Rectangular microstrip antenna with corrugation like defects at radiating edge: A new approach to reduce cross polarization radiation

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Abstract. In this paper, single layer, simple and compact RMA, with corrugation like defects at the radiating edge, is studied thoroughly to reduce XP radiation from the patch. Unlike the earlier works reported on defected ground structure integrated patches and defect patch structures, in this work, corrugation like linear defects have been placed at the radiating edges of the patch to reduce cross polarisation radiation. Around 30-40 dB of CP-XP isolation is observed in H-plane with 7% impedance bandwidth and in E-plane also, more than 55 dB CP-XP isolation is found. The proposed structure is very simple to design and easy to fabricate.

1. Introduction

Rectangular microstrip antenna (RMA) is probably the most useful antenna structure for its variety of applications due to its simple design, ease of implementation and low profile. Apart from these desirable properties, a simple RMA suffers from some severe disadvantages such as low gain (around 2-3 dBi) and narrow impedance bandwidth (around 2-3%) when fabricated on a substrate which possesses high dielectric constant. Moreover, a RMA radiates linearly polarized wave along its broadside direction called, co polarized (CP) radiation along with a few degrees of cross polarized (XP) radiation due to spurious and higher order modes [1]. Hence, such antennas suffer from low polarization purity i.e. CP-XP isolation (around 8-10 dB) and improvement of CP-XP isolation is a challenging issue to enhance the radiation characteristics of a RMA without affecting the CP radiation. The XP radiations are much significant in the H plane than in the E plane [2], [3]. It is also worthy to mention that polarization purity gets worse at higher frequency as the XP radiation increases with frequency [1], [4].

In [5], a Ψ shaped RMA on two-layer substrate was reported and only 3-10 dB peak CP-XP isolation is achieved over 4-8 GHz. In [6], an E-shaped RMA fabricated on glass epoxy substrate with an finite air gap over the ground plane was reported, and around 191 MHz bandwidth and 18 dB peak CP-XP isolation were found. In [7], a comparative study on the bandwidth and XP characteristics of C shaped, U shaped, E shaped RMAs was discussed.
Defected ground structure (DGS) is a well-known technique for RMA to improve CP-XP isolation [8]-[11]. It is observed that, the polarization purity of 20-25 dB is achieved from slot DGS [8], bracketed DGS [9] and circular headed dumbbell DGS [10], non-proximal [11] and asymmetric [12] DGS integrated RMA. However, any DGS integrated antenna, in rectangular patch geometry enhances the back radiation from the antenna structure which puts a severe limitation in its use. Compared to these, defected patch structure (DPS) is a newer technique to suppress XP radiation [13], [14] without enhancing back radiation level from a RMA. It was firstly introduced by Ghosh et al for circular patch antenna in [13]. Around 25-30 dB of CP-XP ratio is revealed from [13], [14]. In both these works, the defects have been judiciously placed at the non-radiating edges of the patch so that, the electric field distributions of spurious higher order modes particularly that of TM_{02} can be nullified with hampering the electric field distribution of dominant TM_{10} mode.

In this paper, single layer, simple and compact RMA, with corrugation like defects at the radiating edge, is studied thoroughly to reduce XP radiation from the patch (Fig. 1). Unlike the earlier works on DGS and DPS integrated RMAs, the defects have been judiciously placed at the radiating edge of the RMA. Earlier, different research groups reported application of corrugated circular patch [15] for miniaturization and corrugated ground plane [16] for improving CP-XP isolation at \( \phi=45^\circ \) plane and to reduce side lobe levels. Around 18 dB CP-XP isolation was achieved at \( \phi=45^\circ \) plane in [16]. The structures reported in [15], [16] were very much complex to fabricate and XP radiation minimization at principal E and H-planes were not explored in these work.

On the contrary, from the present work around 40dB, 30 dB CP-XP isolation have been revealed at principal E and H plane, respectively, over whole elevation angle (\( \pm 180^\circ \)), whereas, for a RMA the same is around 8-10 dB in the H-plane. The structure resonates around \( f=7.72 \) GHz with 7\% impedance bandwidth when defect length \( L_e=4 \) mm. However, it has also been observed that with a slight increase in the defect length (\( L_e=5 \) mm), the structure exhibits dual resonance at \( f=6.61 \) GHz and \( f=7.72 \) GHz probably due to a weak resonance of TM_{10} mode at the lower side of frequency spectrum. In the latter case, CP-XP isolation are around 11 dB, 30 dB in the principal H plane at \( f=6.61 \) GHz and \( f=7.72 \) GHz, respectively. The antenna has been designed on FR-4 substrate (\( \varepsilon_r=4.4 \)) of dimensions 25x25 mm\(^2\). The peak CP gain from the proposed structure is around 5 dBi. The proposed structure is very simple to design and easy to fabricate.

Figure 1. Schematic representation of RMA with corrugation like defects at radiating edge (top view).
2. Proposed structures
A thin copper strip of length \( (L) = 8 \text{ mm} \) and width \( (W) = 12 \text{ mm} \), is utilized as patch and it is fabricated on FR-4 substrate with height \( (h) = 1.575 \text{ mm} \) and \( \varepsilon_r = 4.4 \) of dimensions \( 25 \times 25 \text{ mm}^2 \) (Fig. 1). Here we have studied two antenna structures. In antenna 1, four defects of dimensions \( (L_t \times W_t) = 4 \times 1 \text{ mm}^2 \) have been cut on the patch surface at the radiating edge. In antenna 2, the length of each defect has been increased to \( L_t = 5 \text{ mm} \) but, the width of the slot \( W_t \) is kept unaltered. The ground plane dimensions are \( 25 \times 25 \text{ mm}^2 \). The antenna 1 and antenna 2 are fed at \( p_c = 1.4 \) and \( 1.6 \text{ mm} \) from the center of the patch, respectively, through a co-axial probe. Ground plane dimensions are \( (L_g \times W_g) = 25 \times 25 \text{ mm}^2 \).

3. Results and discussions
In this section, the simulated results [17] of a conventional RMA and RMAs with corrugated edge with slot dimensions \( (L_t \times W_t) = 4 \times 1 \text{ mm}^2 \) and \( 5 \times 1 \text{ mm}^2 \) have been presented.

![Figure 2. Reflection coefficient profile (S11) for conventional RMA, antenna 1 and antenna 2.](image)

3.1. Conventional RMA
Figure. 2 and fig. 3 shows the simulated reflection coefficient \( (S_{11}) \) and radiation patterns for a conventional RMA. The conventional RMA resonates at \( f = 7.61 \text{ GHz} \) with 4\% impedance bandwidth (fig. 2). It can be noted that for the conventional patch, peak CP-XP isolation is nearly 12 dB at around \( \pm 50^\circ \) in H-plane whereas, in E plane, CP-XP isolation is around 40 dB (Fig. 3).

3.2. Antenna 1: RMA with corrugated radiating edge with slot dimensions \( (L_t \times W_t) = 4 \times 1 \text{ mm}^2 \)
The antenna 1 resonates at \( f = 7.72 \text{ GHz} \) with 4.2\% impedance bandwidth (fig. 2). It can be noted that for antenna 1, peak CP-XP isolation is nearly 30 dB at around \( \pm 50^\circ \) in H-plane whereas, in E plane, CP-XP isolation is around 50 dB (Fig. 3). It is evident that, 30-40 dB of XP suppression is achieved over whole elevation angle \( (+180^\circ \text{ to } -180^\circ) \) than that of a conventional RMA (fig. 3).
3.3. **Antenna 2: RMA with corrugated radiating edge with slot dimensions \(L_t \times W_t = 5 \times 1 \text{ mm}^2\)**

The antenna 2 exhibits dual resonances at \(f=6.61 \text{ GHz}\) and \(f=7.72 \text{ GHz}\) with 6% impedance bandwidth (fig. 2). It can be noted that for antenna 2, at \(f=6.61 \text{ GHz}\), peak CP-XP isolation is nearly 12 dB at around \(\pm 50^\circ\) in H-plane whereas, in E plane, CP-XP isolation is around 55 dB (fig. 4). At \(f=7.72 \text{ GHz}\), peak CP-XP isolation is nearly 30 dB at around \(\pm 50^\circ\) in H-plane whereas, in E plane, CP-XP isolation is around 55 dB (Fig. 4). At \(f=7.72 \text{ GHz}\), 30-40 dB of XP suppression is achieved over whole elevation angle (+180° to -180°) than that of a conventional RMA. It is also observed that the CP radiation patterns are nearly same at \(f=6.61 \text{ GHz}\) and \(f=7.72 \text{ GHz}\) which indicate excitation of dominant modes at both the frequencies.

![Figure 3](image1.png)

**Figure 3.** Radiation patterns of conventional RMA and antenna 1 at the centre frequency at: (a) H-plane, (b) E-plane.

![Figure 4](image2.png)

**Figure 4.** Radiation patterns of antenna 2 at: (a) \(f=6.61 \text{ GHz}\) and (b) \(f=7.72 \text{ GHz}\).

4. **Conclusions**

In this work, single layer, simple and compact RMA, with corrugation like defects at the radiating edge, is studied thoroughly to achieve improved polarization purity over whole elevation angle. To the best of our knowledge, this work happens to be the first report where linear defects have been placed...
at the radiating edges of the patch to reduce cross polarisation radiation. Around 30-40 dB of CP-XP isolation is observed in H plane with 7% impedance bandwidth in case of antenna 1 and in E plane also, more than 55 dB CP-XP isolation is found. Also, in case of antenna 2, dual resonances have been found due to an increase in defect length. The proposed structure is simple and easy to fabricate. It will surely find applications in array antenna design and establishing wireless links where, improved polarization purity is required over wide angular range.

5. References
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[17] HFSS, High Frequency Structure Simulator, USA

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