New Technique for Inset-Fed Microstrip Patch with Reduced Cross Polarized Radiations

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Abstract

Cross polar (XP) radiations in an inset-fed microstrip line-fed patch are mainly caused by the unwanted fields radiated from the transition between the feed and the patch, and due to the higher order modes in the patch cavity. The XP isolation has been significantly improved by a new and simple configuration of defected ground structure (DGS). The DGS is designed to act as magnetic dipoles and thus compensates the unwanted XP radiations. This concept has been validated by inset fed antenna designs in S- and C-bands. The results indicate co-to-cross polarized isolation of more than 35 dB with DGS, compared to about 20 dB for a patch with conventional ground plane. The DGS does not affect other parameters such as impedance bandwidth and peak gain of the antenna. This design should be ideal for wireless and satellite communication applications where large XP isolation is required.

1. Introduction

Microstrip line-fed technique with inset-feed is one among the popular feeding techniques for exciting the microstrip patch antennas (MPAs). This feed is compatible with other monolithic designs and retain the low profile and conformable nature [1]. However, inset-fed MPAs suffer from few inherent disadvantages of narrow bandwidth and poor polarization purity. Though, employing a thicker substrate can resolve the issue of improving the matching bandwidth, it happens at the cost of increased cross polarized (XP) radiations [2] and have been attributed to spurious feed radiations from several discontinuities occurring in the matching of feed structure with radiating element [3]-[6].

Several non coplanar feed mechanisms such as proximity coupled feed, aperture coupled feed, coplanar waveguide feed etc., sequentially rotated balanced feeding and sub-arraying as in [7], application of dual thickness substrate as in [8] and cavity backing as in [9] have been suggested leading to complex feed mechanisms but have reduced the spurious radiation from feed resulting in improved XP performance.

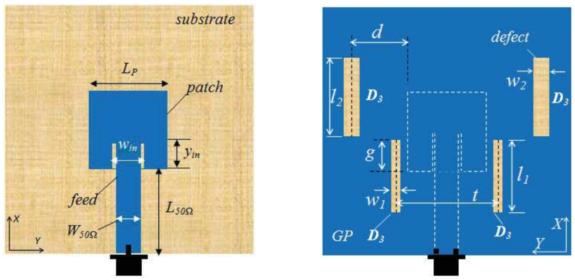
Defected ground structures (DGS) is yet another promising area which has been extensively employed to improve the radiation properties of linearly polarized probe-fed MPAs while demonstrating the same to improve XP performance of circular, elliptical, and rectangular patches with coaxial probe feed [10]-[13]. Quite a few works have employed DGS for microstrip line-fed patches with a view of compacting and multiband operations as in [14], and bandwidth enhancement as in [15]. However, not much work has gone into the field of application of DGS for microstrip line-fed patch antennas with a view to improve its radiation properties. Recently, in [16], a new dimension has been added to the DGS integrated design by simultaneously compensating the XP generating higher order modes as well as spurious feed radiations from feed of the edge-fed patch.

In this paper, a improvised DGS structure has been proposed for the inset-fed rectangular patch antenna to improve the polarization purity. The proposed DGS design has been investigated for antennas near 4 GHz and 6 GHz. The design has resulted in improved XP isolation in H-plane over the entire impedance bandwidth without affecting other radiation properties such as co-polar radiation, and impedance bandwidth. To the best of our knowledge this is the first time the DGS has been integrated with inset-fed microstrip patch antennas for improving the XP isolation.

2. Investigations

2.1 Conventional Inset-Fed Patch

Initially, a conventional inset-fed microstrip square patch operating in S- and C- bands has been designed on a grounded RT5870 dielectric substrate with $\epsilon = 2.33$ and thickness, $h = 1.575$ mm [1]. Both the patches have been optimized, using [17], for impedance matching by inset-cut method for matching the higher patch impedance to 50Ω feed-line with a ground plane dimension of about $\lambda_0 \times \lambda_0$; λ_0 being resonant wavelength. Fig. 1(a) shows the top view of conventional inset-fed antenna. As studied theoretically in [3]-[6] and analyzed in [16] for edge-fed patches, the discontinuities in feed line contribute to XP radiations. However, the fields are differently set in inset-fed antennas. As such, a set of inset fed patches are investigated using simulated results. Their radiation patterns in H-plane are indicated in Fig. 2 for both S- and C- bands. This plot indicates that the XP radiations for C-band design are more than the S-band design.



(a) (b)

Figure 1. Schematic view of inset-fed patch (a) top view of conventional patch (b) ground plane side view of the DGS-integrated inset-fed square patch (dotted line indicates patch).

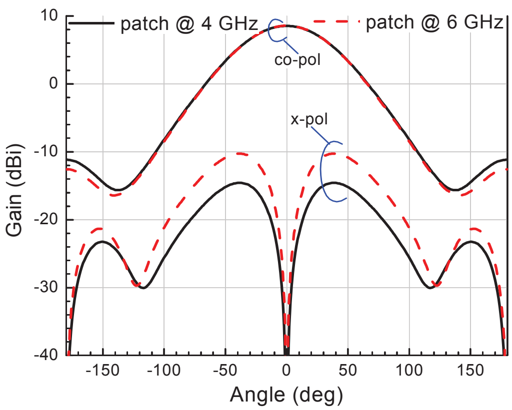
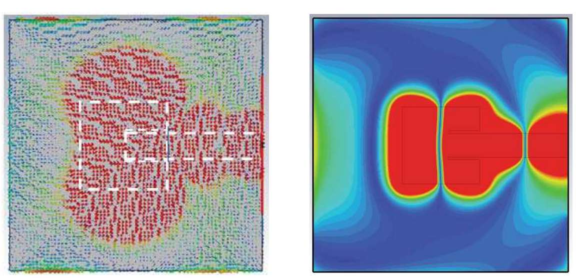


Figure 2. Simulated H-plane radiation patterns of inset-fed patch, at 4 GHz and 6 GHz, with conventional ground plane; parameters (L_P, w_{in}, y_{in}, $L_{50\Omega}$, $W_{50\Omega}$) in mm: (24, 10.2, 7.6, 25.5, 4.65) for 4 GHz design and (15.22, 5.7, 6.1, 17.39, 4.7) for 6 GHz design.



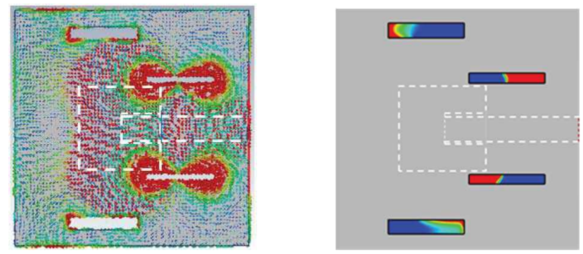
(a) (b)

Figure 3. Captured portrays during simulations for conventional inset-fed patch at 6 GHz: (a) ground plane currents (b) substrate fields; red indicates strongest and blue indicates weakest field; parameters in Fig. 2.

This demonstrates spurious radiation that is more for thicker substrate indeed contributes to the XP radiations.

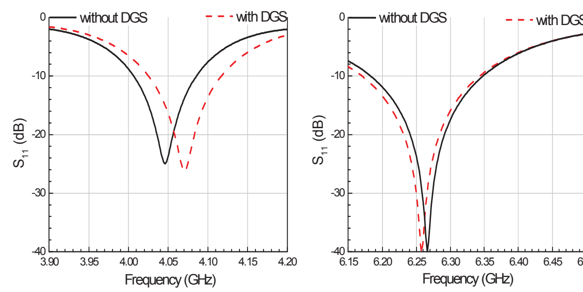
2.2 DGS-Integrated Inset-Fed Patch

Based on our investigations in [16] and the analysis of substrate fields and ground plane currents in conventional inset-fed patch as shown in Fig. 3, it has been intuitively



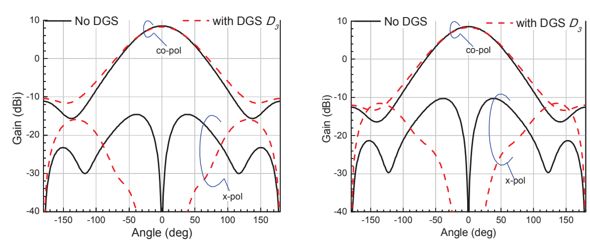
(a) (b)

Figure 4. Inset-fed patch with DGS at 6 GHz (a) ground plane currents (b) induced magnetic fields; red indicates maximum and blue indicates lowest field; parameters (l_1, l_2, w_1, w_2, d, g, t) in mm: (24, 24, 3, 4.5, 13.25, 6.1, 25.7) for 4 GHz design and (15.22, 15.22, 2, 3, 12.5, 5, 20.7) for 6GHz design.



(a) (b)

Figure 5. Simulated input impedance of inset-fed patch with and without DGS at (a) 4 GHz (b) 6 GHz; parameters as in Fig. 2 and Fig. 4.



(a) (b)

Figure 6. Simulated H-plane radiation patterns of inset-fed patches with and without DGS at (a) 4GHz (b) 6GHz; parameters as in Fig. 5.

understood that a DGS compensating the fields due to higher order modes as well as spurious radiations from the feed can improve the XP isolation of inset-fed patch. Extending our previous knowledge and experience [10]-[13], [16] we have conceived a DGS configuration with two sets of DGS; D_1D_1 and D_2D_2 deployed as shown in Fig. 1(b). The size and location of defects are optimized using [17] for obtaining lowest possible XP radiations in the H-plane without affecting co-polarized radiations and input impedances.

When compared to the composite DGS conceived for edge-fed configuration in [16], the deployment of the defects D_1 and D_2 has taken an inside shift due to the change in the location of feed to patch junction.

Interestingly, the ground plane current examined in Fig. 4 reveals identical current loops around defects as was seen in [16] for the case of edge-fed patch and exactly similar type of equivalent magnetic diploes across the defects thus indicating the cancellation of the fields responsible for XP.

3. Results and Discussions

Verification of the proposed DGS integrated design has been carried out by comparing the radiation properties of the conventional inset-fed design with that of proposed design with DGS. Both the designs, i.e. at 4 GHz and 6 GHz have been examined extensively using commercial electromagnetic simulation tool [17] for optimized impedance and radiation characteristics. Input impedance as shown in Fig. 5 indicates similarity with and without DGS except for a small shift in the resonant frequency for the DGS-integrated patch. H-plane radiation characteristics of the square patch have been compared for both S- and C- bands as shown in Fig. 6 indicating a significant improvement in XP isolation of up to 15 dB without affecting any other radiation properties and is a significant feature to explore its use in wireless applications.

4. Conclusion

A very simple and novel technique has been suggested in here to improve the XP isolation of inset-fed patch by mitigating the effects of unwanted spurious radiations from the feed-line and fields due to higher order modes opening up the new possibilities for achieving advanced features in planar patches with no cost or complications in design.

5. References

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