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Study the Effect of Double Sided Triangular Defected Ground Structure Technique on Microstrip Patch Antenna Parameters

Ghufran Saady Abd-almuhsen[a]*, Noora H. Sherif [b], Mohammed Hussein Ali[c]

[a]*Madenat Alelem University College, Baghdad-Iraq*
[b,c] *Al-Turath University College, Baghdad-Iraq*
[a]*Email: ghufransaady@yahoo.com*
[b]*Email: noora.hani.na@gmail.com*
[c]*Email: m_alzubadi@yahoo.com*

Abstract

In this paper, a quite simple design of a double-sided triangular patch antenna has been proposed. An efficient technique utilizing the Defected Ground Structure (DGS) has been employed. A simple double-sided triangular slot in the ground plane helped to increase the band-width and shift the resonant frequency from 6.37 GHz to 4.97 GHz without modifying the basic geometry of the antenna. The reflection coefficient of the final design of the proposed antenna showing a good matching at 4.97 GHz with a bandwidth equal 647 MHz, a return loss of less than -10dB and voltage standing wave ratio (VSWR)<2. Microstrip patch antenna (MPA) has been designed and simulated using FEKO simulator software based on FDTD solver. Microstrip line is used to feed the antenna. The simulation results are found to be in good agreement with the measurement's results. Results indicate that the double-sided triangular defected ground structure is effective in suppressing spurious radiations, and the patch antenna considered here can be widely applied in active integrated communication systems.

Keywords: Patch; DGS; FEKO; VSWR; return loss.

1. Introduction

Microstrip antennas have extensive applications in wireless communication systems due to their excellent characteristics such as low cost, light weight and easy fabrication [1,2].

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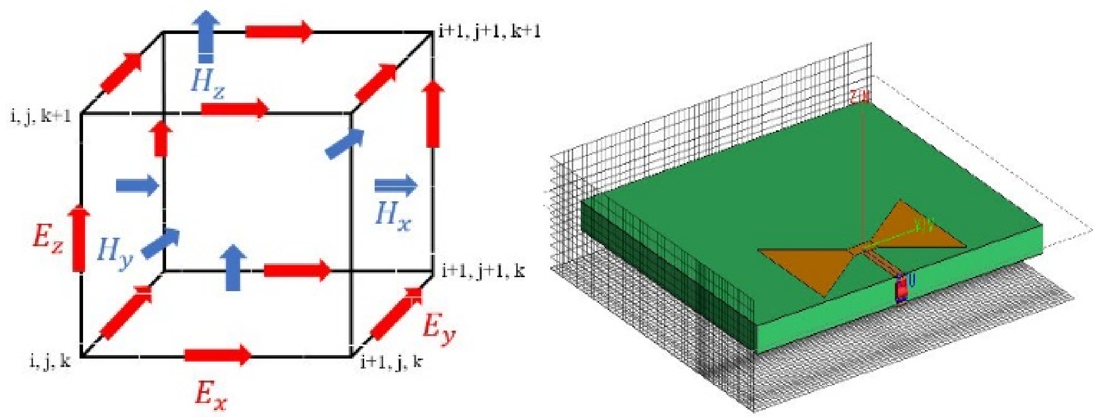
* Corresponding author.

Wireless technology is one of the main areas of research in the world of communication systems today, and a study of communication systems is incomplete without an understanding of the operation of antennas. Surface waves are one of the drawbacks of the microstrip antennas because when a patch antenna radiates, a portion of the total available radiated power becomes trapped on the surface of the substrate. Surface waves increase the level of side lobes, reduce the efficiency and antenna gain, limit the bandwidth and increase crossed polarization [3,4,5].

Some of these problems can be removed by modifying the ground plane of the antenna, which supports multi-band and can operate at different frequencies to a single device [6]. Application of defected ground structure (DGS) in improve the radiation properties of microstrip antenna was started in 2005 [7]. Since then, several new designs and applications have been explored for different antenna geometries.

Many shapes of defected ground structures provide many good performances in terms of reducing the size of the antenna, and improving the bandwidth [8]. In this paper, double-sided triangular DGS has been adopted to enhance the bandwidth at the resonant frequency of 6.26 GHz in the range of C-band, which is used for the applications of long-distance radio telecommunications. The antenna is designed with dielectric substrate having dimensions 120 X 105 X 5.1 mm with dielectric constant of 2.2. Recently, many authors had been interested in the field of using defected ground structure technique.

The FDTD method can solve complicated problems, but it is generally computationally expensive. Solutions may require a large amount of memory and computation time. The method combines the computational simplicity of the structured FDTD scheme with the versatility as well as flexibility of the finite-element method (FEM) and enables us to accurately model curved geometries and those with fine features. FDTD solutions can cover a wide frequency range with a single simulation run. The arrangement of electric- and magnetic-field nodes in space and time and the boundary condition (PEC) are shown in Fig.1.



(a) (b)

Figure 1: (a) arrangement of electric- and magnetic-field nodes in space and time; (b) boundary condition (PEC)

The strategic location and dimension of the defect on the orthogonal plane are chosen in a way that they do not affect the dominant mode fields under the patch and as such do not change the input impedance of the element or cause any backward radiation through the defect.

Many authors have been realized the benefits that Defected ground Structures can provide in terms of increasing the impact of their work, and some of these works are presented briefly in this paper.

(Acharjee, Mandal, Mandal, & Sarkar, 2016) presented a microstrip line fed inset cut rectangular shaped patch antenna for controlling higher-order modes up to fourth harmonic of the fundamental frequency is demonstrated successfully.

Complete harmonic rejection has been achieved by using two simple I-shaped DGS beneath the feed line.

Through this paper, DGS's stop band characteristics have been studied to increase the stop band spectrum and to eliminate the higher order harmonics [9].

(Rameswarudu & Sridevi, 2016) designed a novel and compact microstrip patch antenna with step slots etched on the ground plane and split square ring slots etched on the patch. In this study, a wide bandwidth and minimal return loss characteristic had been achieved for UWB applications [10].

(Jilani & Alomainy, 2016) presents a T-shaped antenna at millimeter-wave (MMW) frequency ranges to offer a number of advantages including simple structure, high operating bandwidth, and high gain.

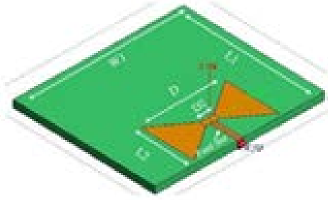
Defected ground structures (DGS) proposed in this study have been symmetrically added in ground in order to produce multiple resonating bands, accompanied by partial ground plane to achieve continuous operating bandwidth.

The antenna consists of T-shaped radiating patch with a coplanar waveguide (CPW) feed, and it is considered as a potential candidate for the 5G wireless networks and applications [11].

2. Design Concept

Microstrip patch antenna consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side.

The basic configuration for the proposed microstrip antenna is double triangle-shaped patches in opposite direction printed on a substrate having the dimensions of (W1 X L1), low dielectric constant of 1.001 and thickness h=3.2 mm. The distance between two triangular patches is (D) as shown in Fig.2. The idea was to develop new configurations by modifying the ground plane by using new structure subtracted from the ground plane. Defected ground structure having the same geometry of the proposed patch antenna (double triangular) with distance (D3) between them. The performance of the antennas was analyses by using FEKO software based on Finite-difference time-domain (FDTD) solutions. Microstrip line is used to feed the antenna. All other dimensions are presented in Table 1.



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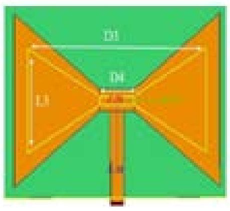

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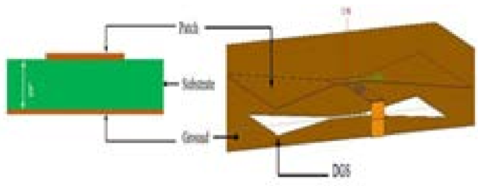


(c)

Figure 2: Antenna Structure: (a) Top view show the MPA dimensions; (b) Defected ground structure dimensions; (c) Side view of proposed antenna

Table 1: Dimensions of the proposed antenna

Parameter	Value
Substrate width W1	120 mm
Substrate length L1	105 mm
Triangular base of patch L2	40 mm
Distance between triangles patches D	60 mm
Plane connected between the patches D2	10 mm
Thickness of substrate h	3.2 mm
Distance between triangles of DGS D3	52 mm
Triangular base of DGS L3	22 mm
Plane connected between the DGS D4	10 mm
Feed line width	4 mm
Feed line length	20 mm
Dielectric constant of substrate	2.2

The following block diagram in Fig.3 shows that the process details of design and simulation.

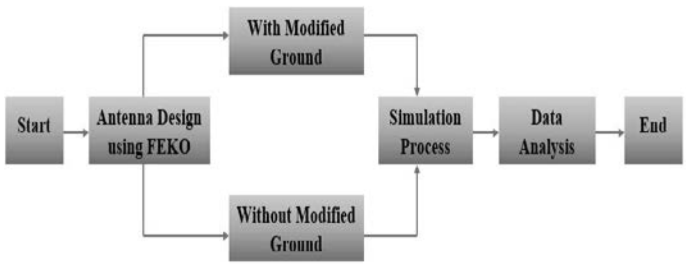


Figure 3: Scheme of antenna design and simulation

3. Results and Discussions

FEKO Simulator software used to design and simulate the microstrip patch antenna, and it also used for computing and plotting return Loss, VSWR, bandwidth, gain and impedance. We have used electromagnetic solvers FEKO based on the Finite-difference time-domain. Return loss is defined as the loss of power in the signal returned in a transmission line which is reduced to 33.01 dB after modified the ground plane see Fig.2. VSWR which is represented the ratio of the maximum to minimum voltage of the antenna [12], is minimized up to 1.05 as shown in Fig 5. Besides that, the effect of the DGS shaped permit to shift the resonant frequency from 6.37 GHz to 4.97 GHz. The total results are presented in Table 2.

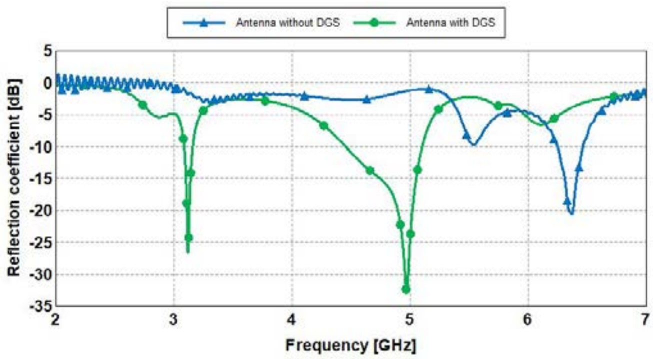


Figure 4: Return loss results produced by FEKO software

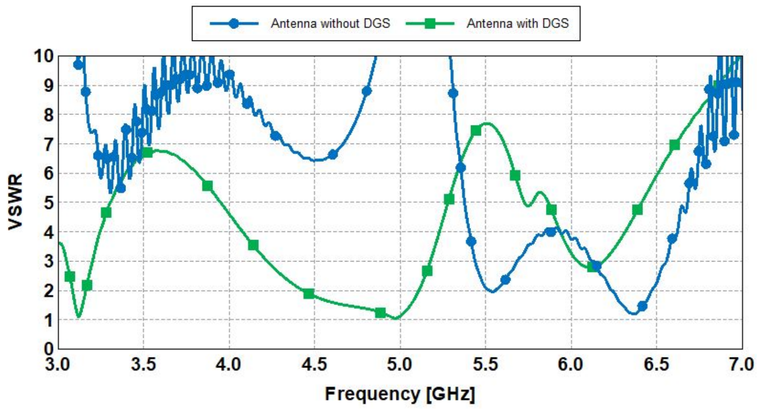


Figure 5: VSWR results produced by FEKO software

Observe that, the proposed microstrip antenna has double-side triangular slots on its ground plane, which reduces the resonance frequency by 21.97% compared to the conventional patch antenna. This effect is due to the disturbance of the current on the ground plane, where the current path lengths have actually increased. Antenna is simulated using FEKO software designer version 7.0.

Table 2: Return loss and VSWR results

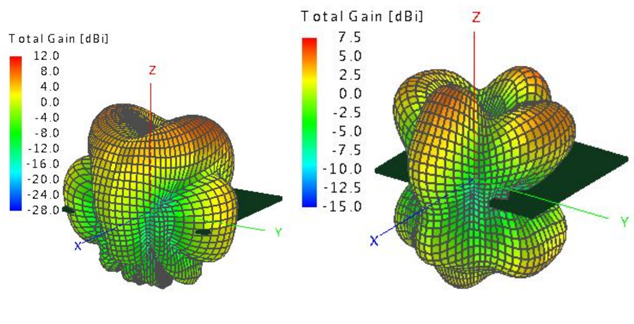
Antenna	Resonant frequency (GHz)	Return loss (dB)	VSWR
MPA without DGS	6.37	20.56	1.21
MPA with DGS	3.12	26.54	1.1
	4.97	33.01	1.05

Bandwidth is represented the range of frequencies. In this paper, bandwidth is enhanced to 647 MHz after using DGS technique compared with bandwidth value of the conventional antenna (without DGS) as shown in Table 3, which made this antenna more suitable to use in more applications.

Table 3: Bandwidth results

Antenna	Maximum frequency (GHz)	Minimum frequency (GHz)	Bandwidth (MHz)
MPA without DGS	6.46	6.25	210
MPA with DGS	3.15	3.08	70
	5.101	4.454	647

The value of gain is 12 dB in the conventional antenna, but this value is reduced to 7.5 dB at the MPA with DGS as represented in Fig 6 and Table 4. On the other hand, the best value of impedance matching of 48.4 Ω is achieved by using DGS technique see Fig.7. All the results related to gain and impedance are represented in Table 4.



(a) (b)

Figure 6: 3D total gain results at x-y plane: (a) MPA without DGS at 6.37 GHz; (b) MPA with DGS at 4.97 GHz

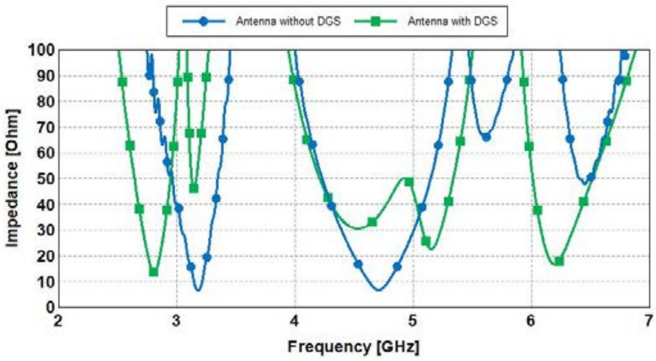


Figure 7: Impedance results produced by FEKO software

Table 4: Gain and impedance results

Antenna	Resonant frequency (GHz)	Total Gain (dB)	Impedance (Ω)
MPA without DGS	6.37	12	55.5
MPA with DGS	3.12	5	51.4
	4.97	7.5	48.4

4. Experimental Observation

Antennas are fabricated with defected ground structure at resonant frequencies 3.15 and 5.02 GHz and tested in the laboratory (see Fig 8). Experimental observations are found to be satisfactory. Fig 9 shows measurement of return losses of microstrip patch antenna with DGS, measured values of the reflection coefficient are -27.43 and 27.28 dB respectively, besides that, the values of VSWR is 1.09 for both of frequencies.

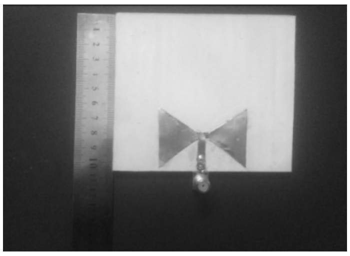


Figure 8: Photograph of the prototype proposed antenna

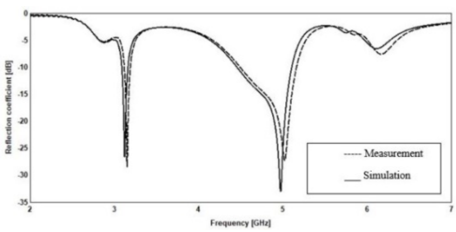


Figure 9: Measured and simulation return loss versus frequency of the proposed antenna with DGS.

5. Conclusion

The concept of Defected Ground Structures (DGS) has been developed to improve the characteristics of many microwave devices, the performance of a reconfigurable antenna with a defected ground structure (DGS) is improved. For this purpose, the DGS is also used in the microstrip antenna for some advantages such as antenna size reduction, mutual coupling reduction in antenna arrays, etc... By the simulation results produced by FEKO software, it is observed that the following points: (i). the model presented in this paper showed that the better radiation pattern with minimize return loss and VSWR characteristics, both are reduced to 33.01 dB and 1.05 respectively. (ii). Bandwidth is improved to 647 MHz (iii). Best value of impedance matching of 51.4 and 48.4 Ω at 3.12 and 4.97 respectively have been achieved. The photograph of the fabricated sample is in good agreement with the simulation results. On the other hand, gain has been reduced by 4.5dBi through this study. All the points above with the exception the small drop in the gain made the antenna appropriate to use in different applications.

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