, mounted on an FR-4 substrate having a dielectric constant 4.4, a loss tangent tan (ϕ)=0.025, thickness of 1.6 mm with the whole area of 34X34 mm2.The proposed antenna is suitable for ISM (Industrial, Scientific and Medical) applications at 2.5 GHz with S11 ≤(-10) dB. The antenna is fed by 50ohm input impedance and it has good performances in terms of matching input impedance and radiation pattern. The proposed antenna was fabricated and tested.Simulation and measurement results are in good agreement.

Keywords: *Defected Ground Structure (DGS), Miniaturisation, Planar Antenna, CST-MW, ISM*

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1. Introduction

Microwave components such as filters, couplers, antennas are used in the wireless communication chain, but the important constraints for engineers in radio frequency (RF) researches in recentyears are to obtainhigh performance with small size, lowcost, and ease of integration. Microstrip planarantennas have been an important candidate for this new progress research.

To miniaturize microstrip antennas several methods are used to achievethis goal, amongthese techniques wedistinguish for instance: In [1] U-shaped slot canbeutilized as Fractal shapes for miniaturization of patch antennas, also we can use meta-materials for size reduction of patch antenna [2] and in [3] miniaturization is obtained by the complementary split ring resonators. A Combination of the discussed techniques canalsobeused for getting miniaturized antenna for example: Electromagnetic Band Gap (EBG), Photonic Band Gap (PBG), Defected Microstrip Structure (DMS) and Defected Ground Structures (DGS) [4-6].

DGS is a famous technique used to miniaturize the size of planar antennas, thismethodconsists of etching a simple shape in the ground plane or for the best performance wecanetch a complicatedshape, this last serves to influence the distribution of current in the antenna, also DGS technique canbeused in planar antenna for manyapproachessuch as: reduction of mutual coupling, harmonic suppression reduction, size reduction of antennas array [7, 9].

There are variousshapes structures whichcanbeetched in the ground plane such as: fractal, dumbbell, periodic, spiral, circular, and L shaped [10], DGS shape is composed of twodefected areas and a connecting slot which are the sources of the equivalent LC elements. In otherwords, When DGS is inserted in a planar antenna, we can have an enhancement of the effective capacitance and inductance, this changecl out its input impedance and as a results thus shifting its frequency without change of antenna dimensions [11].

Therefore, in the present paper a new shaped slot are used in the ground plane as a defectedground structure for the size reduction and miniaturization of the patch antenna. Initially the proposedantennaresonatesat 5.8 GHz in the ISM band [12-13], and then the integration of DGS permits to shift the resonancefrequency to 2.5 GHz having the same dimensions of the

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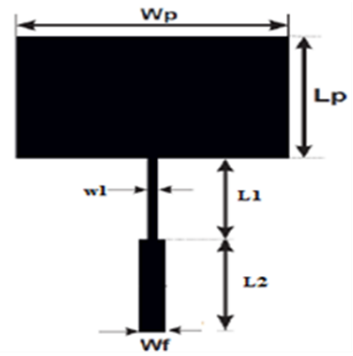
antennavalidatedat 5.8 GHz. More details of the proposedantenna design procedures; simulated and measuredresults are presented and discussedbelow.

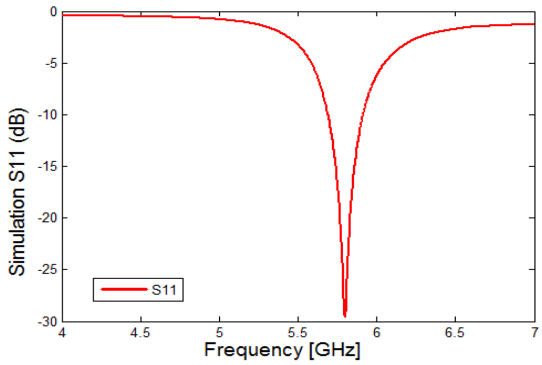
2. Antenna Design
2.1. Antenna without DGS

The ideawas to achieve an antenna that functions in a high frequency band in order to have miniature dimensions of the microstrip patch. Figure 1(a) shows the simple antenna structure resonatingat 5.8 GHz; thisantenna is mounted on an FR4 substrate due to itslowcost and easy fabrication.By using the CST-MW solver which integrates the various optimization methods, the different parameters of the designedplanarantenna are as follows: $W_{P=}$16mm, $L_{P=}$10.89mm, L_1=7mm, L_2=7mm W_f=3mm, W_1=0.85mm and metallizationthickness of t=0.035mm. The dimensions of the ground plane are W_G=34mm and L_G=34 mm.

Figure 1(b) presents the simulated reflection coefficient (S11) obtained for this antenna. As we can see, we have an antenna which functions at 5.8GHz with a return loss under -30dB.



(a)



(b)

Figure 1. (a) Geometry of the proposed planar antenna, (b)The return loss versus frequency

2.2. Antenna with DGS

Figure 2(a) presents the extracted equivalent circuit for the proposedDGS.By using the equations below (1), (2) and the theoretical part as explained in [14] we can calculate the various value of equivalent circuit illustrated in Figure 2(a).

$$L = \frac{1}{4\Pi^2 f_0^2 c} \tag{1}$$

$$C = \frac{f_c}{2z_0} \bullet \frac{1}{2\Pi(f_0^2 - f_c^2)} \tag{2}$$

With z_0 is the characteristic impedance of the microstrip line. F_o and F_c are the resonantfrequency and the cutofffrequencyrespectively. Figure 2(b) shown the located place of DGS in the metallic ground plane. The position of DGS plays an important role in shifting the resonance frequency of the microstrip antenna previously presented in Figure 1(a).

Figure 2(c) illustrates the details of the DGS parameters in terms of values: the length and the width of ground plane where LG=34mm, WG=34mm, the different values of the inner and outer of the concentric rings shaped and different parameter values of the rectangular slot are as follows: a=6.4 mm, b=3 mm, c=6 mm, d=5.9 mm, e=2.4 mm, f=1 mm, g=0.4 mm, h=0.8mm.

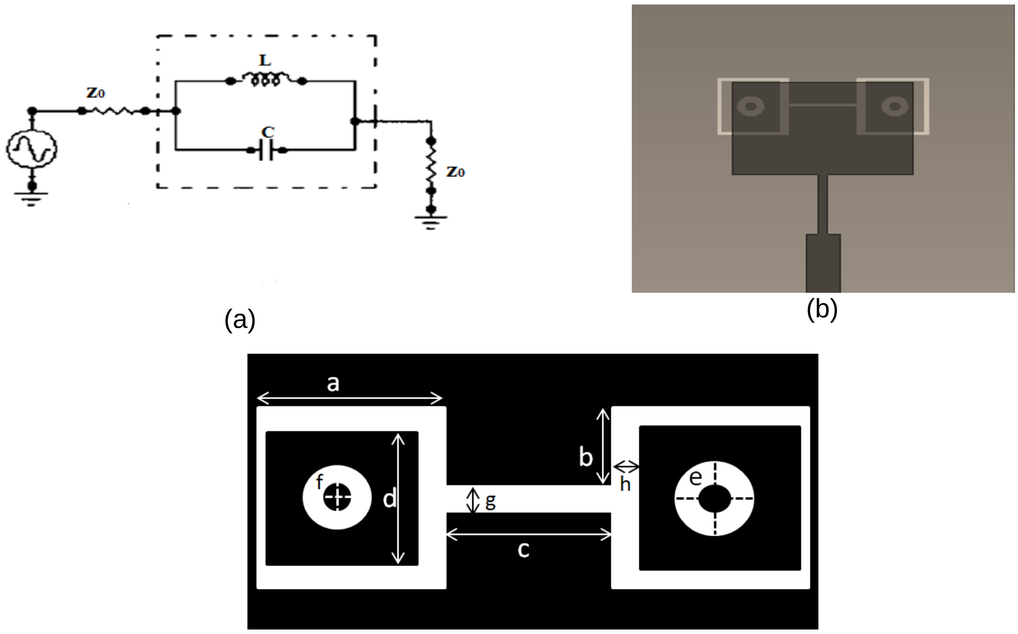


Figure 2. (a) The equivalent circuit of presented DGS, (b) The position of the proposed DGS inserted with the microstrip patch antenna, (c) The different parameters of the proposed DGS.

3. Simulation Results

After the integration of DGS structure, as illustrated in Figure 3 the simulation result permits to obtain a good matching input impedance at 2.5 GHz with a value less than -30dB. We can see that the DGS technique allows shifting the resonant frequency from 5.8 GHz to 2.5 GHz, which permits to have at the end a miniature antenna.

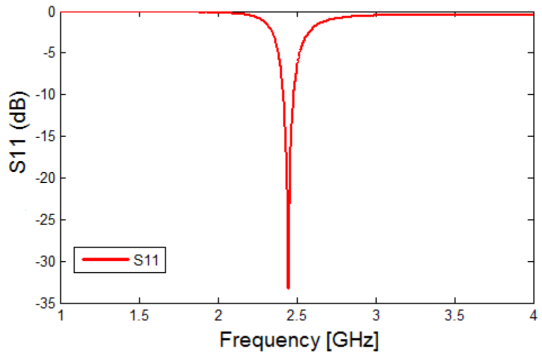


Figure 3. The return loss (S11) of the planar antenna integrating DGS elements

3.1. The Surface Current

Figure 4 shows the distributions of the surface current of the proposed planar antenna integrating DGS elements at 2.5 GHz. As seen in Figure 4, the current density is most concentrated along the finally the DGS structure; however a large surface current density was observed over the structure without DGS.

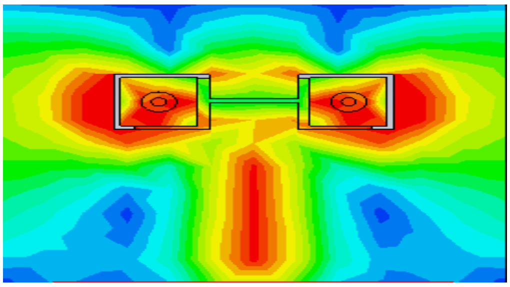


Figure 4. The current distribution of patch antenna at 2.5GHz

3.2. Radiation Pattern and Gain results

The simulated radiation patterns of the planar antenna integrating DGS at 2.5 GHz in H-plane and E-plane are illustrated in Figure 5. Into simulation; we obtain a gain value equal to1.75dBi of the proposed antenna at 2.5 GHz.

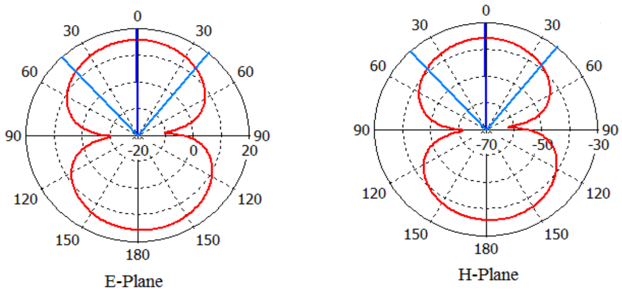


Figure 5. 2D Radiation pattern of the planar antenna at 2.5GHz (in E-plane and H-plane)

4. Fabrication and Measurement

After the validation of the simulation results of the proposed patch antenna, we have passed to fabrication. Figure 6 presents the photo of the fabricated antenna with DGS having a volume of 34x34x1.6 mm^3. The proposed antenna structure with DGS is fabricated by using LPKF machine and tested by using Vector Network Analyzer (VNA) from Rohde & Schwarz.

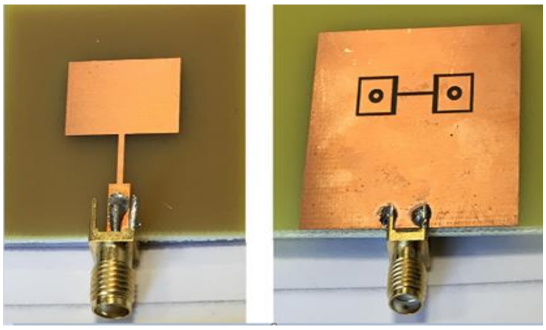


Figure 6. A Photo of the fabricated antenna with DGS

The return loss (S11 parameter) was measured and compared to the simulated results. As we can see in Figure 7, we have a good agreement between the simulated and measured results. The result presented in Figure 7 shows that the proposed antenna can be suitable for ISM applications at 2.5 GHz.

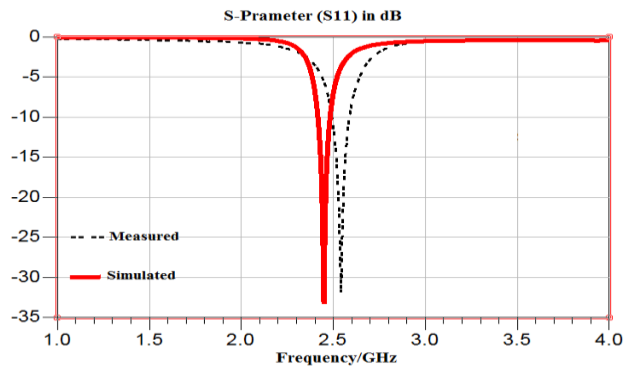


Figure 7. The comparison between simulation and measurement of the reflection coefficient.

Figure 8 shows the Photograph of the fabricated antenna in the anechoic chamber. The measured radiation patterns in E- and H-plane at 2.45 GHz are presented in Figure 9(a) and (b) respectively.

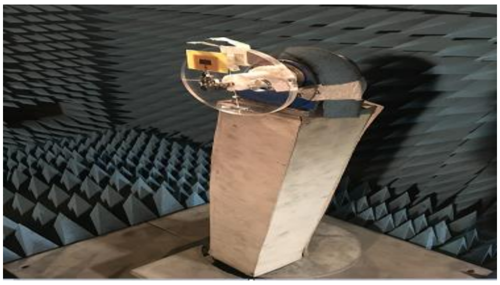


Figure 8. Photograph of the fabricated antenna (Tested in the anechoic chamber)

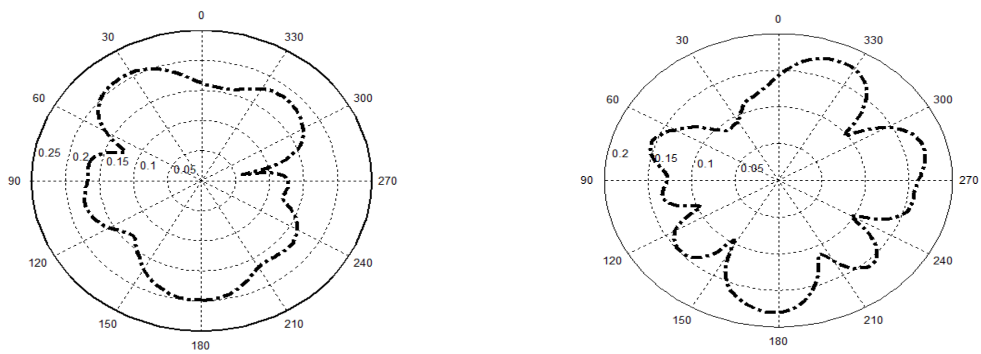


Figure 9.(a) Radiation pattern in E-plane at 2.45 GHz; (b) Radiation pattern in H-plane at 2.45 GHz

5. Conclusion

In this paper, we have presented the miniaturization of a microstrip patch antenna by using DGS technique. The proposed antenna firstly was validated at 5.8GHz and after that shifted by integrating DGS structures to a frequency of 2.5 GHz which permits to reachat the end small dimensions. After the achievement and the test of the final miniature patch antennawe have obtained good agreement between simulation and measurementresults. The final circuit is suitable for ISM applications.

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