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THE HIGHER MODE ELIMINATION IN MICROSTRIP PATCH ANTENNA USING DEFECTED MICROSTRIP SURFACE FOR SUPPRESSION OF CROSS POLARIZED RADIATIONS AND IMPROVED ISOLATION

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Abstract

This paper proposes unique design technique using defected microstrip surface (DMS) for the suppression of higher mode, reduced cross polarization (XP) and improved isolation. The proposed technique can be easily adapted to any conventional working rectangular microstrip patch antennas (RMPA) in the practical applications. The modification can be made by etching the rectangular slots called DMS of optimized dimensions in the rectangular microstrip patch. This will enhance the radiations by suppressing XP radiations and eliminates nearby undesired higher order mode, which is the source for the XP radiations. In this design the conventional RMPA is designed to resonate at 3.04 GHz with broad side radiations with co-polarized peak gain of 5.2dBi and XP of -15.5dB. The proposed RMPA resonates at the same frequency with a gain of 6dBi. The XP is significantly suppressed by 31dB and it is -46.5dB over the span of ±500, with co-pol to cross-pol isolation of 52.5dB is achieved for S-band applications. The performances of the designed antennas have been experimentally verified.

Keywords:

Cross–polarization, DMS, Isolation, RMPA

1. INTRODUCTION

Rectangular microstrip patch antenna (RMPA) is popular and used in all wireless and mobile applications. The microstrip antennas are attractive because of light weight, low cost, tininess, easy fabrication process, compatibility to MMIC and has broadside radiations etc. [1]-[2]. The MPAs has limitations like, narrow bandwidth, low gain, high cross-polarized radiation (XP) etc. Radiation pattern gets distorted like high cross-polarised radiation is obtained by probe-fed microstrip patches [3]. The cross polarized (XP) radiation is more significant in the H-plane than in E-plane and is not required in the field of wireless applications [4]-[5].

A probe-fed RMPA has a fundamental TM_{01} mode which radiates along its broadside direction with linearly polarized fields. These designs have normally higher XP radiations due to vertical probe, which also acts as monopole radiator and orthogonal field components, very poor isolation can be observed between co-pole and cross-pole radiations [6]-[7]. This is the main drawback in some of applications like adaptive antenna arrays for mobile communications, RADAR and microwave communications, where improved polarization purity is required. Many research groups have taken an interest to reduce the cross polarized (XP) radiation since from last three decades. Researchers have tried to suppress the cross-polarized radiation with different methods of feed surface [8]-[9]. The defected ground structure (DGS) technique established to reduce the XP radiation like, arc shapes concentric ring, circular dot shape, spiral DGS, slot type, L-shape [10]-[15], folded non-radiating DGS slots gives the XP suppression of 10-13dB [16]. XP suppression of -30dB is achieved in resonating DGS (RDGS) slots technique [17]. The asymmetric geometry of DGS used for the suppression of XP and claimed the total isolation of 28dB [18]. These DGS suffers from back radiations and also reduced gain.

There is an alternate technique called defected microstrip surface (DMS) similar to DGS used for the enhancement of various characteristics of MPAs. The different shapes of DMS also reported and implemented like bent slots, square slots, cross slot, circular slot [19]-[23] etched in the patch of an MPA and are used for different purposes like dual band, miniaturization, multiband, wideband, frequency tuning and also for harmonic suppression [24]. XP radiation is suppressed by incorporating a semicircular defect on the patch with miniaturization surface of RMPA [25]. Most of these configurations were complex due to the defect structure implementation complicated. The same author recently presented a work on XP suppression by suppressing the higher order mode by the metallic stub insertion technique [26] but it is very complex for fabrication.

In the proposed configuration with DMS is very simple and helps to eliminate nearby higher order mode and suppress the cross-polarized (XP) radiation. In this technique two symmetrical rectangular slots etched in the radiating patch near non- radiating edge. This RMPA configuration is excited by a coaxial probe feed technique.

The following are attractive advantages of the proposed RMPA.

- Higher order mode suppressed
- The suppression of XP is achieved
- Isolation between co-pole and cross-pole is improved.

2. ANTENNA DESIGN PROCEDURE

2.1 THE ANTENNA CONFIGURATION

The conventional RMPA is designed to resonate at 3.04 GHz using coaxial probe feed based on Transmission Line Model (TLM) theory. The Glass Epoxy (FR4) dielectric substrate with dielectric constant (ε_r) 4.4 with a thickness h=1.6 mm is used. The copper material is used for the radiating patch with a thickness of 0.03mm. The substrate and ground plane are in square shape with a dimension of W_g=W_s=80 mm and L_g=L_s=80 mm. The conventional antenna configuration is as shown in Fig.1.

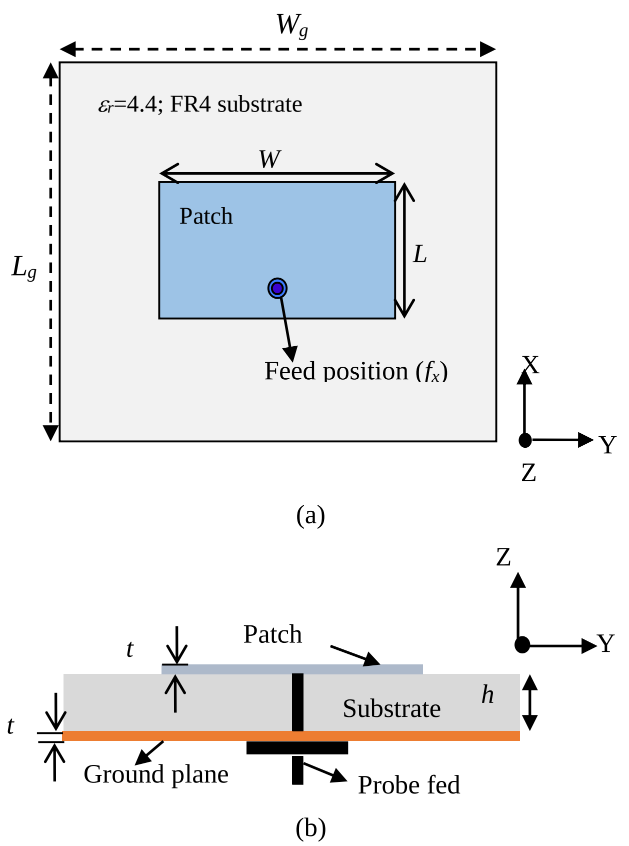

Fig.1. Schematic diagram of conventional rectangular microstrip patch antenna configuration: (a) Top view (b) side view. Parameters: $W_g = L_g = 80$ mm, $W = 40$ mm, $L = 22$ mm, $t = 0.03$ mm, $h = 1.6$ mm, $f_x = 7$ mm, $\varepsilon_r = 4.4$

2.2 PROPOSED ANTENNA DESIGN THEORY

In the proposed antenna design, the cross-polarized (XP) radiation is suppressed by incorporating a rectangular slot defect in the patch as shown in Fig.2.

The optimized dimensions of two etched slots are $W_1 = 2.5$ mm and $L_1 = 20$ mm, which are etched in patch. The placement of both DMS slots in the patch is estimated by using the theoretical approach given in [14]. The position of slot 1 is at 5.5 mm gap from the center of the probe feed position. Similarly slot 2 is at 11mm from the center of the probe feed.

The electric fields from higher order mode (TM_{02}), which is orthogonal component near the non-radiating edges of the patch, are mainly responsible for cross-polarized radiation (XP). The pair of the rectangular slot defect is placed in such a way that, it flatters only the electric fields in that region without disturbing the co-polarized radiation.

The electric field components near non-radiating edge corresponding to orthogonal TM_{02} mode below the patch is

$$E_Y = C \cos\frac{2\pi}{W} Z \quad (1)$$

At $z = 0$ and $z = W/2$; $E_y = C$ and E_y value is maximum.

Therefore null occurs between these limits $0 < z < W/2$

$$E_y = C\cos\frac{2\pi}{W} z = 0 \quad \text{for } 0<z<0.5W \quad (2)$$

Therefore, for null to occur,

$$\frac{2\pi}{W} z_1 = \frac{m\pi}{2}, \text{ where } m = 1, 3, 5... \quad (3)$$

$$z_1 = \frac{mW}{4} = \frac{W}{4}; \text{ with } W=22 \text{ mm}; z_1=5.5\text{mm}$$

The defect should be incorporated in this region i.e., $z_2 = W/2 = 11$ mm; z_1=5.5 mm. Therefore these DMS slots will perturb the electric fields responsible for reduction of cross polarization (XP) radiation. It also increases isolation between co-pol to cross-pol.

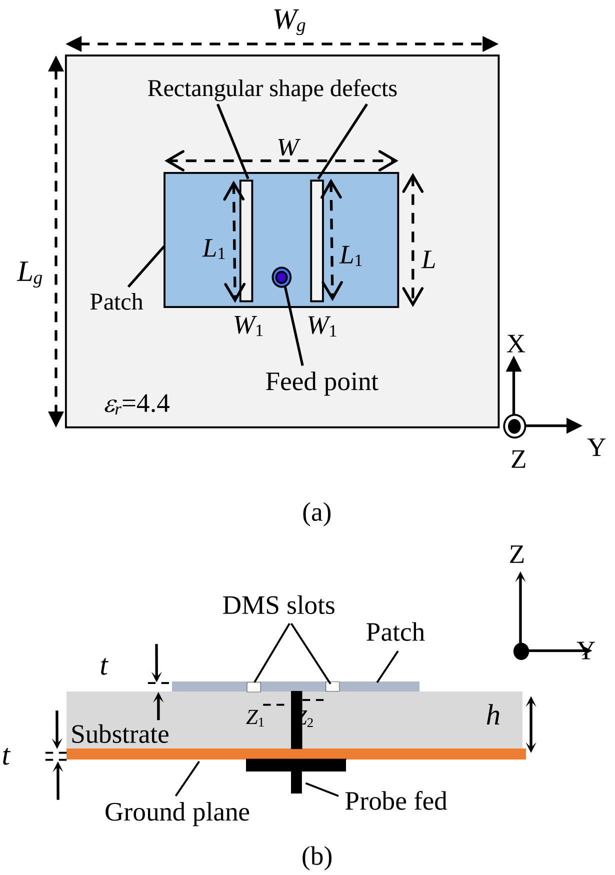

Fig.2. Schematic diagram of proposed RMPA (a) Top view (b) Side view. Parameters used: $W_g = L_g = 80$ mm, $W = 40$ mm, $L = 22$ mm, W_1=2.5 mm, L_1=20 mm, Z_1= 11mm, Z_2=5.5 mm and $f_x = 7$ mm

3. SIMULATED RESULT ANALYSIS

The comparison of conventional and proposed simulated S_{11} parameter is as shown in Fig.3. The conventional RMPA is resonating at 3.04GHz with S_{11}=-27.9dB along with nearby higher order mode, which is responsible for XP radiation is at 3.6 GHz. The proposed antenna also resonating at 3.04GHz with S_{11}=-15.9dB, due to etched slots in the radiating patch shows little bit inductive loading effect. This can be easily observed in the S_{11} minima. The higher order mode is totally eliminated as we can clearly observe in the plot. The comparison of principal plane radiations is shown in Fig.4. The conventional RMPA has peak co-pol gain of 5.2dBi with cross-pol of -15.5dB and isolation of 20.7dB. The proposed RMPA has co-pol peak gain of 6dBi with the drastic reduction in cross-pol with peak value of -46.5dB and isolation between co-pol to cross-pol is 52.5dB.

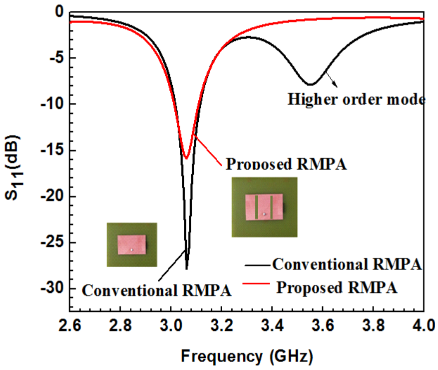

Fig.3. Simulated return loss characteristics of conventional and proposed RMPA

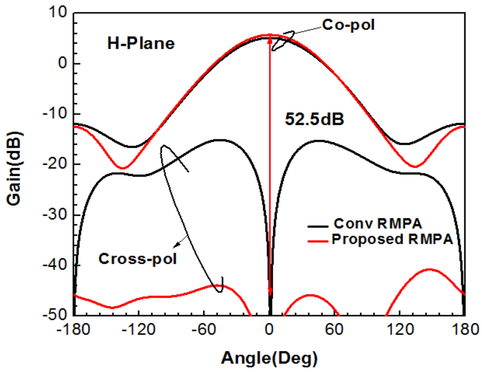

Fig.4. Simulated radiation characteristics: H-plane radiation of conventional and proposed RMPA

4. PARAMETRIC STUDIES OF RMPA PROPOSED RMPA

The dimensions of pair of rectangular slots etched in the patch are thoroughly optimized by series of simulations using the simulator HFSS v.13 [27].

4.1 EFFECT OF SLOT WIDTH ON XP

The plot in Fig.5 shows the variation of H-plane radiation characteristics of proposed antenna because of change in width of slots.

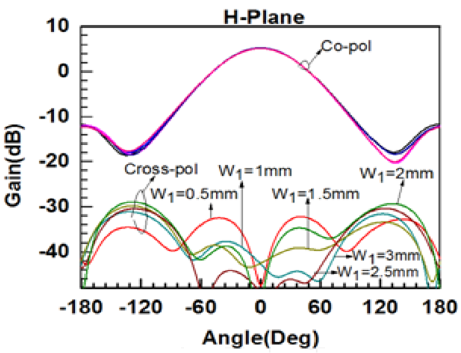

Fig.5. Simulated characteristics of H-plane radiation varying width dimensions of rectangular slot defect on patch

In this study rectangular slots length is fixed, and by varying the width the changes in XP values are observed. The value of rectangular slot defect patch width W_1 is varies from 0.5mm to 3mm with a step size of 0.5mm. Maximum cross polarization suppression is achieved for width W_1=2.5mm with an increase in isolation. The value of XP radiation improves instead of suppression for W_1=3mm.

4.2 EFFECT OF SLOT LENGTH ON XP

The plot in Fig.6 shows the variation of H-plane radiation characteristics of proposed antenna because of change in length of slots. In this study the rectangular slots width is fixed, and by varying the length the changes in XP values are observed. Length of rectangular slots etched in the patch is varied from 18mm to 24mm with the step size of 2mm as shown in Fig.6. The value of XP reduces for the length L_1=20mm.

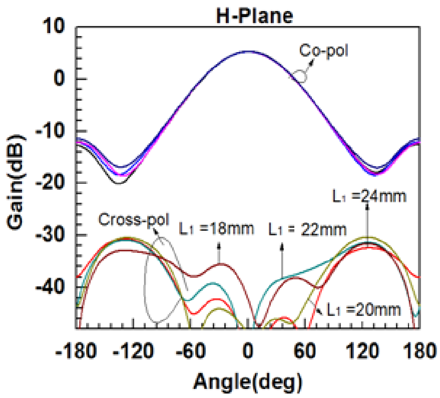

Fig.6. Simulated H-plane radiation characteristics varying dimensions length of rectangular slot defect on patch

5. PROTOTYPES AND EXPERIMENTAL VERIFICATION

The prototypes of conventional and proposed RMPA are fabricated using commercially available glass epoxy FR4 substrate with dielectric constant 4.4. The prototypes antennas are measured using automatic VNA and in anechoic chamber .The top view of conventional RMPA and proposed RMPA configurations is as depicted in Fig.7(a) and Fig.7(b) respectively. The experimental set up for measurement of S_{11} is shown in Fig.7(c), and radiation measurement set up is shown in Fig.7(d).

The simulated and measured S_{11} characteristics of conventional and proposed RMPA are compared as shown in Fig.8. The value of S_{11} shift from -27.9dB to -15.9dB, because of the effect of rectangular slot in radiating patch shows some inductive interference on impedance matching. In the proposed antenna defected patch is not affecting the dominate mode. Higher order mode is suppressed by defected patch which is the main source to cause cross polarization.

The radiation characteristics of conventional and proposed RMPA are also compared in Fig.9. The XP in H-plane is more important than E-plane characteristics, because it decides the polarization purity of the antenna and it is very much important in many applications of wireless communication system. The measured result has close agreement with simulated data. The little gain enhancement is also achieved here. The Cross polarized

(XP) radiation reduction of about 31dB depicted in Fig.9. It results in high CP-XP isolation of about 51.75dB.

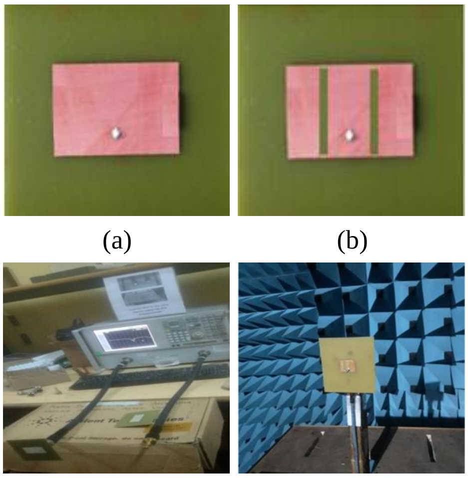

Fig.7. Top view of Fabricated RMPA (a) conventional RMPA. (b) Proposed RMPA with rectangular slots as DMS in patch. (c) The experimental set up for measurement of S_{11} (d) Radiations measurement in anechoic chamber

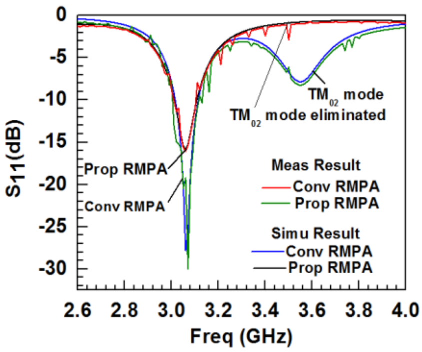

Fig.8. Return loss comparison of simulated and measured results of conventional and proposed RMPA

The electric surface current density $\left(\bar{J}_s\right)$, on the patch surface is represented as

$$\bar{J}_s = \hat{n} \times \bar{H} = \hat{a}_y \times |H_x| \hat{a}_x \quad (4)$$

$$\text{Therefore, } \bar{J}_s = \left| C \sin \frac{2\pi}{W} \right| \hat{a}_z \quad (5)$$

Thus, the surface current density flows along an orthogonal direction of higher order TM_{02} mode, which produces strong cross polarization (XP) radiation over a broadside angular range ±50° in H-plane as shown in Fig.10.

So the rectangular slot defect in radiating patch has been introduced near non-radiating edges as shown in Fig.11. The defects are placed within the limit of *z*; consequently interact much with the patch surface current density (Js). As a result, the defect will efficiently perturb the fields of higher order TM_{02} mode which significantly reduce the cross polarization (XP) with higher isolation. The comparative study of results of conventional and proposed RMPA is shown in Table.1.

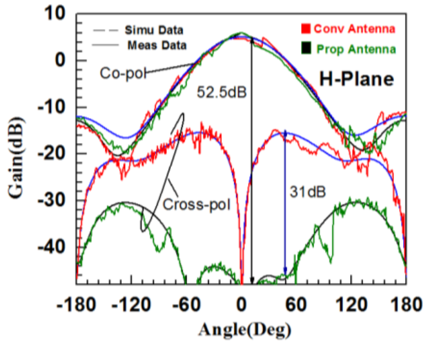

Fig.9. H-plane radiation characteristics of simulated and measured results of conventional and proposed RMPA

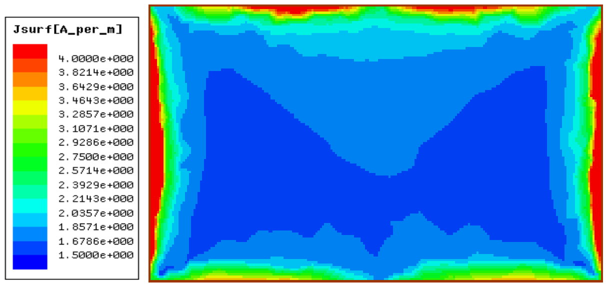

Fig.10. Surface electric current density on patch of top view of conventional RMPA

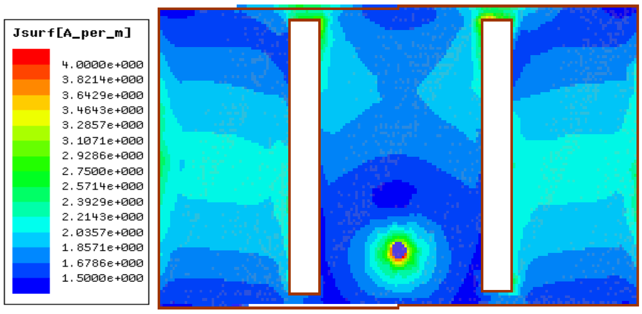

Fig.11 Surface electric current density on patch of top view of proposed RMPA.

Table.1. Comparison of conventional and proposed RMPA

Parameter	Conventional RMPA	Proposed RMPA
Resonance Frequency	3.04GHz	3.04GHz
S_{11}	-27.9dB	-15.9dB
Gain	5.2dBi	6dBi
Cross polarization (XP)	-15.5dB	-46.5dB
Isolation (CP-XP)	20.7dB	52.5dB

6. CONCLUSION

A pair of rectangular shaped slots etched patch surface rectangular microstrip patch antenna is proposed for cross polarization (XP) radiation reduction. In this design the XP suppression is achieved by suppressing the higher order mode. The high isolation is observed, compared to conventional patch antenna without affecting the dominant mode radiation characteristics. Around 31dB cross polarization suppression over a span of angle ± 50^0 and 51.75dB CP-XP isolation is obtained from the proposed structure. The proposed structure is very simple and can be utilized for the S-band applications.

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