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Microstrip X-band Antenna with Improvement in Performance Using DGS

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Abstract Simple and new microstrip patch (MSP) antenna for dual operation in X-band using Defective Ground Structure (DGS) is proposed here. DGS structure is used for improving the performance of microstrip patch antenna. By using four rectangular slots in patch we achieved two frequency bands one (9.24-9.68GHz) and other band (11.63-11.87GHz) both are in X-band. And for improving parameter like return loss, bandwidth, gain and directivity of MSP antenna one rectangular slot is cut in ground plane. The proposed antenna is compact in size with dimension 10 x 10 x 1 mm^3 with the ground plane. For designing and fabrication of this structure FR-4 substrate of thickness 1 mm with Dielectric constant 4.9 is used. The parameters of proposed antenna like return loss; Voltage Standing Wave Ratio (VSWR), radiation pattern; gain and directivity are simulated and analyzed using commercial computer simulation technology microwave studio (CST MWS). A good agreement between simulated and measured results is obtained. The designed antenna structure is very simple, compact and occupies less space all these qualities make this antenna suitable for practical applications. The main application of proposed antenna is to make compatible with radiolocation, radio navigation and fixed satellite applications in X-band (8-12GHz).

Keywords DGS (Defective Ground Structure), MSP (Microstrip Patch), PBG (Photonic Band Gap), RADAR (Radio Detection and Ranging), SIW (Substrate Integrated Waveguide), VSWR (Voltage Standing Wave Ratio), X-Band

1. Introduction

According to IEEE standards X-band ranges from 8.0 to 12.0 GHz which belongs to the microwave radio region of the electromagnetic spectrum. The X-band has wide applications in radar engineering. This band is widely used or short range tracking, missile guidance, marine, radar, and airbone intercept [1]. Basically it is used for RADAR communication and RADAR is an electromagnetic system for the detection and location of reflecting objects such as aircraft, ships, spacecraft, vehicles, people and the natural environment.

Due to increase in demand of small antennas for RADAR communication there was huge increment in interest of research work on compact microstrip antenna [2-4]. We use microstrip antenna as ideal choice for RADAR applications because of various advantages such as the small size, light weight, thin profile, low cost and ease of fabrication [5]. MSP has lots of advantages but it also has few disadvantages like low gain, narrow band width and low efficiency. There are various methods to overcome from these disadvantages few of them are:

1. Array configuration [3]
2. Multilayered structure [6]
3. Change in shape of patch and adding different shaped slots in patch in proper position [1], [7].
4. Using low dielectric constant of substrate or increase the thickness of substrate [8].
5. Proper feeding [4] and using metamaterial structure [9].
6. And use different structure like photonic band gap (PBG)[10-11], substrate integrated waveguide (SIW) [2], and Defective Ground Structure (DGS) [12].

Due to increasing demand for microstrip patch (MSP) performance enhancement in MSP antenna we used DGS structure. Using DGS we can add an extra degree of freedom in microwave circuit design which opens the door to a wide range of applications [12]. DGS structure is realized by etching simple shape from the ground plane [13]. DGS disturbs the shield current distribution in the ground plane cause the defect in the ground. Due to this disturbance there will be changes in characteristics of a transmission line such as capacitance and inductance [12].

In this paper a new simple, compact MSP antenna is designed using defective ground structure for radiolocation, radionavigation and fixed satellite applications in X-band. Feeding is provided in this MSP antenna using microstrip line feeding technique.

The performance of this antenna is optimized by

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introducing four rectangular slots on patch and for improving performance we etched one rectangular shape slot in ground plane by this slot in ground bandwidth, gain and directivity of proposed antenna are improved. In this paper the fabricated structure and measured results of proposed antenna with their results are included.

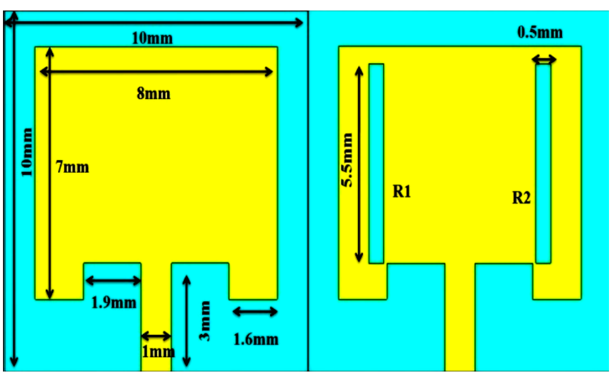
In this paper there are four sections. In second section the designed and fabricated structure of antenna is explained. In third section the simulated and measured results of the designed and fabricated MSP antenna are explained, in results return loss, VSWR, farfield radiation pattern, gain, directivity etc. are discussed. Then finally we will conclude the paper in conclusion portion.

2. Antenna Designing

For proposed MSP antenna four rectangular slots R1, R2, R3 and R4 are introduced in patch the geometry of proposed structure is shown in Figure 2(a) And the fabricated structure is in Figure 3(a). By simulating the structure in Figure 2(a) We achieved two bands in X-band then to improve proposed antenna parameters like return loss, gain, directivity etc. we cut a rectangular slot in its ground geometry of this structure is in Figure 2(b). And fabricated DGS structure is in Figure 3(b). The proposed antenna is designed on FR-4 substrate with dielectric constant 4.9 and height of substrate is 1mm. For this antenna Microstrip line feeding technique is used, dimensions of microstrip line are 1 x 3 mm^2. The designing steps of proposed antenna are explained in following steps:

2.1. Simple MSP Antenna

Firstly we designed a simple patch antenna with overall size 10 x 10 x 1.07 mm^3 and its patch dimension is 7 x 8 mm^2 as shown in Figure 1(a). This simple patch antenna is working on single resonant frequency and for getting desired X-band frequency hit and trial method is used.

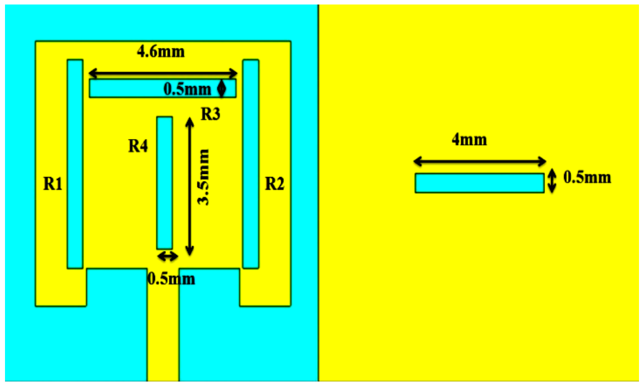


(a) (b)

Figure 1. (a) simple MSP antenna (b) MSP antenna with slot R1 and R2

2.2. MSP Antenna with slot R1, R2

Slots on patch are responsible for the excitation of the multi resonant mode and for better performance we cut two rectangular slots R1 and R2 on simple patch with identical dimensions 5.5 x 0.5 mm^2 and placed vertically and parallel to each other as in Figure 1 (b) By introducing these two slots on patch we got two resonant frequencies one is 9.7 GHZ and second is at 12.05 GHz shown in Figure 5 (a) as the second frequency is out of X-band and its return loss is also not good so we need to modify this structure.



(a) (b)

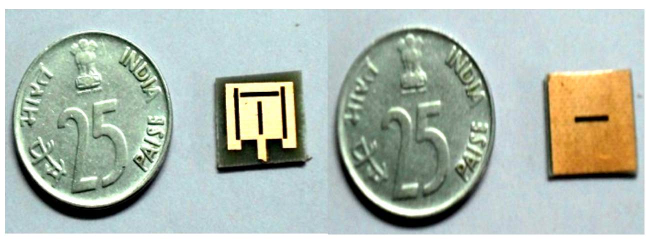
Figure 2. Proposed MSP antenna (a) front view (b) back view

2.3. MSP Antenna without DGS

For modifying structure Figure 1(b) we cut two more rectangular slot R3 with dimension 4.6 x 0.5 mm^2 and R4 with dimension 3.5 x 0.5 mm^2 shown in Figure 2(a). R3 and R4 are normal to each other and placed between R1 and R2. By simulating this structure two bands are achieved both are in X-band and by introducing R3 and R4 slots our return loss is improved which is explained in result section.

2.4. Modified MSP Antenna with DGS

For more improvement in return loss, bandwidth, and gain etc. Parameters of MSP antenna we used DGS. For DGS we cut a rectangular slot with dimensions 4 x 0.5 mm^2 in ground plane in Figure 2(b).



(a) (b)

Figure 3. Fabricated Proposed MSP antenna (a) front view (b) back view

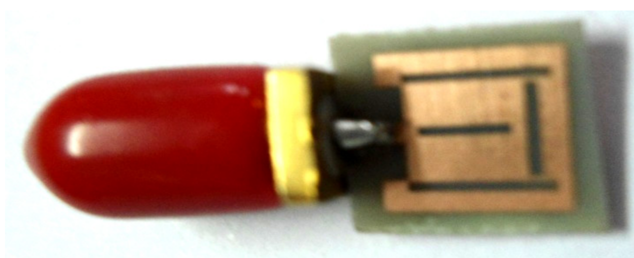
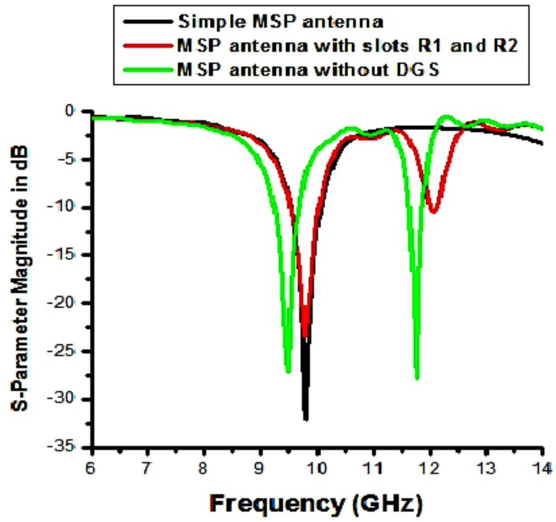
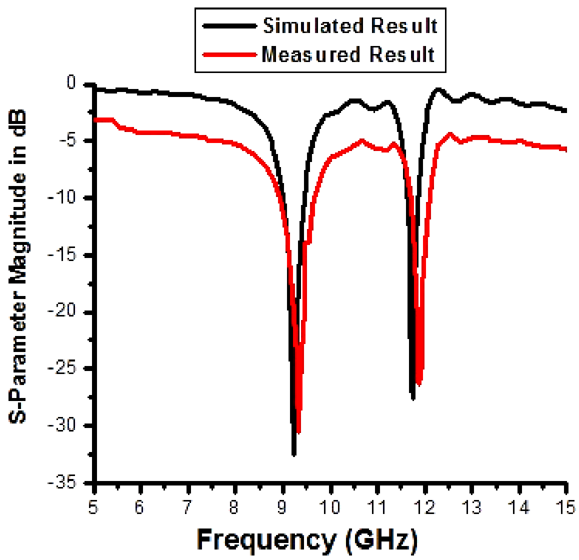


Figure 4. Proposed fabricated MSP antenna



(a)



(b)

Figure 5. (a) comparison of return loss due to different slots and without DGS (b) comparison of simulated and measured results of proposed MSP antenna with DGS

As explained in introduction part using DGS in ground plane current distribution in it is disturbed and due to that transmission line characteristics changes. By simulating this structure our results are improved which are explained in next section and final fabricated structure is in Figure 4.

3. Simulated and Measured Results

The proposed MSP antenna is simulated using Electromagnetic (EM) simulation software CST MWS. In results the return loss, VSWR, gain and directivity are discussed.

As Figure 5(a) shows the simulated results of simple MSP antenna is resonant and by introducing different rectangular slots in patch simple patch is working at single frequency 9.8 GHz and due to slots two bands are achieved as well as their return loss is improved by cutting slots. The important parameter of MSP antenna is VSWR the requirement of VSWR for MSP antenna is ≤ 2. This requirement is fulfilled by all resonant frequencies. The variation in frequency bands, resonant frequencies, return loss and VSWR of MSP antenna due to different slots is tabulated in Table 1. And their simulated return loss and VSWR comparison is shown in Figure 5(a) and Figure 6(a) Respectively. As from Table 1 it is clear that by using DGS structure our return loss and bandwidth is improved as compared to without DGS structure.

Table 1. Comparison of Variation in Return Loss and VSWR due to Slots in Patch or Ground

Type of antenna	Bands (GHz)	Resonant frequency (GHz)	Return loss (dB)	VSWR
Simple MSP antenna	9.54-10.0	9.8	-32.07	1.1
MSP with R1,R2 slot	9.5-10.0 12-12.12	9.7 12.05	-23.78 -10.61	1.17 1.9
MSP antenna without DGS	9.24-9.68 11.63-11.87	9.47 11.7	-26.83 -27.63	1.03 1.07
Modified MSP antenna with DGS	8.99-9.4 11.63-11.88	9.24 11.7	-32.23 -28.02	1.04 1.09

Table 2. Comparison of simulated and measured results of proposed antenna with DGS

Antenna	Resonant frequency (GHz)	Return loss (dB)	VSWR
Simulated MSP antenna	9.24 11.7	-32.23 -27.29	1.04 1.09
Measured MSP antenna	9.32 11.89	-30.5 -26.4	1.06 1.1

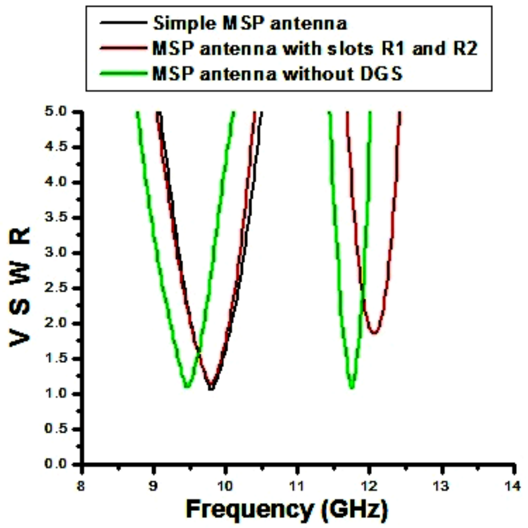
Table 3. Comparison in different far field parameters of with and without DGS structure

Antenna	Resonant frequency (GHz)	Main lobe Magnitud e (dB)	Main lobe Direction (deg.)	Angular width (3dB)
MSP antenna without DGS	9.47 11.7	2.5 4.3	-90.0 180	95.3
Modified MSP antenna with DGS	9.24 11.7	2.5 4.3	-90.0 179.0	58.7

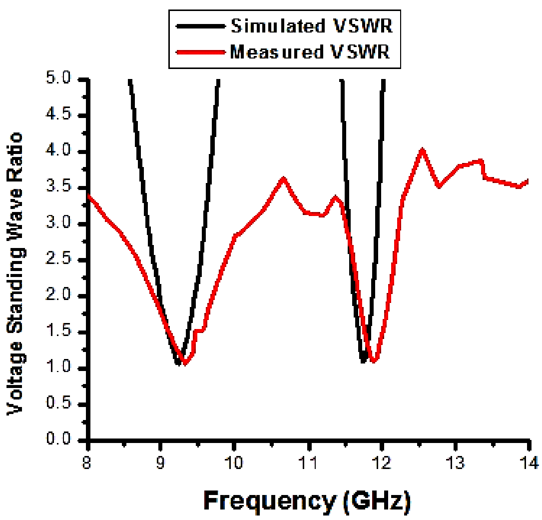
Table 4. Comparison in Gain, directivity and bandwidth of proposed antenna with DGS and without DGS

Antenna	Resonant frequency (GHz)	Gain (dB)	Directivity (dBi)	Bandwidth (MHz)
MSP antenna without DGS	9.47 11.7	3.9 4.0	3.0 6.4	430 241.1
Modified MSP antenna with DGS	9.24 11.7	4.59 4.34	3.2 6.7	450 266

The simulated and measured return loss and VSWR graphs of proposed MSP antenna are shown in Figure 5(b) and Figure 6(b) respectively. And Comparison of simulated and measured results of proposed antenna is tabulated in Table 2. The simulated and measured results are almost same which shows that this antenna can be used practically too. The simulated and measured VSWR of the proposed antenna is ≤ 1.1 which is very good. Farfield gain Abs (theta = 90^o) at resonant frequencies 9.24 and 11.7 GHz is sown in Figure 7 (a-b) and the farfield parameter of MSP antenna without DGS and with DGS are tabulated in Table 3. At 11.7 GHz angular width (3dB) is almost negligible. Directivity, gain and bandwidth of proposed MSP antenna for with and without DGS structure are tabulated in Table 4 which shows that by introducing DGS in patch antenna all three parameters are improved.



(a)

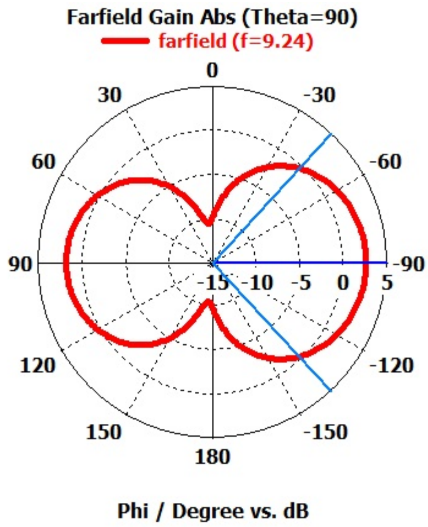


(b)

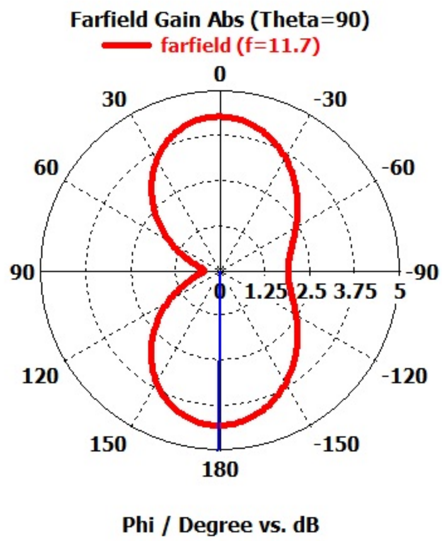
Figure 6. (a) comparison of VSWR due to different slots and without DGS structure (b) Comparison of simulated and measured VSWR of proposed MSP antenna with DGS

4. Conclusions

A simple and compact dual band MSP antenna for X-band applications like radiolocation, radio navigation and fixed satellite applications is proposed. Proposed antenna is compact with overall size 10 x 10 x 1 mm^3 with patch dimension 7 x 8 mm^2. For designing and fabrication of this antenna FR-4 substrate with dielectric constant 4.9 and thickness 1 mm is used. By using four rectangular slots two resonant frequencies 9.4 and 11.7GHz are achieved. For improving the return loss and other characteristics of antenna DGS is used.



(a)



(b)

Figure 7. Farfield gain pattern at (a) 9.24 GHz (b) 11.7 GHz

From final DGS based design structure two frequency band with return loss -32.23dB and -27.29dB at resonant frequencies 9.24 and 11.7GHz respectively is achieved. At resonant frequencies VSWR ≤ 1.1, gain is 4.59 and 4.34dB and directivity is 3.2 and 6.7dBi respectively. A good agreement between simulated and measured results is obtained. The low profile nature and simple configuration of antenna make this antenna suitable for practical applications. The main application of proposed antenna is to make compatible with radiolocation (industry, military services, biomedical and radiology), radio navigation and fixed satellite applications in X-band.

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