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MINIATURIZED RECTANGULAR PLANAR PATCH ANTENNA USING DGS FOR WIFI APPLICATION

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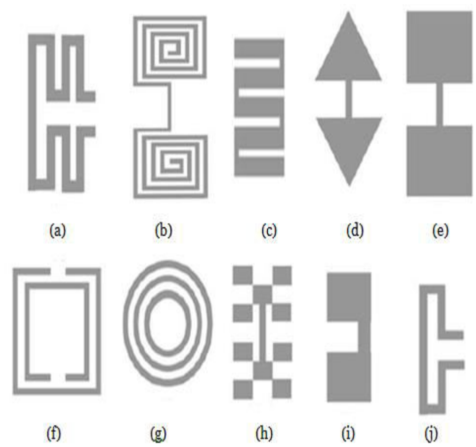
Abstract
In this article, a miniaturized and meander line slot loaded rectangular planar patch antenna using DGS for S, C and ku-band application is proposed. A new design of Inverted U- shaped defected ground structure is employed in the ground plane. To attain this goal, at first, we design a simple conventional planar antenna (Ant#1) which operates at 16 GHz with a return loss (S_{11}) of −34.97 dB. To get miniaturization of 78.12%, 22.8% and 55% , an inverted U- shaped defected ground structure resonates at 3.5GHz single band frequency with a return loss (S_{11}) of -28.79 dB. (Ant#2), and meander line slot loaded Rectangular Planar Patch Antenna Using modified DGS is designed (Ant#3), which operates at dual-band frequencies 7.18 GHz and 12.35 GHz with a return loss (S_{11}) of, −21.55 dB and −25.79, respectively, is presented. The proposed antenna is designed on a Roger RT Duroid substrate with thickness 0.8 mm and dielectric constant 2.2.The Entire size of antenna is 16 X 16 mm^2 and it is simulated by two distinct solvers HFSS and ADS layout.

KEYWORDS: Microstrip patch antenna, Defected Ground Structure (DGS), meander line slot, dual-band HFSS and ADS.

1. INTRODUCTION

The demand for compact size and miniaturized antennas has brought a significant focus in modern wireless communication systems. An electrically small antennas are especially preferred for the concept of miniaturization antenna with $K_a \leq 1.0$, where K is the wave number ($K = 2\pi/\lambda$) and a is sphere radius which enclosing the antenna is expressed [1].There are various miniaturization methods mentioned below to improve the antenna performance like Slot, Strip, Slit and Loop Loading Techniques used on the ground and patches [2, 3]. A miniature Patch Antenna Using Defected Ground Structures (DGS) [4], Different shapes or structures such as Half U-Slot and Half E-Shaped Patch Antennas with proper location



used for miniaturization [5]. This in turn to introduce meander line slot loaded antennas [6-9] have been investigated for wireless communication. The patch electrical length can be increased by loading meander line slot in the patch. So this leads the patch resonates at lower frequency and the antenna size can be reduced such methods have been used in a microstrip patch antenna which shows a significant reduction in the antenna size [10]. A miniaturized antenna based on fractals [11], Electromagnetic Band Gap (EBG) [12], SRR structure [13], metamaterial [14] and array is suggested [15].

Basically, we have followed the literature study with respect to miniature concepts, which operates in single operating bands. So this article presents a new miniaturized and meander line slot loaded rectangular planar patch antenna using HFSS and ADS Layout. The aim of proposed antenna design is based upon chu-limit which consists of compact size and it is operating at single and dual band frequencies at 3.5GHz, 7.18 GHz and 12.35 GHz, respectively, is achieved for S, C and ku-band application. The proposed antenna with specific literature DGS based shows in the Table 1.

2. A MINIATURIZED ANTENNA DESIGN CONFIGURATION

A planar antenna with inset feed operates at 16 GHz in K_u-band is presented in Fig2. At first, we planned to design and analyze of a basic patch

Defected Ground Structure (DGS) is simple and has been employed as a technique for improving different characteristics of microwave planar circuits. It contains several or single defects on the ground plane. The different shapes of DGS schematics are shown in the Fig. 1 and it includes simple structures such as meander lines spiral-shaped, interdigital, arrow head dumbbell, dumbbell-shaped, split-ring resonators, concentric ring shaped fractal, square slots, L-shaped. [25]

Figure 1. A few structures of DGS [34]

antenna (Ant#1) from hypothetical formulas [22-25].These are calculated from following equations 1 to 4.

$$L = \frac{1}{2 f_r \sqrt{\varepsilon_{eff}} \sqrt{\varepsilon_0 \mu_0}} - 2\Delta L \quad (1)$$

$$W = \frac{1}{2 f_r \sqrt{\varepsilon_0 \mu_0}} \sqrt{\frac{2}{\varepsilon_r + 1}} \quad (2)$$

$$Z_T = \frac{60}{\sqrt{\varepsilon_r}} \ln\left(\frac{8h}{w_T} + \frac{w_T}{4h}\right) \quad (3)$$

$$L_T = \frac{\lambda}{4} = \frac{\lambda_0}{4\sqrt{\varepsilon_{re}}} \quad (4)$$

The suggested planar antenna is printed on a Roger RT Duroid substrate with 0.0009 loss tangent (tan δ), permittivity of 2.2, and an entire area of antenna is16 X 16 X 0.8 mm^3.

Table1. Comparison of different literature study with proposed antenna.

Basically, the etched off aperiodic and periodic structures as defects in the metallic ground plane of microwave planar devices are known as DGS. This will bring major attraction to the microwave researchers. By utilizing these periodic structures, higher degree of miniaturization with greater slow wave rate is obtained. Repetition of single or multiple defects with a limited distance is known as periodic shaped structures. When DGS is employed with a microstrip patch antenna, the defect structure is etched off on the ground plane which interrupts its current distribution. This interruption produces meandered in the current distribution.it leads to change the values of line inductance and capacitance [16] Secondly, a novel design of Inverted U- shaped DGS is employed on the ground plane (Ant#2) which resonates the antenna with single band at lower frequency (3.5GHz) for WiMAX application. So here we introduced miniature concept leads to shift the frequency from high to low without changing the dimensions of suggested antenna. The basic principle of miniaturization is to accomplish switching of frequency from K_u band (f_1) to S, X and ku-bands (f_2).

The miniaturization factor [26] is given in Equation (5).

$$m=\frac{f_2}{f_1} \quad (5)$$

After achieving above model, thirdly we introduced modified DGS with meander line slot load Antenna (Ant#3) for dual band application. These meandering line forces controls the flow of current to the entire path that increases an electrical length of current (βl), which reduces the resonant frequency from

Ref.	Technique	Substrate material	Thickness of substrate/ Dielectric constant	Antenna size (mm^3)	Switching Resonant Frequency GHz	Miniaturized Percentage	Application
[16]	DGS	FR4	1.58 mm/ 4.3	13 X 12 X1.58	5.7 to 3	47.36	WiMAX
[17]	DGS	FR4	1.6 mm/ 4.4	34 X 34 X 1.6	5.8 to 2.5	56.89	ISM
[18]	DGS	FR4	1.6 mm/ 4.4	27.9 X 35.75 X 1.6	5.8 to 2.45	57.77	ISM
[19]	DGS	FR4	1.6 mm/ 4.4	34 X 34 X 1.6	5.8 to 2.45	57.77	ISM
[20]	DGS	FR4	1 mm/ 3.3	11.5 X 10.5 X 1	7.4 to 5.4	27.02	ISM
[21]	DGS	FR4	1.6 mm/ 4.4	27 X 30 X 1.6	10 to 3.5	65.0	WiMAX
Proposed system	DGS and meander line slot	Rogers RT/ Duroid 5880,	0.8mm/2.2	16 X 16X 0.8	16 to 3.5,7.18 and 12.35	78.12%, 22.8% and 55%	Wireless data transmission

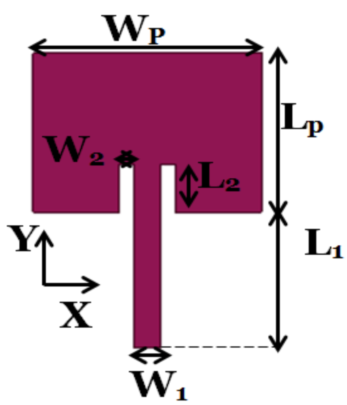
16 to 3.5GHz, 7.18 GHz and 12.35 GHz respectively. A miniaturized dual-band antenna is designed that satisfy a Chu-limit given in Equation (6).

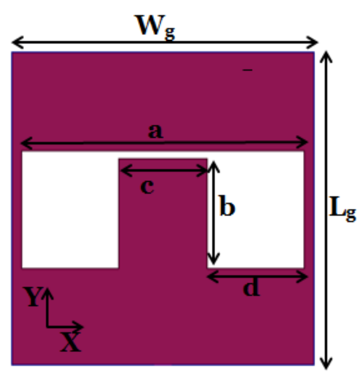
$$Chu_Q = \frac{1}{k_a} + \frac{1}{(k_a)^3} \tag{6}$$

The dimensions of the proposed antenna are listed in the Table 2. Figure 3 shows pictorial representations of iterations of antenna.

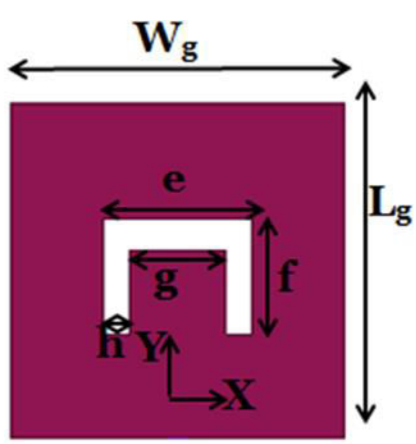
Table2. The optimized dimensions of the proposed antenna [mm]

w_p	w_1	w_2	L_p	L_1	L_2	a	b	c
7.85	0.9	0,5	5.85	5	1.75	15	5.6	4.7
d	e	f	g	h	i	j	W_g	L_g
2.43	7.05	10.46	4.6	1.25	2.41	4.2	16	16





(a) (b)

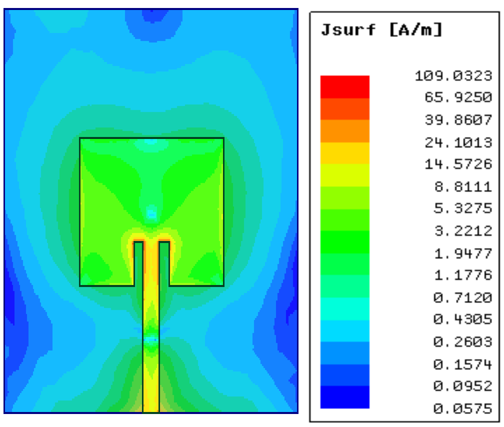


(c) (d)

Figure2 (a) Top view of planar antenna (Ant#1), (b) Bottom view of miniaturized antenna with only inverted U- shaped DGS (Ant#2), (c) back view of modified DGS (Ant#3).

3. RESULTS AND DISCUSSIONS

The simulated return loss (S_{11}) of steps involved in designing a miniaturized dual-band antenna is presented by using ADS and HFSS as shown in the Figure 4. It yields good impedance matching at 16GHz with a small change in ADS as compared with HFSS solver. The reflection coefficient of Inverted U- shaped defected ground structure, modified DGS and modified DGS and meander line slot gives good matching at 3.5 GHz .7.18 GHz and 12.35 GHz with a return loss (S_{11}) of -28.79 dB, −21.55 dB and −25.79dB, respectively ,is obtained.



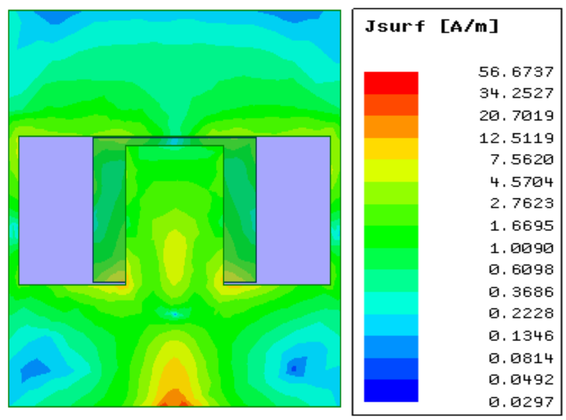


Figure 4 simulated return loss for proposed antenna

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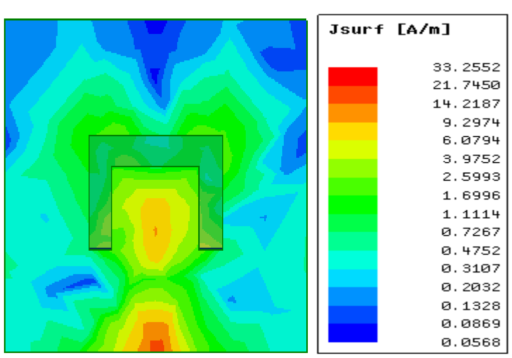
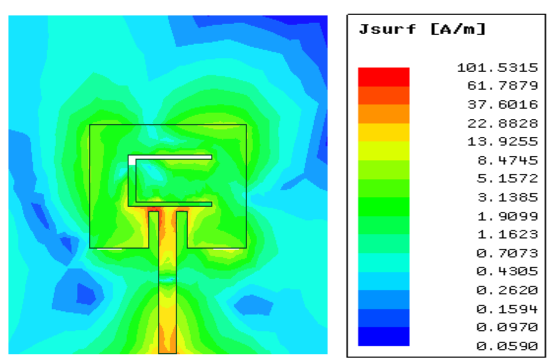
(a) (b)





(c) (d)

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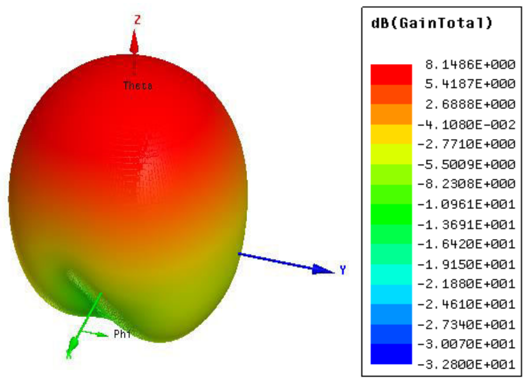
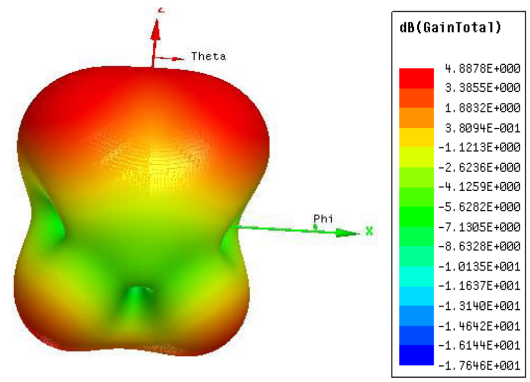
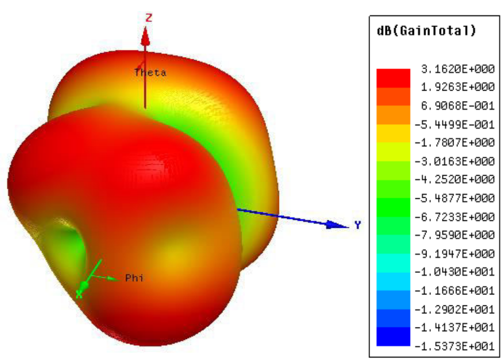
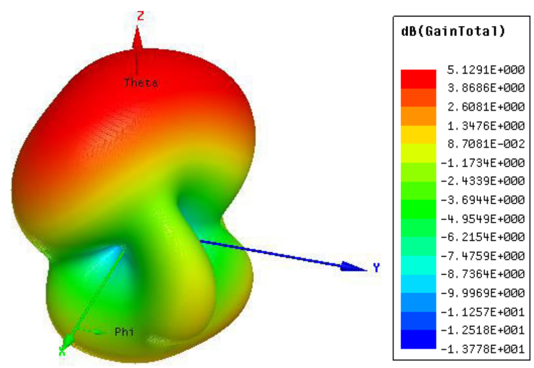




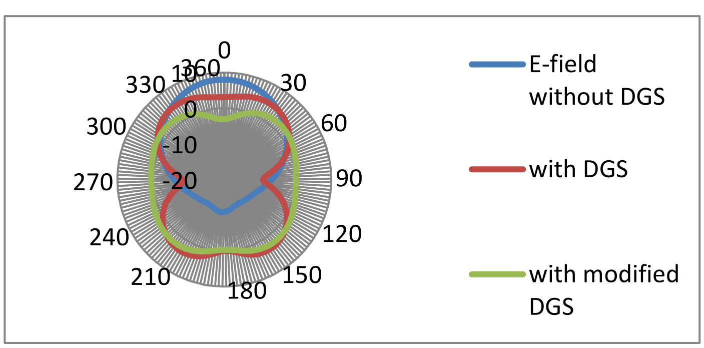
(e) (f)





(g) (h)

Figure5 (a) & (e) The distribution of Surface current and three dimensional gain plot at 16 GHz without DGS (Ant#1); (b)&(f) at 3.5GHz with only DGS(Ant#2); (c)&(g) at 7.3GHz with modified DGS (Ant#3);(d)&(h) at 7.18GHz and 12.35GHz with modified DGS and meander line slot



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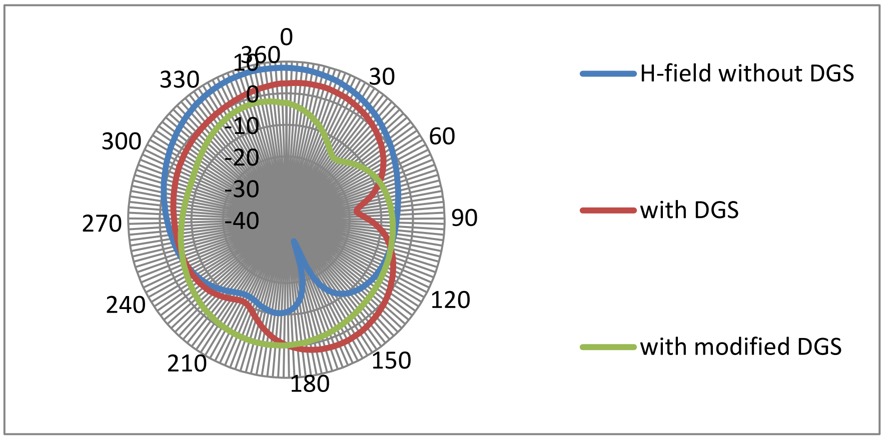
(a)



(b)

Figure6 (a) Simulated E-Field radiation patterns (b) Simulated H-Field radiation patterns Table2. Comparison between various parameters of proposed antenna.

Type of Antenna	Resonant frequency (GHz)	Gain (dB)	Return loss (dB)	Directivity (dB)	Bandwidth (GHz)	VSWR
Patch without DGS	16	8.14	-34.97	8.14	0.81	1.04
Patch with inverted U shaped DGS	3.5	4.93	-28.79	4.89	0.21	1.07
Patch with modified DGS	7.3	3.16	-27.10	3.24	0.40	1.09

The distribution of different surface currents and three dimensional gain plots were observed in the Figure 5a-h.The E-plane is consists of electric field vector and maximum radiation at particular direction. Similarly, H-plane which consists of magnetic field vector and also exists maximum radiation at particular direction. The radiation patterns of H-plane (ϕ=90) and E-plane (ϕ=0) of the miniaturized dual-band antenna is presented in the Fig. 6.

4. CONCLUSION

In this paper, we have designed, analyzed and simulated. A new novel dual-band miniaturized antenna for S,C and ku-band applications is designed using DGS and meander line slot rectangular planar patch antenna that operates 3.5GHz,7.18 GHz and12.35 GHz with a return loss (S_{11}) of −30.76, −21.55 dB and −26.87, respectively as well as a miniaturization of 78.12%, 22.8% and 55% respectively, is achieved successfully.

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