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A Gain Enhanced Multi band Microstrip Patch antenna for WIMAX Application

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ABSTARCT

This paper demonstrates the design and result of a high gain miniaturized slit loaded microstrip patch antenna with Defected Ground Structures (DGS) for wireless applications. The proposed antenna is coaxially probe fed, has an array of rectangular slits etched on the patch and a pair of rectangular shaped DGS loaded into the ground plane of the antenna. The bandwidth of a slit loaded microstrip patch antenna is 12% whereas it increases up to 14% when DGS is loaded into the ground plane. The proposed compact antenna resonates at multiple frequencies between 1 to 9 GHz frequency range at 3.28 GHz, 3.6 GHz, 5.6 GHz and 6.9 GHz with a bandwidth of 160 MHz, 150 MHz, 70 MHz and 260MHz having return loss of -17 dB, -27 dB,-17 and -23 dB respectively. The antenna has been simulated at 5.5 GHz using an electromagnetic simulation tool named CADFEKO. The proposed multiband antenna finds useful applications with an improved performance in WIMAX (3.2-3.8 GHz, 5.2-5.8 GHz, 6.9-7.8 GHz) applicaton. The plots of various antenna parameters like Return loss, Voltage Standing Wave Ratio (VSWR), Gain, Bandwidth etc. of the proposed antenna has been observed with and without DGS and the analysis of the simulated results shows that the proposed slit loaded antenna with DGS is more efficient than Conventional Rectangular Microstrip Patch Antennas (CRMPA) in terms of bandwidth of operation and miniaturization.

Key words*:* Gain Enhancement, WIMAX, CADFEKO, Miniaturization.

INTRODUCTION

Recently there has been a tremendous growth in the field of wireless communication for various applications and most of the systems focus on improving the Gain and achieving miniaturization of the antennas used in it. Miniaturization and Gain enhancement have mutually inverse relationships and improvement of one characteristics result in degradation of the other. Hence a trade-off needs to be considered between these two properties. A miniaturized multiband antenna with a high gain is an essential requirement for portable mobile communication devices and Radio Frequency (RF) applications in providing good Quality of Service (QOS) and throughput. The most commonly used antenna to achieve this goal is microstrip patch antennas due to its low cost, multiband of operation, small size and easy integration with Microwave Integrated Circuits (MIC). It has a radiating patch on one side of a dielectric substrate and ground plane on the other side. However such antennas also have drawbacks like narrow bandwidth and low gain due to surface wave excitation. The practical applications demand a high gain of operation. These requirements forced for modifying the regular patch antenna geometry. Several techniques have been used in enhancing the gain of an antenna and achieving miniaturization. The most commonly used technique is by the defecting of the ground plane and by placing slits at proper positions of the patch.

Slits causes meandering of the surface current path causing reduction in the resonant frequency and thereby achieving miniaturization by introducing a mode near the fundamental mode. DGS was first proposed by Park et al in 1999 and is realized by etching periodic or non-periodic structures in the ground plane that changes the shielded current distribution and thereby affecting the current flow and input impedance of the antenna. It controls the excitation of electromagnetic waves propagating through the substrate that depends on the shape and dimension of the defect being introduced.

Comparing an antenna with DGS and an antenna without DGS, it is observed that the antenna loaded with DGS achieves more size reduction by shifting the resonant frequency from 5.5 to 3.2 GHz and a high gain of 9 dB. The area of the ground that is defected is directly related to the miniaturization achieved. Different shapes of DGS have been used in planar microstrip antennas design that provides size reduction, bandwidth enhancement or gain increment. DGS also modifies a transmission line such as line capacitance and inductance characteristics thereby achieving a band stop characteristics in the same frequency bands with less number of unit cells.

This paper discusses the design and simulation of a conventional patch antenna, slit loaded antenna without DGS and slit loaded antenna with DGS. There are different feeding techniques for a patch antenna. Here a coaxial probe feeding technique is used for impedance matching at 50 Ω. Section II provides the antenna design of the proposed slit loaded patch with dumbbell shaped DGS, Section III provides the simulation result and discussion of the antenna parameters and section IV provides conclusion followed by references.

ANTENNA DESIGN

There are several methods to design and analyze a Microstrip patch antenna such as transmission line model, cavity model etc. The proposed antenna uses transmission line model where a rectangular patch of length ‘L’ and width ‘W’ can be viewed as a wide transmission line that is resonating with electric field varying sinusoidally along its resonant length ‘L’. There are 3 parameters for designing rectangular Microstrip patch antenna, (i) Resonant frequency (f) of the antenna, (ii) the dielectric constant of the substrate (εr), (iii)_substrate thickness (h).

A conventional planar rectangular Microstrip patch antenna that resonates at a designed frequency of 5.5 GHz with dimensions L X W as 12mm X 16mm is shown in Fig.1 and this antenna is used as the reference antenna. The substrate material used is an inexpensive FR4 which has a relative permittivity of εr= 4.4 and loss tangent of 0.002. The thickness of the substrate is 1.6mm. The radiating patch is made of copper and it is coaxially probe fed, having radius of 0.1 mm placed at (L/3, 0) from the centre of the patch along the line of symmetry that provides an impedance match of 50Ω.

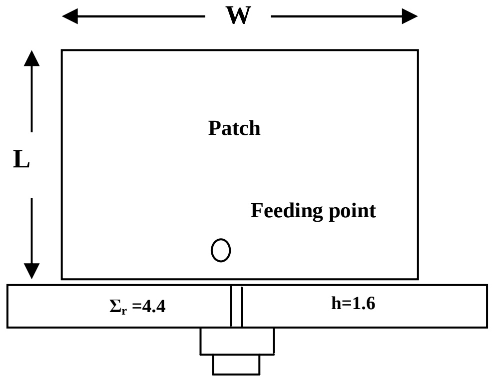
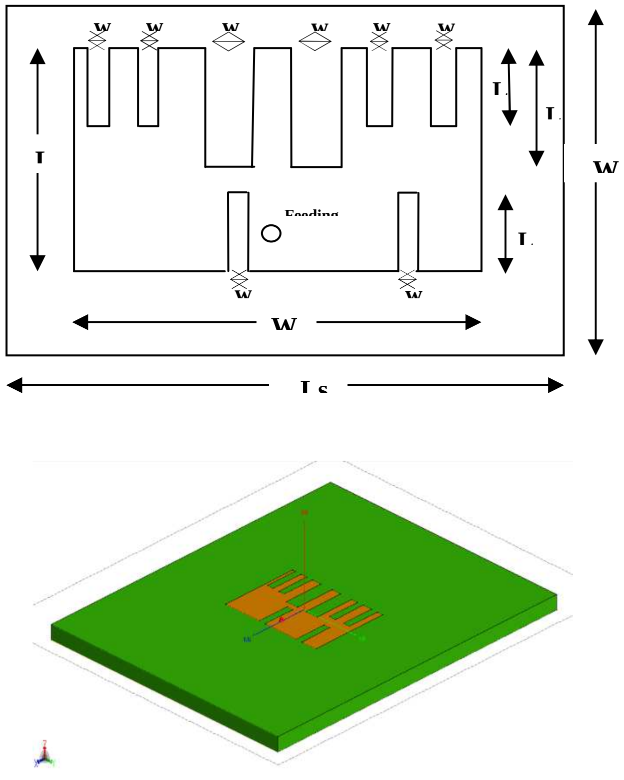


Fig.1: Conventional microstrip patch antenna

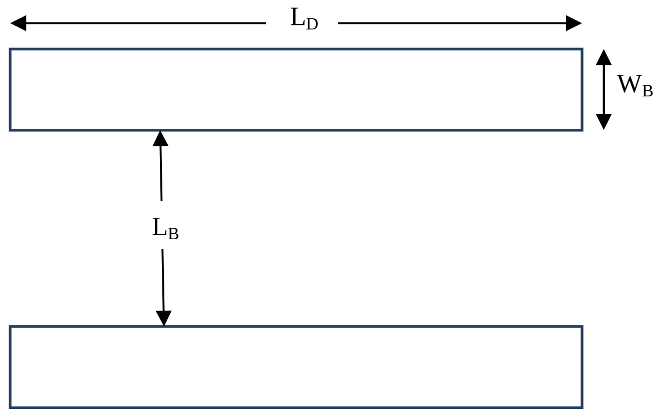
The proposed antenna with top view geometry shown in Fig. 2 (a) and the 3 D geometry shown in Fig.2 (b).The proposed antenna is made by etching rectangular shaped slits on the non-radiating edges of the patch. Here ‘L’ and ‘W’ represent the length and width of the patch, ‘Ls’, ‘Ws’ and ‘hs’ represent the length width and height of the substrate. ‘l1’, ‘l2’ and ‘w1’, ‘w2’ represent the length and width of the rectangular slits on the patch. The dimension of the proposed antenna is shown in Table 1.



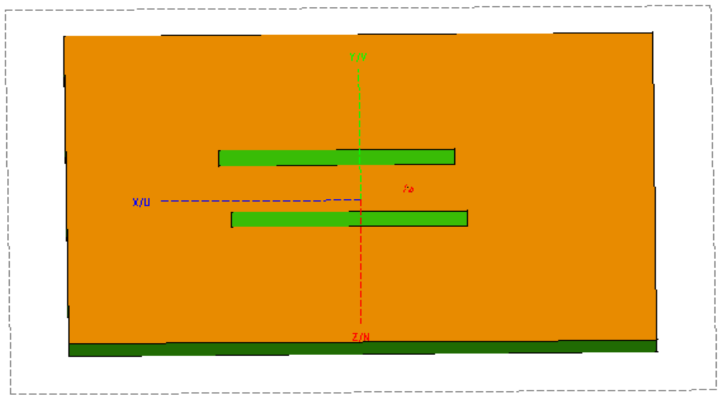
(b)

Figure.2. Geometry of the proposed antenna, (a) Top view (b) 3D view

The patch of the proposed antenna is made by a perfect electric conductor placed in the XY plane with base centred alignment. The rear view of the Rectangular shaped DGS placed just below the patch surface is shown in Fig 3 (a).The ground plane is a perfect electric conductor and is of dimension 50 mm X 40 mm. The dimensions of the DGS are shown in Table 1. These dimensions are obtained through a parametric study by varying each dimension of the DGS separately and noting down the various antenna parameters.



(a)



(b)

Fig.3. Geometry of the proposed antenna, (a) Rear view (b) 3D view

Table1. Parameters of the Proposed Antenna

Parameters	Value (mm)
Length of patch (L)	12
Width of Patch (W)	16
Length of substrate (L_s)	50
Width of substrate (W_s)	40
Length of slits (L_1)	5
Width of slits(W_1)	1
Length of slits (L_2)	6.2
Width of slits(W_2)	2

Length of DGS (L_D)	20
Spacing between DGS (L_B)	6
Width of DGS (W_B)	2

RESULTS AND DISCUSSION

The proposed antenna is simulated using an electromagnetic simulator, CADFEKO and parameters such as Return loss, Bandwidth, Gain, Voltage Standing Wave Ratio (VSWR) are measured. The Fig 4 shows the variation of return loss with frequency of a conventional patch antenna, a slit loaded microstrip patch antenna and a slit loaded Rectangular shaped DGS microstrip patch antenna and the bandwidth of operation can easily be calculated from this plot. The conventional patch antenna (Reference antenna) resonates at a single frequency of 5.54 GHz and has a return loss of -13.93 dB and impedance bandwidth of 180 MHz (5.44-5.62 GHz). A slit loaded antenna resonates <-10dB at 2.48 GHz with a return loss of -19 dB and impedance bandwidth of 50 MHz (2.46-2.51 GHz), at 5.72 GHz with a return loss of -20 dB and impedance bandwidth of 290 MHz (5.56-5.85GHz) , at 6.26 GHz with a return loss of -21 dB and impedance bandwidth of 310 MHz(6.17-6.48 GHz). While the proposed antenna with DGS antenna resonates <-10dB at 3.28 GHz with a return loss of -17 dB and impedance bandwidth of 160 MHz (3.21-3.37 GHz), at 3.6 GHz with a return loss of -27 dB and impedance bandwidth of 150 MHz (3.54-3.69 GHz), at 5.6 GHz with a return loss of -17 dB and impedance bandwidth of 70 MHz (5.54-5.61 GHz), at 6.9 GHz with a return loss of -23 dB and impedance bandwidth of 260 MHz (6.82-7.08 GHz. Hence Defected Ground Structures make an overall improvement in the impedance bandwidth of an antenna

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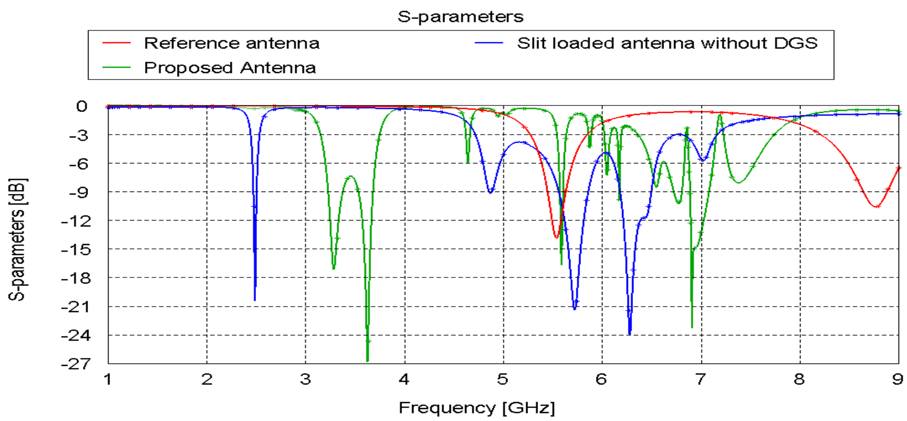


Fig 4. S_{11} curves for reference antenna, slit loaded antenna without DGS and proposed antenna

VSWR is a parameter that shows the level of impedance mismatch and is always a positive real number. The VSWR ratio of the proposed antenna is 1:1.2 as given in Fig 5 at the frequencies 3.28 GHz, 3.6 GHz, 5.6 GHz and 6.9 GHz.

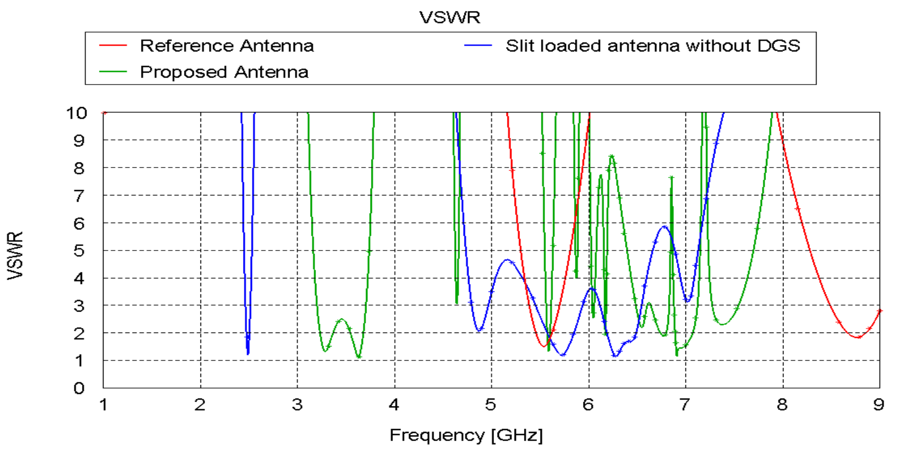


Fig 5. VSWR curves for reference antenna, slit loaded antenna without DGS and proposed antenna

The Fig 6 shows the simulated antenna gain plot of a conventional patch antenna, slit loaded antenna without DGS and slit loaded antenna with DGS. Gain is the ratio of radiation field intensity of test antenna to that of the reference antenna. It is usually expressed in dB. The observed value of gain of the reference antenna at resonant frequency of 5.5 GHz is 6.80 dB whereas for the slit loaded antenna it is estimated to be 4.47 dB and for the DGS antenna it is 9.4 dB. Thus we can conclude that the antenna gain Increases when DGS is loaded into the ground plane.

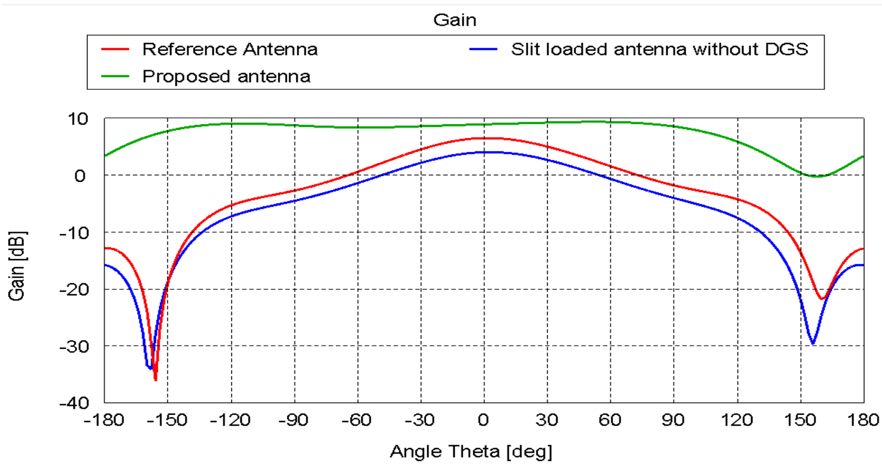
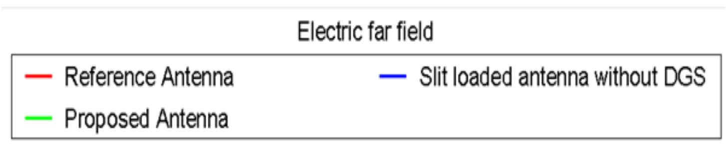


Fig 6. Gain plot for reference antenna, Slit loaded antenna without DGS and proposed antenna at 5.5 GHz

The 2-D radiation plot of the conventional, slit loaded antenna without DGS and the slit loaded antenna with DGS is shown in Fig 7 (a) and Fig 7 (b) in XZ and YZ planes. The radiation pattern in YZ plane is almost omni-directional. The radiation pattern in 3D is shown in Fig.7c).



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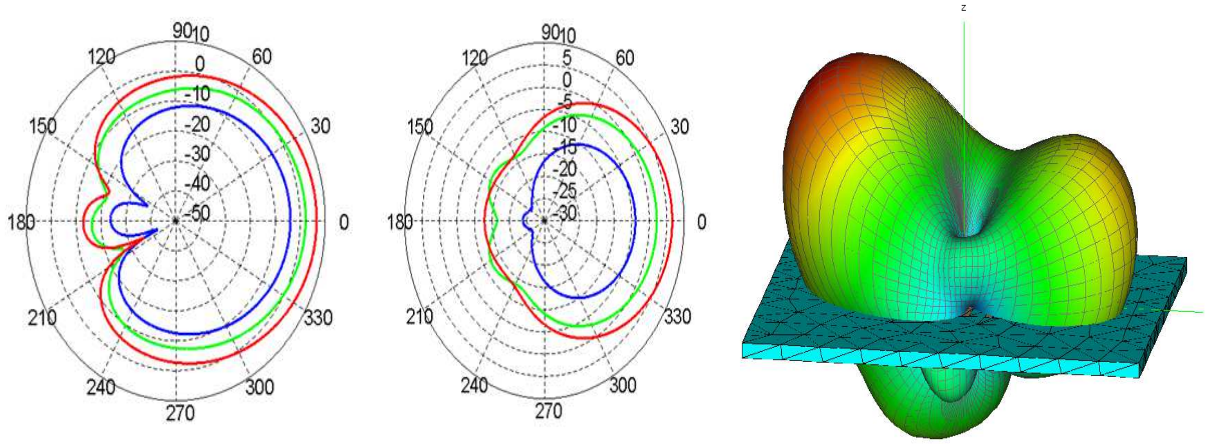

Fig 7. Radiation pattern of reference antenna, slit loaded antenna without DGS and proposed antenna
(a) XZ Plane (b) YZ Plane (c) 3D View.

For constant values of W_B and L_B (W_B=2 mm, L_B=6mm) the S_{11}graph for different values of L_D (L_D=10, 15 and 25mm) are plotted and is shown in Fig. 8 Table II presents a parametric study on the variation of length of the DGS on the antenna parameters. It is observed that as the length of the DGS increases the resonant frequency and the Bandwidth decreases. The gain of the antenna decreases as the dumbbell length increases .

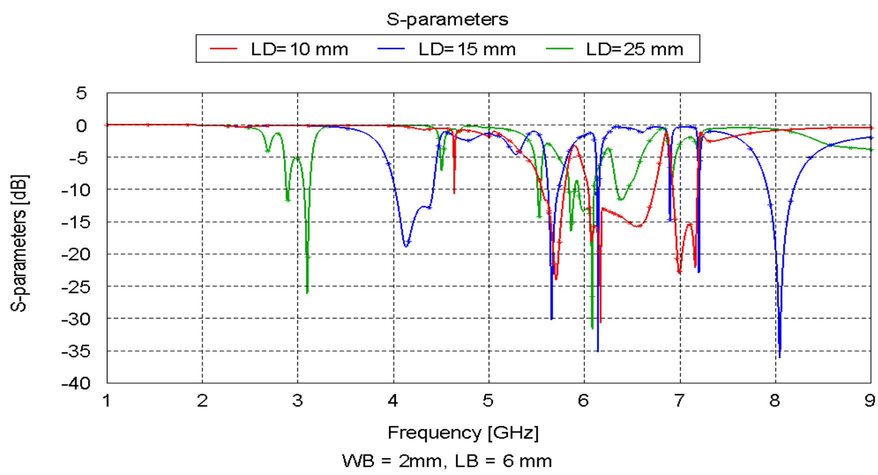

Fig 8. Return loss Vs Frequency for different length of DGS

Sl No	Length of DGS L_D (mm)	Width of DGS W_B (mm)	Spacing between DGS L_B (mm)	Resonant Freq (GHz)	Return Loss (dB)	Bandwidth (MHz)	Impedance Bandwidth (%)
1	10	2	6	4.6	-10.8	2230	33.98
				5.7	-24.1		
				6.1	-30.8		
				6.9	-23.1		
2	15	2	6	4.12	-19	1060	19.1
				5.67	-29		
				6.1	-33		
				6.8	-15		
				7.2	-23		
				8.05	-36		
3	25	2	6	2.88	-12	670	13.72
				3.1	-26		
				5.65	-14		
				5.83	-16		
				6.1	-31		

Table II. Variation of Length of DGS on Antenna Parameters

For constant values of L_D and L_B (L_D =20 mm, L_B=6 mm) the S_{11}graph for different values of W_B (W_B =1, 2.0 and 3mm) are plotted and is shown in Fig. 9. Table III presents a parametric study on the variation of width of the Rectangular shaped DGS on the antenna parameters. It is observed that as the width increases the resonant frequency decreases but the return loss and bandwidth increases initially and then starts to decline.

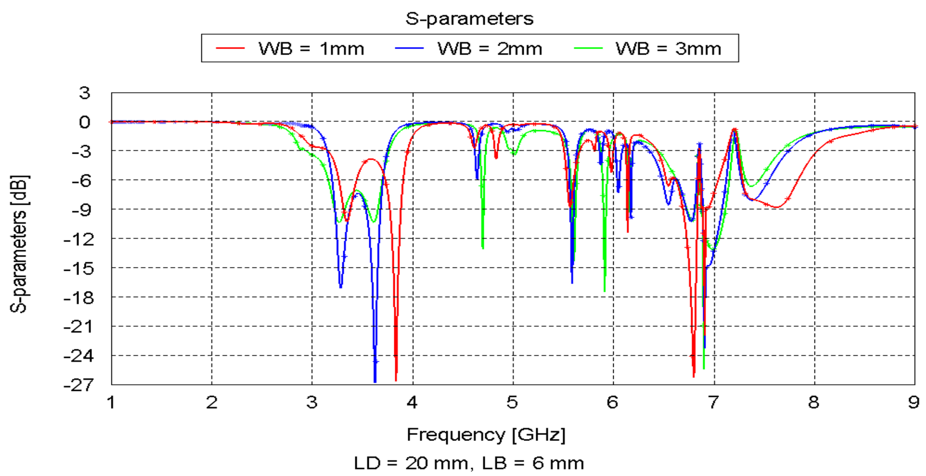

Fig 9. Return loss Vs Frequency for different width of DGS

Table III. Variation of Width of DGS on Antenna Parameters

Sl No	Width of DGS W_B (mm)	Length of DGS L_D (mm)	Spacing between DGS L_B (mm)	Resonant Freq (GHz)	Return Loss (dB)	Bandwidth (MHz)	Impedance Bandwidth (%)
1	1	20	6	3.34	-10.3	490	9.75
				3.85	-26		
				6.1	-11.5		
				6.8	-26		
				6.89	-22		
2	2	20	6	3.28	-17	640	14
				3.6	-27		
				5.6	-17		
				6.9	-23		
3	3	20	6	3.24	-10.4	600	11.9
				3.59	-10.4		
				4.7	-13		
				5.6	-14		
				5.9	-17.6		
				6.89	-25		

The simulated results of conventional rectangular microstrip patch antenna, slit loaded rectangular microstrip antenna without DGS and the slit loaded rectangular microstrip antenna with DGS are presented in a table as in Table 2. From the table we see that the gain is enhanced for the proposed antenna when compared to other antennas.

Table 2. Comparison of Antenna Parameters

Antenna Parameters	Reference Antenna	Slit Loaded Antenna without DGS	Proposed Antenna
Resonant Frequency (GHz)	5.5	2.48, 5.72, 6.26	3.28, 3.6, 5.6, 6.9
Return Loss (dB)	-13.93	-19, -20, -21	-17, -27, -17, -23
VSWR	2.3	1.2	1.2
Gain (dB)	6.80	4.47	9.4
Bandwidth (MHz)	180	650	640
Impedance Bandwidth (%)	3.25	12	14

Miniaturization (%)	-	85	73.45
Application	-	ISM (2.4-2.484), SATELLITE (5.9-6.42)	WIMAX (3.2-3.8), (5.2-5.8), (6.9-7.8)

CONCLUSION

A compact high gain slotted antenna with DGS has been simulated using MOM based software CADFEKO. High gain is achieved by etching the patch and the ground plane of a conventional rectangular microstrip patch antenna. The proposed antenna is very simple in its construction and cost effective due to the use of FR4 substrate material. The proposed antenna with DGS achieved better performance characteristics than an antenna without DGS. Bandwidth of the proposed antenna is also satisfactory at various frequencies. The resonant frequency is shifted from 5.5 GHz to 3.28 GHz thereby providing more than 70% miniaturization, when the defect is introduced into the ground plane. The proposed antenna finds useful application in wireless communication systems that cover both the WIMAX Frequencies. The results obtained are in good agreement with the standard requirements of an antenna in terms of miniaturization and Gain enhancement.

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