The Improved Radiations in Planar Microstrip Patch Antenna using Linear Slot Etched Ground Plane

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Abstract: ***Radiations improvement in a probe fed rectangular microstrip patch antenna using linear slot etched ground plane is proposed. Conventional MPA is designed using Glass Epoxy FR4 substrate. Substrate has dielectric constant 4.4 and its thickness 1.6 mm, operated at resonant frequency 3.05 GHz. The proposed method is simple and easy to etch on a substrate. This will suppress cross-polarized (XP) radiation field only without disturbing the dominant mode and co-polarized radiations. The concept has been tested using HFSS tool and verified its results experimentally. The experimental results show a good agreement with the simulation results.***

Index terms : Co-polarized radiation, Rectangular Microstrip Patch Antenna, Cross-polarized radiation, Defected Ground Structure.

I. INTRODUCTION

Planar microstrip patch antennas (MPAs) are most popular and dominant due to their advantages like light weight, low-cost, compact in size, low-profile, and high efficiency[1-2]. They are widely used in all satellite, mobile wireless communication applications. The main limitations of MPAs are narrow bandwidth, low gain, high cross polarized (XP) fields, low isolation, spurious radiations, unwanted higher modes etc. The radiations of MPA are mainly affected by the excitation of higher modes and there by resulting in high cross-polarized radiations in the dominant mode [3-4]. There are many techniques are reported to enhance the radiations using defected ground structures (DGS) [5-10]. The characteristics of microstrip by suppressing the cross-polarized fields by using arc shaped DGS [7]. The complete analysis of controlling the cross-polarized fields by different DGS shapes like circular and semicircular slots is presented [8]. Along with polarization purity a wide impedance bandwidth is also achieved by the use of DGS [9]. Asymmetric geometry of DGS explored in the reduction of cross polarization (XP) radiation and achieved more than -28dB isolation [11]. There are other shapes of DGS like square cells, rectangular cells, dumbbell shapes, circular cells are used in the literature [12-15].

In this paper, we proposed the enhancement of radiation characteristics in a probe fed rectangular microstrip patch antenna using linear slot as DGS. This configuration is applicable for real applications. The simulated result indicating XP fields value -46dB and co-polarized to cross-polarized isolation of 52dB. Results are very good compared to all reported techniques in the literature as summarized in the Table-II in conclusion.

II. METHODOLOGY

1. A conventional rectangular microstrip patch antenna (MPA) is implemented using transmission line model (TLM) analysis method.
2. The designed antenna is simulated using HFSS simulator.
3. Designed MPA has etched ground plane as DGS slots and simulated in HFSS. The dimensions of linear DGS slots are optimized.
4. Prototypes are fabricated using suitable dielectric material using latest PCB technique.
5. Simulated results are experimentally verified by series of experiments and found that the simulated predictions are well matched with the experimental data. The measurements are done in microwave laboratory, Indian Institute of Science (IISc) Bangalore.

III. ANTENNA DESIGN AND ANALYSIS

The proposed antenna configuration is shown in Fig.1. The conventional rectangular MPA is designed using transmission line model (TLM) method so as to resonate at 3.05 GHz frequency, FR4 dielectric substrate with ε_r = 4.4 with a thickness h = 1.6 mm is used [1-2]. As per the TLM method the dimensions the rectangular microstrip patch can be estimated by using the following equations. The width and length of the patch are

$$\text{Width} = W = \frac{C}{2 f_r \sqrt{\frac{\varepsilon_r + 1}{2}}} \quad \text{----------(1)}$$

$$\text{Length= L=} \frac{C}{2 f_r \sqrt{\varepsilon_{eff}}} - 2\Delta L \quad \text{----------(2)}$$

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$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}} \text{----------(3)}$$

Here, ε_r is the dielectric constant of the substrate ε_{eff} is the effective dielectric constant and ΔL is effective length subjected to the correction factor. Radiating patch and ground plane are fabricated by copper metal, with the thickness of 0.035mm. The dimension of ground plane is $0.8\lambda_0$ (Wg) × $0.8\lambda_0$ (Lg), λ_0 is free space wavelength. The coaxial probe feed is used to feed the rectangular MPA.

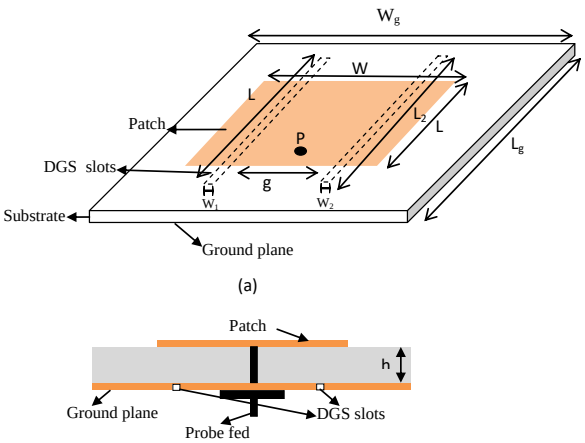


Fig 1. Configuration of Proposed slot etched DGS RMPA.(a) 3D dimension of proposed RMPA.(b) Side view

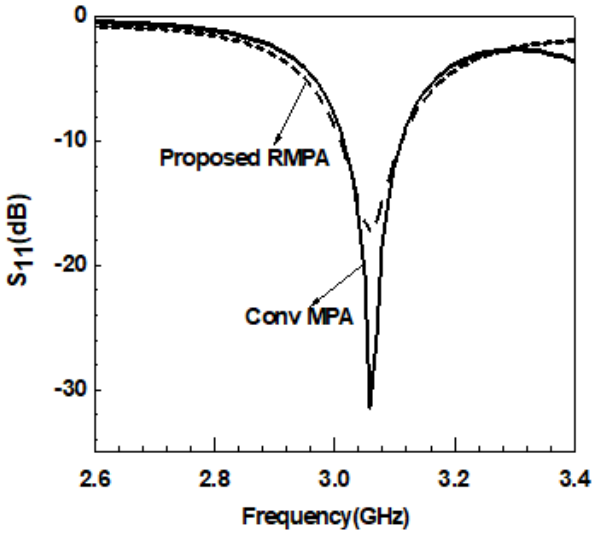
The proposed MPA configuration is made by etching a pair of symmetrical linear slots with dimensions $1.5mm \times 34mm$ on ground plane. Table (I) shows the optimized dimensions of proposed RMPA

Table- I: Parameters of proposed RMPA

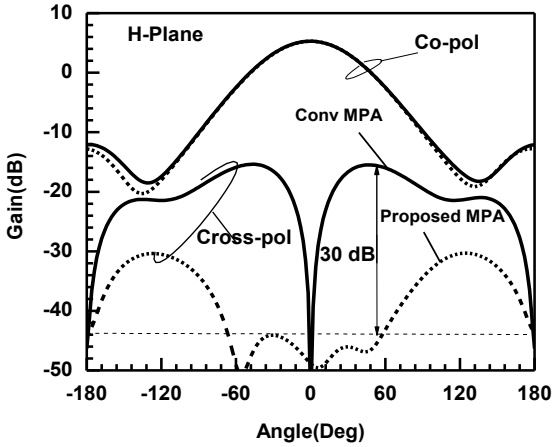
Parameter	Optimized value (mm)
W	38
L	20
p	-7
L1	34
L2	34
Wg	80
Lg	80
g	16
W1	1.5
W2	1.5

IV. SIMULATED RESULTS AND DICUSSION

The simulated result of return loss characteristics is shown in Fig. 2 (a). Characteristic shows the comparison study of conventional and proposed MPA. Due to etching of ground with slots, an inductive loading is revealed here and an S_{11} minimum is observed as depicted in S_{11} comparison plot but no change in resonating frequency. These slots reduce the fringing current density and also minimize the orthogonal components of E-fields and hence it suppresses the cross-polarized (XP) field in H plane, without changing the co-polarized radiations in both the principal planes. The distance between the slots is $\frac{\lambda}{4}$.



(a)



(b)

Fig.2. Simulated result of return loss and H-plane radiation characteristics of conventional and proposed RMPA configurations: (a) return loss characteristics, (b) H-Plane radiation characteristics.

The Fig. 2(b) shows comparison of conventional and proposed configuration of H-plane radiations characteristics. Conventional configuration shows the peak co-pol gain of 6 dBi with cross-pol of -16dB. In proposed configuration gain remains same with cross-pol value of -46dB. The total isolation is 52dB is achieved.

V. PARAMETRIC STUDIES OF PROPOSED ANTENNA

The effect caused by varying dimensional parameters of length, width and gap position of linear slot in a proposed antenna has been investigated by optimization.

A. Variation of length of DGS slot

Length L_1 and L_2 are varied from 25mm to 40mm and radiation characteristics are observed by fixing width of 1.5 mm as shown in fig 3. For L_1= L_2 = 34 mm, highest suppression of XP value is obtained and for L_1=L_2>34mm, cross-polarized radiation improves instead of suppression.

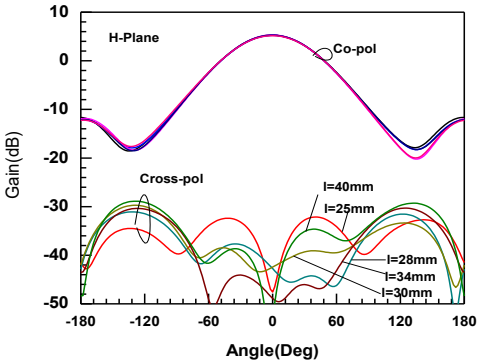


Fig.3. Simulated result of H-plane radiation characteristics with different lengths.

B. Variation of width of DGS slot

Width W_1 and W_2 are varied from 0.5mm to 2mm and radiation characteristics are observed by fixing length of 34 mm as shown in fig 4. W_1= W_2= 1.5mm is the best for XP suppression and this XP characteristics collapses as we increase the width behind 1.5mm.

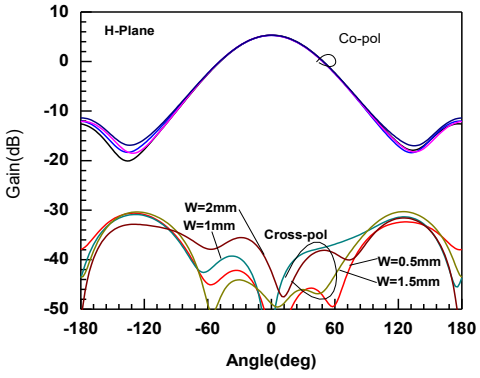


Fig.4. Simulated H-plane radiation characteristics of proposed RMPA with different width.

C. Variation of gap position of DGS slot

The gap position of two DGS slots are varied from 0.5 mm from the center of the ground plate and H-plane radiations are observed in fig.5. When g = 16 mm suppression of about 46 dB is observed. If g = 17mm then XP improves instead of suppression and also asymmetric.

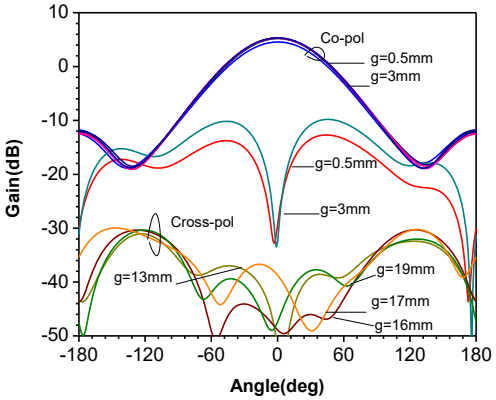
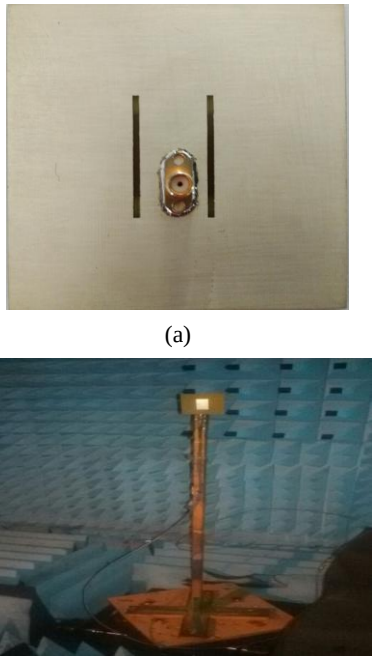


Fig.5 Simulated H-plane radiation characteristics due to varying position of slot of proposed RMPA

VI. EXPERIMENTAL RESULTS AND DICUSSION

Conventional and proposed MPA are fabricated to study experimental concept. Fig. 6 (a) shows a bottom view of proposed coaxial probe fed rectangular MPA .Fig.6 (b) shows radiations measurement in anechoic chamber. In order to validate the simulation data a set of experiments conducted in microwave laboratory at Indian Institute of Science (IISc) Bangalore.



(a)

Fig.6. (a) Fabricated proposed MPA (b) Radiations measurement in anechoic chamber.

The comparison of conventional and proposed antenna shows shift in S_{11} from -34dB to -18dB, because of inductive load,effect on the impedance match is observed as shown in fig.7(a).The comparative plot of measured radiation patterns of conventional and proposed RMPAs is shown in fig.7 (b). Cross-polarized suppression (XP) radiation in H-plane appears significantly as per our simulation study.

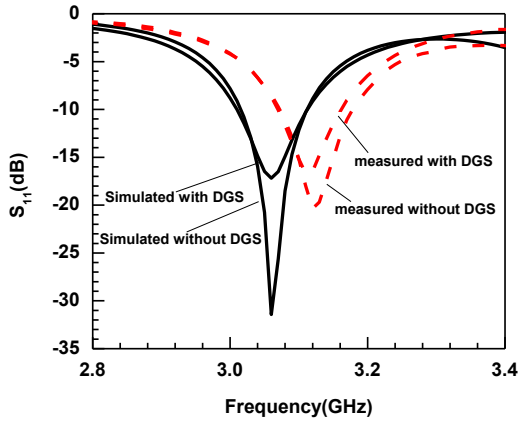


Fig.7(a). Simulated and measured results of return loss characteristics of with and without DGS.

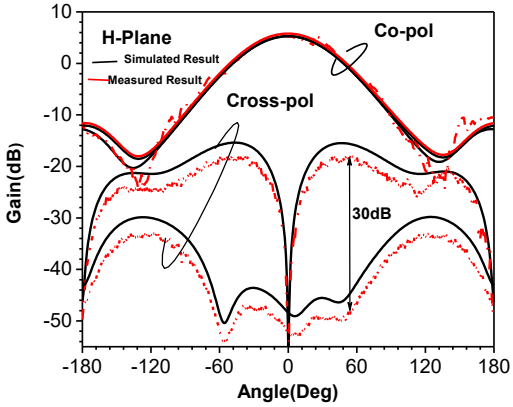
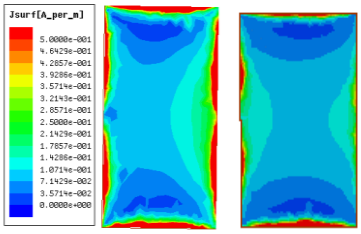


Fig .7(b). Comparison result of simulated and measured H-plane radiations of conventional and proposed RMPA.



(a) (b)

Fig.8. Fringing current density of RMPA (a) conventional RMPA (b) proposed RMPA

DGS slots minimize fringing current density and hence it suppresses the cross –polarized (XP) fields without changing the co-polarized radiations in both the principal axis are shown in fig 8.

VII. CONCLUSION

Higher value of cross polarized radiation (XP) is a major limitation in microstrip antenna over broad side radiation. A coaxial probe fed rectangular microstrip patch antenna with simple technique of DGS is implemented for the suppression of cross-polarized (XP) radiation. Cross polarized (XP) suppression about 30 dB is obtained in proposed configuration, when compared to conventional antenna configuration. The XP level of -46dB symmetric with broadside and the total isolation of about 52dB are achieved in proposed antenna. The proposed antenna arrangement is helpful for S-band applications.

TABLE II

PERFORMANCE COMPARISION OF DIFFERENT DGS SHAPES

DGS Shapes	fr (GHz)	Co-Pol Gain in (dB)	Cross-Pol Suppression in(dB)	Improved Isolation in(dB)	Applications
Rings	10.7	--	--	5	Mutual coupling reduction
Arc Shape	5.9	6.1	10-12	30	XP Suppression
V-Slot Shape	5.7	-	-	10	42% BW enhancement
Circular dot shape	5.9 and 10.05	6.3	10-12	17	C and X-band
Pair of folded and Linear DGS slots	10.2	6.5	11-18	25-30	X-Band
L-shaped DGS	10	6.2	9-10	15	X-Band
Slot Type DGS	8.5	5.8	25	15-25	X-Band
Proposed Pair of Linear Slot DGS	**3.05**	**6**	**30**	**52**	**S-Band**

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