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Compact Slit-Type DGS Integrated X-Band 2×2 Microstrip Antenna Array with Improved Radiation Characteristics

Rohan Das(1), Pranoti Bandose(1), Subhendu Chakraborty(2)(3),Ayan Bandyopadhyay(2)(3), and Chirag P. Mistry(3), Amitavo Roy Choudhury(3), S. Chakraborty(3)

(1) Savitribai Phule Pune University, Pune, India

(2) Academy of Scientific and Innovative Research, India

(3) CSIR-CEERI, Pilani, India

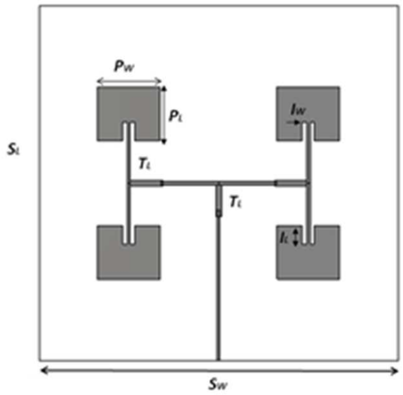
Abstract

Slit type DGSs integrated compact microstrip-line-fed 2×2 microstrip antenna array with around 30 dB CO-XP radiation isolation. In spite of having microstrip line based phase shifters and feed network in the same plane as that of patch antennas, CO-XP radiation isolation has been improved. The work emphasis on compact DGS for antenna array applications unlike most of the earlier reported works in which large DGSs were used over antenna ground plane. The electrical length of DGS size exactly resembles to that of unit patch length. Also, the introduction of DGSs do not hamper co-polar radiation characteristics of the proposed antenna.

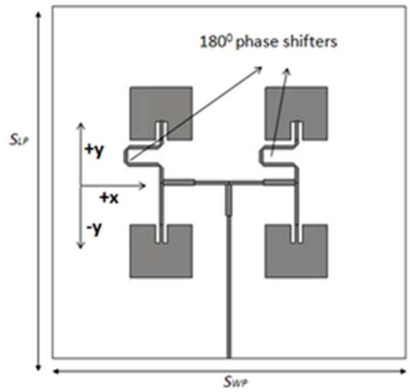
1. Introduction

In the present era of wireless communications, rectangular microstrip antennas and their arrays find significant relevance in various aeronautical applications, satellite applications, telemetry, tracking, and command system antennas, phased array radars, weather radars etc. However, these antennas suffer from spurious radiations when used in their conventional form. In general, microstrip antennas have poor co polarization (CO) to cross polarization (XP) isolation as the operating frequency of the antenna increases with frequency [1,2].This problem is more prominent for the microstrip-line-fed patch arrays in which the feed and patches are on the same side of the substrate. As the same substrate is used for the feed and patch, it is much difficult to control on the radiation from the feed. Another aspect is the spurious radiations emanating from the discontinuities in the feed network [3]. In some cases, the spurious radiations from the feed is so much pronounced that it affects the overall XP radiation level from the antenna array.

In recent decades, a number of techniques have emerged to mitigate problem of high XP radiations from a microstrip antenna for instance use of defected ground structures (DGS) [1], use of defects over patch surface [2], shorted patch configurations [4], use of modified feed structures etc. However, efficacies of these techniques in case of microstrip antenna arrays need to be more explored. It is well known that in most of the works, in which DGSs were introduced to suppress XP radiation from single microstrip



(a)



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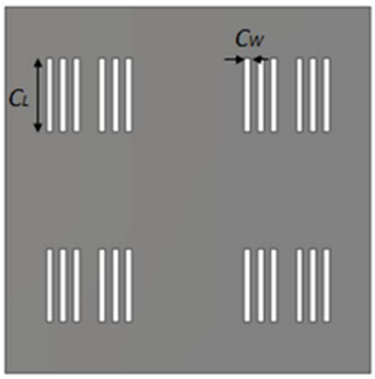

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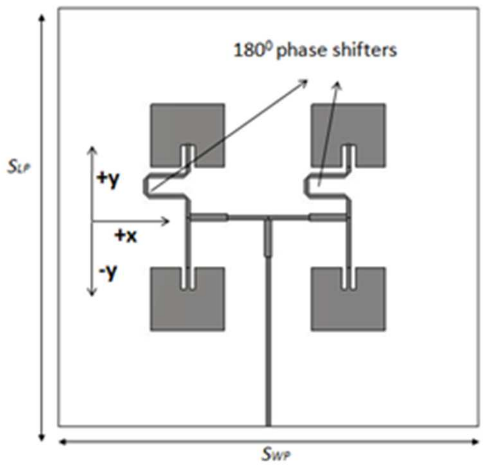

(d)

Fig. 1. Schematics of (a) Antenna-I or (top view), (b) Antenna-II (top view), (c) Antenna-III Ground Plane (bottom view), (d) Antenna-III (top view).

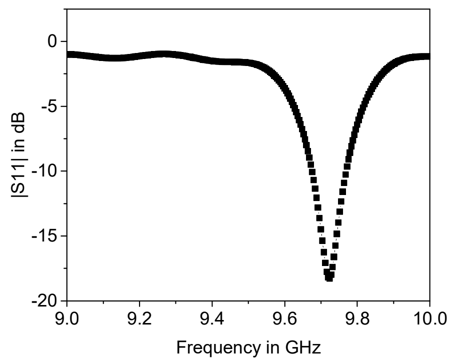

Fig. 2 Simulated reflection coefficient for Antenna-I.

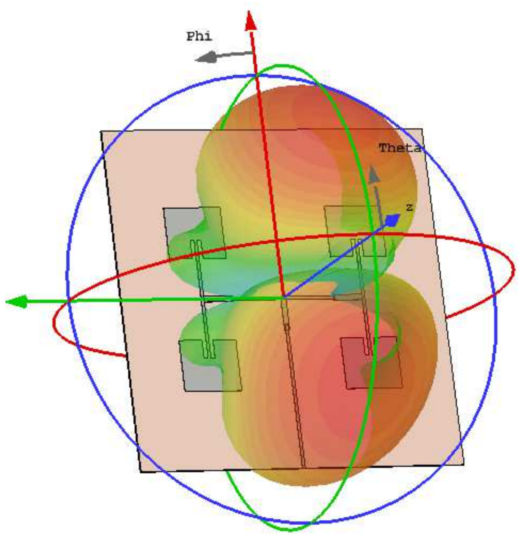

Fig. 3 Simulated 3D radiation pattern for Antenna-I at f=9.7 GHz .

antenna, the size of the DGS were large which in turn may limit use of the DGSs in antenna array configurations. Therefore, in this paper, we have proposed a compact 2×2 microstrip-line-fed microstrip antenna array with compact slit type DGSs to improve CO-XP radiation isolation with hampering the CO gain and CO radiation patterns of the proposed antenna. Here, a number of slit DGSs have been introduced over the ground plane keeping in view that the slit DGSs do not extend beyond patch periphery. It increases novelty of the design. Earlier, slit type DGS was explored in [5] where slit type DGS were introduced over the ground plane. It is important to mention that based on the antenna array feeding techniques and feed-network, appropriate DGS shape and its location need to be designed to properly reduce the XP radiation from the microstrip antenna array.

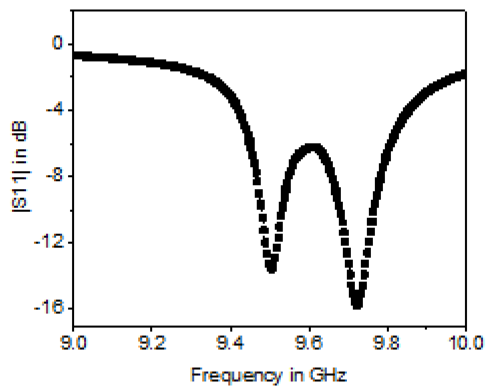

Fig. 4 Simulated reflection coefficient for Antenna-II.

2. Antenna Evolution

A. Conventional 2×2 Rectangular Microstrip Antenna Array:Antenna I

First, we have designed a 2×2 rectangular microstrip antenna array in which two rectangular microstrip antennas are placed in front and two rectangular microstrip antennas are placed in back as shown in fig 1a. This is antenna I. The grounded PTFE substrate size is $S_L \times S_W$ = 40×40 mm^2 with thickness 0.254 mm. Each patch size $P_L \times P_W$= 6×7 mm^2 , then inset in the patch is $I_L \times I_W$ = 2.1×0.5 mm^2. The impedance transformer which is of 35 ohms , has the dimensions of $T_L \times T_W$= 3.57×0.64 mm^2 (Fig 1a). The Antenna-I resonates around 9.7 GHz. The simulated [6] 3D radiation pattern shows in fig. 3 that there is a null in broadside direction and the CO radiation pattern has a conical pattern. The simulated realized gain is around 7 dBi.

B. 2×2 Rectangular Microstrip Antenna Array with phase shifters: Antenna II

In order to modulate the overall radiation pattern from conical to broadside shape, two 180º phase shifters are added with the microstrip-feed lines connected with microsrtip patch antennas placed in $+y$ direction as shown in fig 1b. It will help to make a constructive interference in the broadside direction from the microstrip antenna array. This is Antenna-II. The grounded PTFE substrate size is $S_L \times S_W$ = 30×30 mm^2 with thickness 0.254 mm and Each patch size $P_L \times P_W$ = 6×7 mm^2. The simulated reflection co-efficient is shown in Fig 4. The Antenna-II resonates at 9.5 and 9.75 GHz. The resonance at 9.5 GHz may be considered as a spurious resonance. However, Antenna-II saves more than 40% substrate and ground plane area in comparison with Antenna-I. The broadside co-polar radiation patterns in both principal E and H planes are plotted in Fig 5. The simulated gain of the array is around 9.7 dBi at 9.7 GHz. However, till now attentions were given to achieve a broadside pattern from a compact 2×2 X- band microstrip antenna array.

C. 2×2 Rectangular Microstrip Antenna Array with phase shifters and slit type DGSs: Antenna III or Proposed Antenna

Now, we may concentrate to investigate improvement in XP radiation suppression and to suppress any spurious resonance from the antenna array. It is well known that DGS is one of the prominent ways to improve XP radiation suppression from unit microstrip antenna. Here, in order to lower unwanted radiations from the antenna-II, slit type DGS were incorporated beneath the each patch surface. Each rectangular microstrip antenna has six slit type DGSs over the ground plane. It gives berth the proposed antenna or Antenna-III. Fig 1c shows the DGS integrated ground plane of the proposed antenna. The grounded PTFE substrate size is $S_L \times S_W$ = 30×30 mm^2 with thickness 0.254 mm and Each patch size $P_L \times P_W$ = 6×7 mm^2, then inset in the patch is $I_L \times I_W$ = 2.1×0.5 mm^2. The impedance transformer which is of 35 ohms , has the dimensions of $T_L \times T_W$= 3.57×0.64 mm^2. The top view of the Antenna II and III are identical as shown in fig 1b and 1d. Each slit type DGS on the ground plane has the dimensions $C_L \times C_W$= 6 × 0.5 mm^2 i.e.C_L=P_L= 6 mm.

3. Results and Discussions on the Proposed Antenna

The proposed antenna with dimensions as discussed in Section IIC, resonates around 9.9 GHz as shown in fig. 6. The resonant frequency increases towards higher side of frequency spectrum due to introduction of DGS as, it may reduce effective dielectric constant of the proposed antenna. Also, proposed antenna resonates in a single frequency band.Thesimulated CO radiation patterns in both the principal planes are depicted in Fig. 7. The simulated [6] CO gain of the proposed antenna is around 9.5 dBi. The simulated peak CO-XP radiation isolation is around 30 dB in H plane. CO-XP radiation isolation in E plane is more than 30 dB for Antenna I, II, III and therefore, not shown in the paper for brevity. However, Antenna-III saves more than 40% substrate and ground plane area in comparison with Antenna-I.

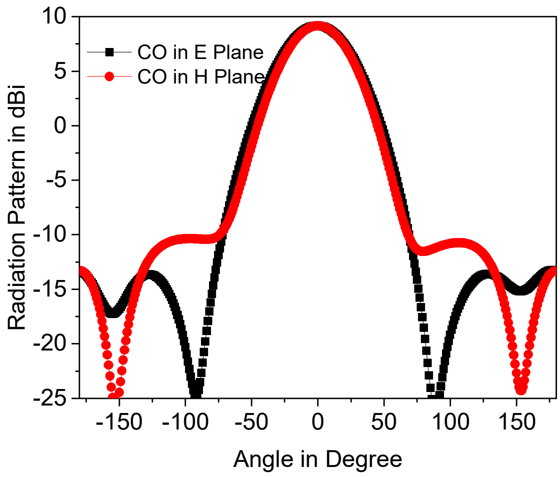

Fig 5. Simulated CO radiation patterns at f=9.75 GHz for Antenna-II.

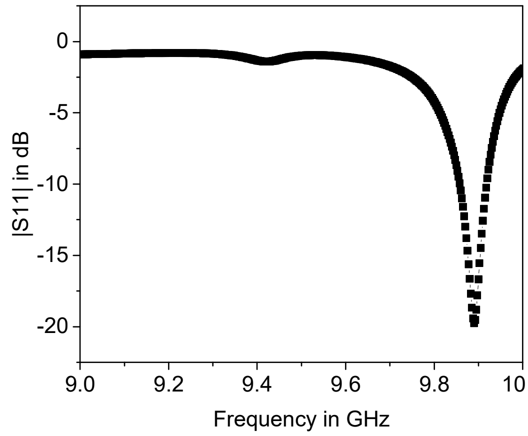

Fig. 6 Simulated reflection coefficient for Proposed Antenna or Antenna-III.

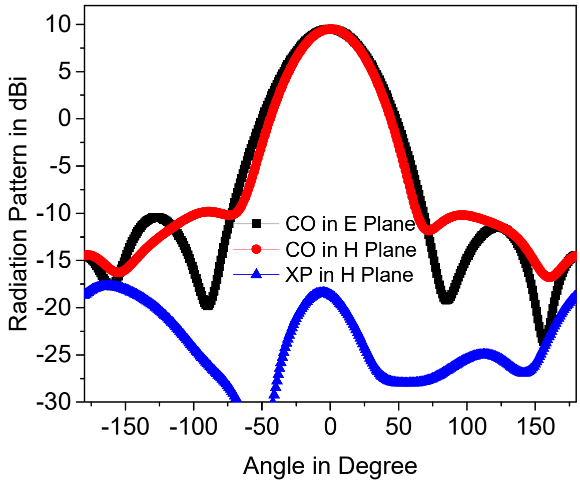

Fig 7. Simulated radiation patterns at f=9.7 GHz for Proposed Antenna or Antenna-III.

4. Conclusions

In this work, slit type DGSs integrated compact 2×2 microstrip antenna array with around 30 dB CO-XP radiation isolation. In spite of having microstrip line basedphase shifters and feed network in the same plane as that of patch antennas, CO-XP radiation isolation has been improved. The work emphasis on compact DGS for antenna array applications unlike most of the earlier reported works in which large DGSs were used over antenna ground plane. Also, the introduction of slit type DGSs do not hamper co-polar radiation characteristics of the proposed antenna. Also Antenna-III or proposed antenna saves more than 40% substrate and ground plane area in comparison with Antenna-I.

6. Acknowledgements

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7. References

1. A Ghosh, S Chakraborty, S Chattopadhyay, A Nandi, B Basu, “Rectangular microstrip antenna with dumbbell shaped defected ground structure for improved cross polarised radiation in wide elevation angle and its theoretical analysis,” IET Microwaves, Antennas, Propagations, Vol. 10, 2016.
2. S. Chattopadhyay and S. Chakraborty, “A Physical Insight Into the Influence of Dominant Mode of Rectangular Microstrip Antenna on Its Cross-Polarization Characteristics and Its Improvement With T-Shaped Microstrip Antenna,”IEEE Access, Vol. 6, 2018.
3. C. Kumar, V. S. Kumar, and D. Venkataramana, “A Large Microstrip Patch Array With a Simplified Feed Network: A low cross-polarized design,” IEEE AP Magazine, pp. 105-111, 2019.
4. D. Ghosh et al., “Physical and quantitative analysis of compact rectangular microstrip antenna with shorted non-radiating edges for reduced cross-polarized radiation using modified cavity model,” IEEE Antennas Propag. Mag., vol. 56, no. 4, pp. 61–72, Aug. 2014
5. S KRafidul, D. Guha , and C. Kumar, “Sources of CrossPolarized Radiation in Microstrip Patches: Multiparametric identification and insights for advanced engineering,” IEEE AP Magazine, pp. 92-103, 2023.
6. CST Studio Suite 2018.