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Cross Polarized Radiations in Probe-Fed Rectangular Microstrip Antenna and Suppression Using Defected Ground Structure

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Abstract: H-plane cross-polarized radiation (XP) suppression has been discussed in this paper. There are many factors such as probe radiations, orthogonal components of dominant mode, fringing fields due to high fringing current etc., which causes the high XP radiations in a probe fed microstrip patch antenna (MPA). There are various techniques of XP suppression as reported in the literature, the etching of resonant slots as defected ground structure (DGS) close to the non-radiating edges of the patch is one of the techniques, simple and significant amount of XP suppression which can be achieved using this technique without changing the co-polarized radiation. The conventional MPA with resonating frequency of 3.1 GHz is designed using FR4 substrate with ε_r= 4.4 and h = 1.575 mm. The simulated result shows broadside radiation characteristics with peak gain of 5.27 dBi and XP fields -16dB is observed. Whereas the proposed MPA resonates at the same frequency and gain with broadside radiations but XP fields are significantly suppressed by 30 dB and it is -46 dB over the span of $\pm 70^0$ with co-polarize to cross-polarize isolation of 51.27 dB is achieved which is good for high quality wireless sensor applications. A prototypes were fabricated using commercially available low-loss dielectric material FR4 (glass epoxy) with dielectric constant (ε_r) = 4.4. The result of this work shows a good agreement with the simulation results.

Keywords: Co-polarized radiation, Cross-polarized radiation, Defected Ground Structure, Isolation, Microstrip Patch Antenna.

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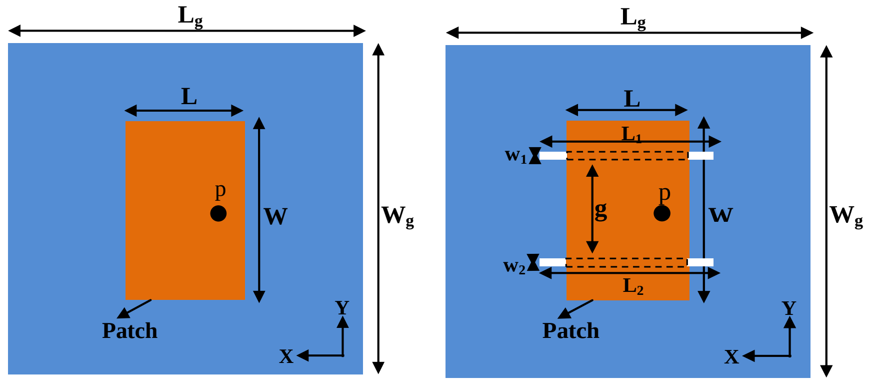
I. INTRODUCTION

Microstrip patch antennas (MPAs) are compact, low-profile, low-cost, light weight and high efficient antennas used in all wireless and satellite communication applications. The MPAs are having some limitations like very narrow bandwidth, low gain, high cross polarized (XP) fields, low isolation etc. To overcome these limits many techniques have been implemented [1-3]. The DGS technique was introduced in 2005 and used to enhance characteristics of MPA such as antenna efficiency, radiations, bandwidth , gain etc. There are different shapes of DGS such as are proposed in the literature, such as dumbbell [4], square [5], spiral [6], U-shape [7] and cross-shape [8],hexagonal ring fractal antenna dumbbell shaped DGS [9] etc., There are some works reported on XP suppression like, concentric ring [10], arc shapes [11], V-slot DGS [12],circular dot shape [13], L-shape [14],slot type [15], The resonating DGS (RDGS) slots and achieved XP suppression of 30dB[16]. The asymmetric geometry of DGS used for the suppression of XP and claimed the total isolation of 28dB [17]. Folded non-radiating DGS slots [18] gives the XP suppression of 10-13dB.

In this paper, we proposed the enhancement of radiation characteristics in rectangular microstrip patch antenna by a simple technique consists of two symmetrical linear resonant slots, etched in a ground plane as defected ground structures placed at non-radiating edge of the patch. The configuration is excited by a coaxial probe feed. The proposed technique is simple and easy to implement for practical applications. The simulated result indicating XP fields about -46 dB, and good co-pol to cross-pol isolation of 51.27dB were achieved.

II. ANTENNA CONFIGURATION

A conventional probe feed rectangular microstrip patch antenna (RMPA) were designed using Transmission Line Model (TLM) to resonate at 3.1 GHz using the FR4 dielectric substrate with ε_r= 4.4 and h = 1.575 mm as per the design guidelines given by [1-3].The probe feed location 'p' from center as shown in fig1 (a) is chosen to excite ideal TM01 mode with impedance matching of 50Ω. The size of ground plane is ($W_g \times L_g$) and the patch length and width based on TLM is W×L, width to length ratio$\frac{W}{L}$= 0.5 to make rectangular



(a) (b)

Fig. 1 Schematic diagram of a probe fed rectangular microstrip patch antenna, considering parameters as Lg = 80mm, Wg = 80mm, W = 40mm, L = 22mm, p= -7mm (from the center), $L_1 = L_2$ = 32mm, $W_1 = W_2$ = 1.5mm, ε_r= 4.4. (a) Top view of Conventional MPA, (b) Top view of Proposed MPA.

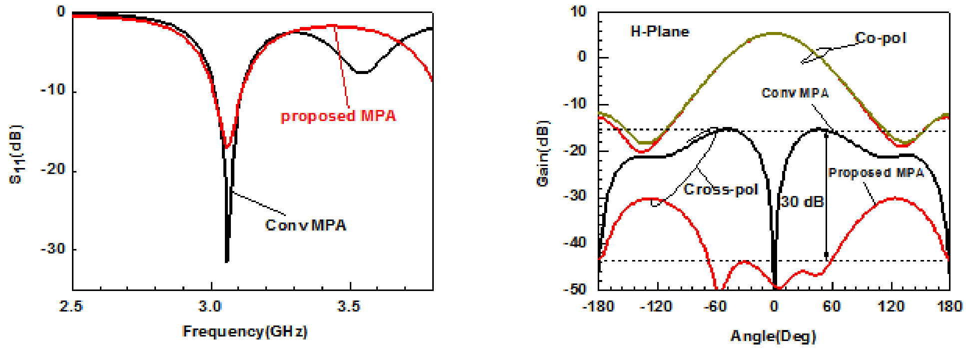
patch. The MPA shows good impedance match, return loss characteristics with broadside radiations. The proposed MPA configuration were made by etching a pair of linear resonating slots with dimensions$W_1 \times L_1$in the ground plane as DGS slots. The slots are placed in such way that they were very close to resonating edges of the MPA to disturb the fringing fields. The dimension of slots and their positions in the ground plane were decided based on optimization. The length and the width of slots were 32mm and 1.5mm respectively and the separation with gap space of 'g' between the two slots is more than λ/4. The top view of conventional and proposed configuration of MPA is depicted fig1 (a) and (b).

III. WORKING CONCEPT

The probe fed microstrip patch antennas have considerably high cross-polarized radiations (XP) in H-plane. There are many factors such as probe radiations, orthogonal components of dominant mode, fringing fields due high fringing current etc. In this work, the H-plane fringing fields get coupled to the resonant DGS slots and become ineffective in producing considerable XP radiation. Also suppress the occurrence of any orthogonal resonance. This would weaken the fringing field and cause suppression in XP level. There are three factors which cause strong fringing effect (1) use of low dielectric constant (ε_r), (2) use of thicker substrate (h), (3) Increase in patch width (W). In our design we have used wider width and also the concept of placing the DGS slots closer to both non-radiating edges to suppress the fringing or shielding current. The control of fringing or shielding current at the non-radiating edges of MPA reduces the electric field loss due to fringing field. This automatically couples the non-linear electric fields to linearly proposed fields on the radiating edges and improves the radiations by suppressing the XP radiations. The DGS technique by etching the two resonant type symmetrical DGS slots with the dimension (32X1.5) mm very close to non-radiating edges of MPA, so that these slots reduce the fringing current density and hence it suppress the XP fields without changing the co-polarized radiations in both the principal planes. The distance between the slots is maintained more than λ/4. We have chosen probe feed along the center line at p=$\frac{W}{2}$, it minimizes higher order modes which also help to strengthen the dominant mode characteristics of MPA.

IV. SIMULATION RESULTS

The comparison of simulated return loss characteristics of both the conventional and the proposed MPA is as shown in Fig. 2 (a). There is no change in resonating frequency of both configurations but due to loading of two DGS slots



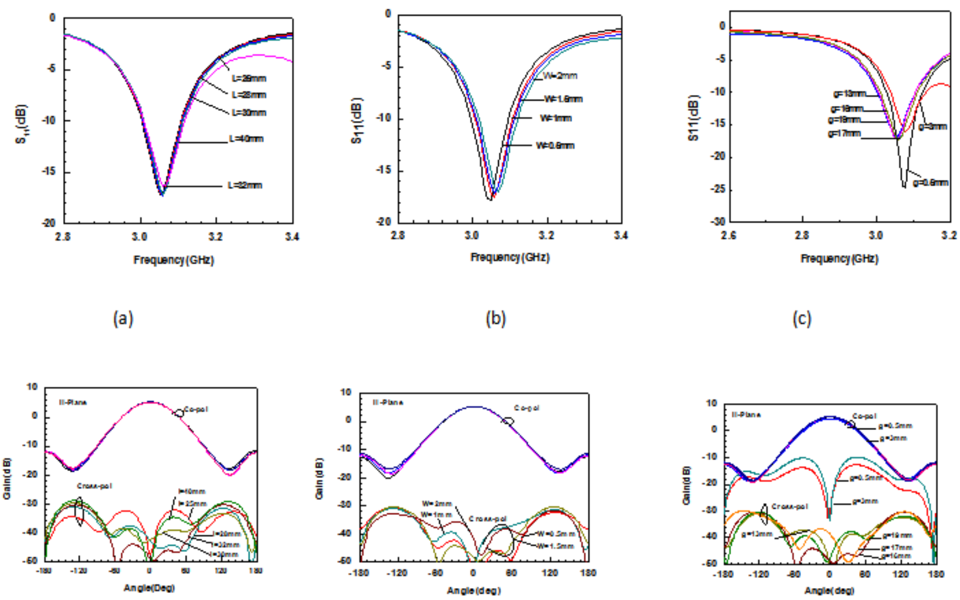
(a) (b)

Fig.2. Simulated S_{11} and H-plane radiation characteristics of conventional and proposed MPA configurations:(a) return loss characteristics, (b) H-Plane radiation characteristics of a rectangular patch with and without DGS.

makes some inductive loading so the variation in impedance matching occurs and hence a relative shift in S_{11} minima is revealed in the proposed configuration. The Fig. 2(b) shows the H-plane radiations characteristics comparison, the conventional configuration shows the peak co-pol gain of 5.27 dBi with cross-pol of -16dB, the total isolation is 21.57dB. The proposed configuration shows the peak co-pol gain of 5.27 dBi and the H-plane cross-polarization (XP) level is -46dB with a suppression of 30 dB without affecting the co-polarized radiations. The total co-to-cross-pol isolation is 51.27dB.

V. OPTIMIZATION OF DGS SLOTS

The length, width and position of linear slots on the ground plane are finalized by optimization. The changes in S_{11} and radiation characteristics are observed by varying the length with a fixed width of 1.5 mm. The comparative plots of S_{11} and radiations are plotted as shown in Fig. 3 (a) and (d) and decided that length $L_1 = L_2 = 32$ mm, which gives



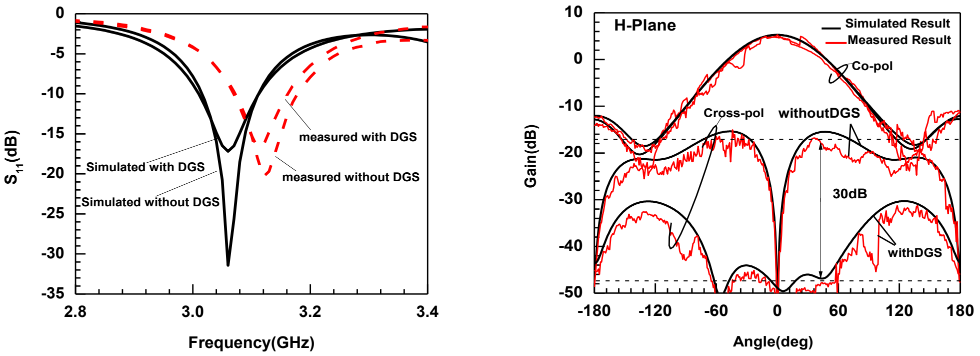
(d) (e) (f)

Figure-3: Simulated return loss and H-plane radiation characteristics due to varying dimensions and gap of two rectangular slots MPA configurations (a) S_{11} for varying Length,(b) S_{11} for varying Width,(c) S_{11} for varying slots gap, (d) radiation characteristics for varying Length,(e) radiation characteristics for varying Width, (f) H-Plane radiation characteristics highest suppression of XP values. If $L_1 = L_2 > 32$ mm then the cross-polarized radiations improves instead of suppression. Similarly the width of the slots are also varied, by fixing the length $L_1 = L_2 = 32$ mm. The resulting effect on S_{11} and radiations are observed to be the best XP suppression for $W_1 = W_2 = 1.5$ mm. This XP suppression characteristics collapses as the width increased beyond 1.5 mm. so, 1.5 mm width is considered for our design. The very sensitive observations on width variations are completely depicted in fig 3(b) and fig 3(e).The position of these two symmetric DGS slots in the ground plane is decided by optimizing the gap (*g*) between the slots. The gap value is changed in a step of 0.5 mm from the center of the ground plane and observed both return loss characteristics and H-plane radiations. It is interesting note that as the slots are closer to each other there is no improvement in the XP suppression but when the gap (g) between the slots increases then there is symptom of XP suppression gradually. As slots closer to non-radiating edges by increasing the gap (g) the significant suppression of XP fields is noticed without change in co-pol radiations of both principal planes. The optimized gap between the slots is g = 16 mm as shown in figure 3 (c) and (f) the XP suppression of about 30 dB is observed. If we increase the gap more than 16 mm then the XP values improves instead of suppression.

VI. PROTOTYPES AND EXPERIMENTAL VERIFICATION

A set of prototypes of conventional and proposed MPA has been fabricated for experimental verification. Fig.4(a) and (b) shows the top and bottom view of proposed probe fed rectangular MPA. In order to validate the simulation data a set of experiments conducted at microwave laboratory at Indian Institute of

(a) (b) (c)

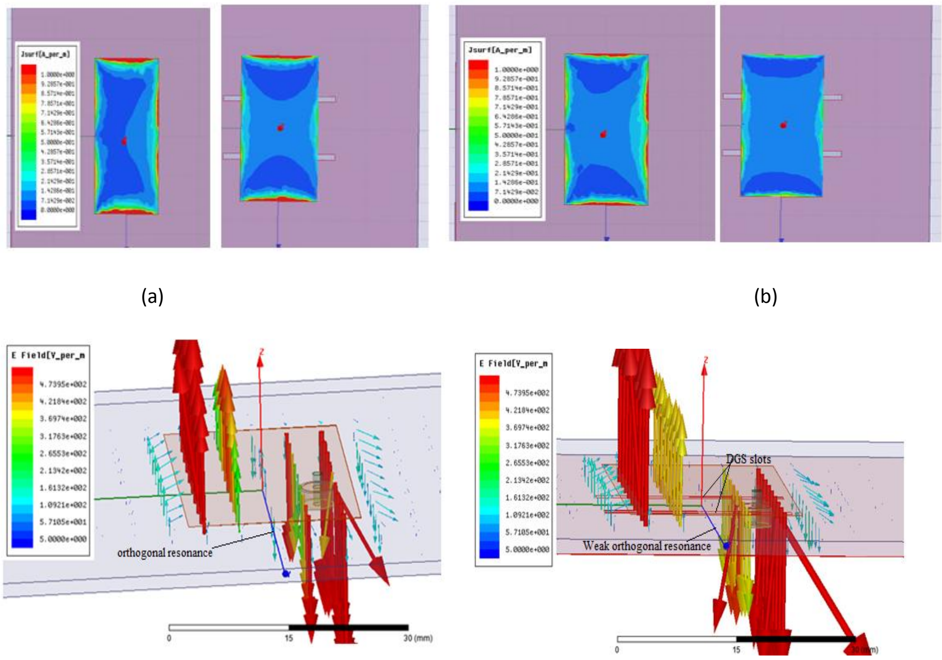


(d) (e)

Fig.4 .Prototypes and Experimental set up of probe fed rectangular microstrip patch antenna: (a) Top view ,(b) Bottom view of proposed MPA (resonating slots seen from bottom side), (c) MPA connected to vector network analyzer for measurement of S_{11}. Comparison of simulated and measured results of conventional and proposed MPA :(d) Return loss characteristics, (e) H-plane radiations of conventional and proposed MPA.

Science (IISc) Bangalore. The S_{11} results are obtained using Vector Network Analyzer and comparative plot shows good agreement as shown in Fig. 4(c).The return loss characteristics comparison of conventional and proposed shows the inductive loading and hence the effect on the impedance matching is observed, which cause marginally shift in S_{11} from -32dB to –18dB as predicted in simulation. The comparative plot of measured principal plane radiation patterns of conventional and proposed MPAs is as shown in fig.4 (d). The XP radiation in H-plane appears significantly suppressed as per our simulation study. The order of reduction of the peak XP values is 30dB as shown in comparative plot and XP is -46dB with symmetric. The isolation between co-pol to cross-pol is 51.27dB**.**

The surface current density (J_{suf}) on patch of the proposed antenna is reduced by linear slots on DGS compared to conventional antenna as shown in Fig.5 at different phase angles i.e. at $20^0$and 40^0. The Fig.5 (a) shows the fringing field current density is very strong in conventional and it is drastically reduced in the proposed MPA at 20^0, similarly the same thing happened at 40^0 also as depicted in Fig.5 (b). This reduced field



(a) (b)

(c) (d)

Fig.5. Surface current distribution on patch comparison of conventional and proposed MPA at (a) 20^0, (b) 40^0 Dominant mode electric field with and without DGS. (c) Conventional MPA Electric fields along orthogonal axis. (d) Proposed MPA weak orthogonal field.

makes the electric field to linearly polarize along with the patch radiation and hence suppresses the XP radiation in H-plane. The presence of orthogonal resonance causing the XP radiation.DGS slots weakens the orthogonal resonance as revealed from Fig 5(d).

VII. CONCLUSION

This communication proposes the improvement of radiation characteristics of rectangular microstrip patch antenna with a simple slot loading technique in ground plane as DGS. The crosspolarization (XP) suppression of about 30dB is achieved when compared to conventional configuration. Prototypes are fabricated and measured, the experimental results shows a good agreement with the simulation data. The XP value is -46dB symmetric along $\pm 70^0$with the total isolation of 51.27dB. The proposed antenna will definitely helpful for antenna society and finds possible applications in the fields of high quality wireless sensors design.

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