

Periodic Octagon Split Ring Slot Defected Ground Structure for MIMO Microstrip Antenna



F. B. Shiddanagouda, R. M. Vani, and P. V. Hunagund

Abstract In this work, a periodic octagon split ring slot defected ground structure for MIMO (Multiple Input Multiple Output) microstrip antenna is proposed. The prototype of MIMO microstrip antenna consists of four similar rectangular microstrip antenna elements with a partition of $\lambda/4$ distance. The antennas are printed on a 1.6mm thick FR-4 substrate with an overall dimension of 62.8 X 60 mm². To improve the antenna parameters, the proposed MIMO microstrip antenna elements are etched with narrow rectangular edge slit and ground plane defected with periodic octagon split ring slot defected ground structure (POSRSDGS). The proposed MIMO microstrip antenna resonates at dual frequency points, i.e., 4.1GHz, 5.9GHz with a bandwidth of 88MHz and 454MHz along with minimum return loss of -22.7 dB and -19.02 dB, respectively. The envelope correlation coefficient (ECC) is lower than the acceptable limit across the dual operating bands. Mutual coupling coefficient (MCC) at dual resonating frequency points are -36.21 dB and -42.93 dB, respectively. The simulated and fabricated results are found in good agreement and ideal for wireless communication applications.

Keywords Microstrip Antenna · MIMO · POSRSDGS · Bandwidth · MCC · ECC

1 Introduction

Industry and academic sectors are predicted, future wireless communication scenarios that, 7 trillion wireless devices are serving 7.5 billion peoples. High data rates and low error rates are the essential requirements for the future generation of

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wireless communication systems. To achieve these requirements, many researchers recommended enabling key technology such as adding many antennas in multiple input multiple output (MIMO) array configuration [1–7].

The following sections of the paper is explained in a systematic way of proposed MIMO antenna design, results and discussions, and finally followed by conclusion.

2 Antenna Design

The prototype of conventional MIMO microstrip antenna (CMMA) consists of a four similar rectangular microstrip patch antenna elements with a partition of $\lambda/4$ distance. The antennas are embedded on FR-4 substrate with loss tangent 0.02 and thickness is 1.6mm, respectively. Separate 50Ω microstrip feed line were excited to four patch antenna elements. The simulated and fabricated CMMA is shown in Figs.1 and 2 and dimensions are represented in Table 1, respectively.

The study carried by conventional MIMO microstrip antenna (CMMA) loaded with periodic octagon split ring slot defected ground structure (OSRSDGS) and radiating patch elements are etched with narrow rectangular slit to improve the antenna parameters and **it is named as proposed MIMO microstrip antenna (PMMA)**. Periodic means repetition of defected ground structure unit cells with finite space. The distributions of periodic defected ground structures in the ground plane have drawn much attention for their extensive applications in antenna design [8, 9]. Figure 3 shows the optimized unit cell of octagon split ring slot defected ground structure (OSRSDGS). The geometry was obtained through simulation and final dimensions are given in Table 2. The corresponding OSRSDGS unit cell is distributed periodically in the CMMA ground plane, which are aligned with an equal spacing of ‘S’= 10 mm, vertically aligned to both radiating edges and four OSRSDGS unit cells are placed horizontal direction with a space of ‘T’=7 mm between each adjacent vertical OSRSDGS and center gap between the horizontal OSRSDGS maintained with a space of ‘R’=12 mm. The complete ground plane look like “H” shape periodic structure. Then radiating patch elements are etched with narrow rectangular

Fig. 1 Geometry of CMMA

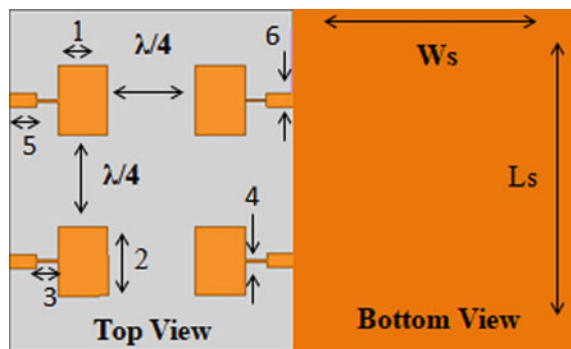


Fig. 2 Photograph of CMMA

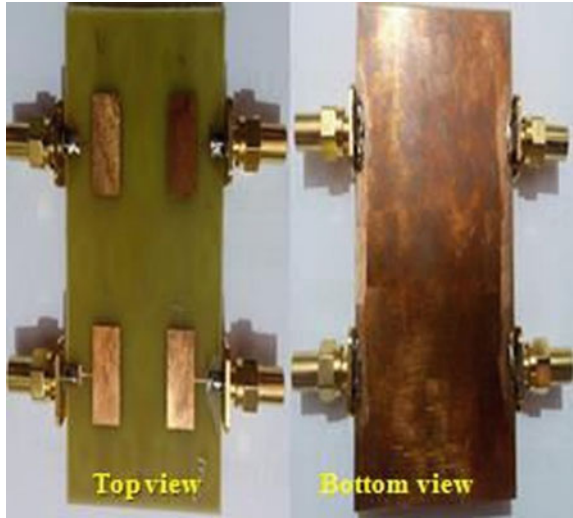


Table 1 Dimensions of CMMA

Parameters	Ls	Ws	1	2
Dimensions (mm)	60	62.8	11.35	15.25
Parameters	3	4	5	6
Dimensions (mm)	4.9	0.5	6.15	3.06

Fig. 3 Geometry of OSRSDGS

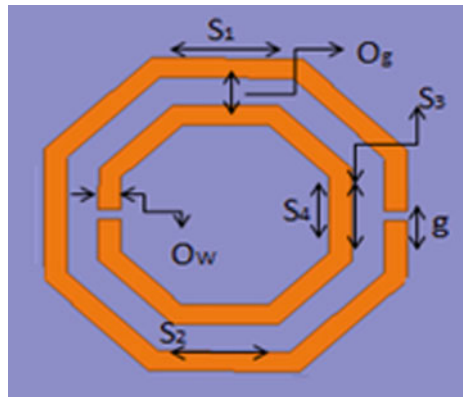


Table 2 Dimensions of OSRSDGS

Parameters	Dimensions (mm)
S1, S2, S3, S4	4, 3.5, 2.8, 2.3
Og	0.845
g	0.3
Ow	0.6

Fig. 4 Geometry of PMMA

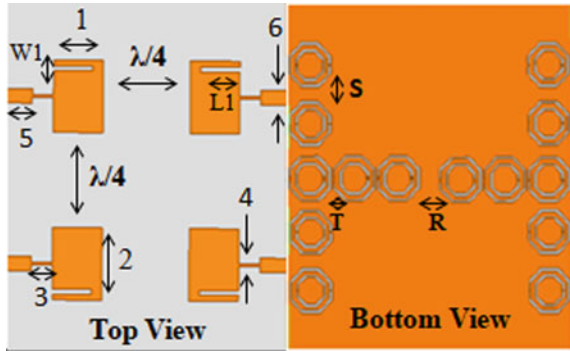


Fig. 5 Photograph of PMMA

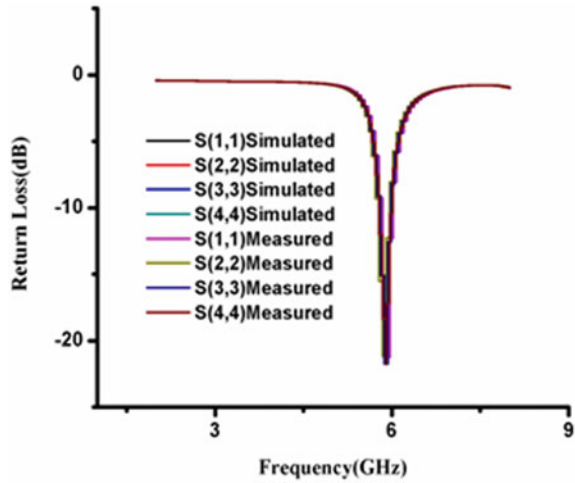


edge slit. The dimensions of the narrow rectangular slits are $(L_1, W_1) = (10 \text{ mm}, 0.5 \text{ mm})$, are cut on the left side of the radiating inset edge patch at a distance of 1 mm from the non radiating edges are taken. Figures 4 and 5 shows the geometry and photograph of PMMA.

3 Results and Discussions

In this work, using ANSYS HFSS 15.0 Electromagnetic simulation software, antennas were designed. The whole experimental works of designed antennas are carried out by using German make Rohde and Schwarz (R&S) Vector Network Analyzer (VNA) of ZVK model (10MHz to 40MHz). The return loss characteristics of simulated and fabricated CMMA are shown in Fig. 6. The antenna resonates at

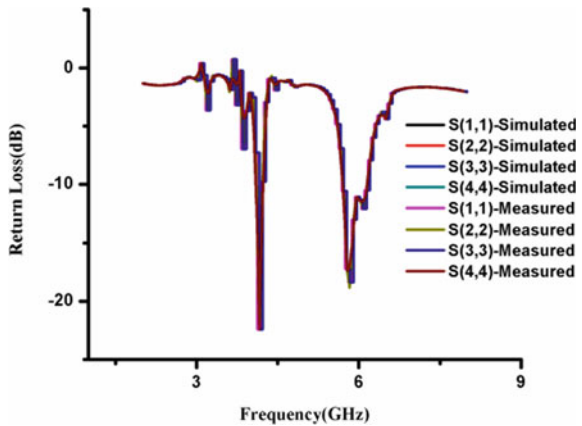
Fig. 6 Return Loss characteristics of CMMA



5.9GHz. The return loss obtained at the resonating frequency is equal to -21.3 dB and bandwidth equal to 204 MHz is obtained.

The return loss characteristics of simulated and fabricated PMMA are shown in Fig. 7. The antenna resonates at dual band frequency points, i.e., 4.1GHz and 5.9GHz with bandwidths of 88MHz and 454MHz along with minimum return loss of -22.7 dB, and -19.02 dB, respectively. Hence, by implementing the narrow rectangular slit, as well as POSRSDGS suppress, the unwanted surface wave and to control harmonics in PMMA to enhance the parameters interns of dual band resonance, bandwidth enhancement as compare to CMMA, as well as virtual size reductions are obtained. So from the Eq. (1), virtual size reduction of antenna is calculated.

Fig. 7 Return Loss characteristics of PMMA



$$\text{Virtual Size reduction}(\%) = \left(\frac{L_C - L_{RA}}{L_C} \right) \times 100 \tag{1}$$

where L_{RA} is the patch length of the reference (conventional) antenna, L_C is the patch length of the antenna resonating at that frequency or at reduced resonant frequencies (proposed antenna). But the width of the patch is the same at both designed and actual resonating frequencies. So that by using narrow rectangular edge slit and POSRSDGS the proposed MIMO microstrip antenna (PMMA) virtual size reduction of 30.5% is obtained.

The mutual coupling coefficient (MCC) is the major factor to be considered while designing MIMO antennas because it degrades the performance of the system. Hence, conventional MIMO microstrip antenna (CMMA) gives mutual coupling between port1 and port 2 is -20.9dB at 5.9GHz as depicted in Fig. 8 and the proposed MIMO microstrip antenna (PMMA) gives very low mutual coupling, i.e., -36.21dB at 4.1GHz and -42.93dB at 5.9GHz , respectively, is depicted in Fig. 9.

The Envelope Correlation Coefficient (ECC) for the CMMA and PMMA are shown in Figs. 10 and 11, respectively. It decides how much the communication channels are isolated. ECC can be estimated of individual elements from the S-parameters [7]. So from the Eq. (2), CMMA achieved 0.001 ECC at 5.9GHz and PMMA dual resonating frequency points, i.e., 0.35 at 4.1GHz and 0.01 at 5.9GHz .

$$\rho = \frac{|S_{11}^* S_{12} + S_{21}^* S_{22}|^2}{(1 - |S_{11}|^2 - |S_{21}|^2)(1 - |S_{22}|^2 - |S_{12}|^2)} \tag{2}$$

Fig. 8 Mutual Coupling Coefficient of CMMA

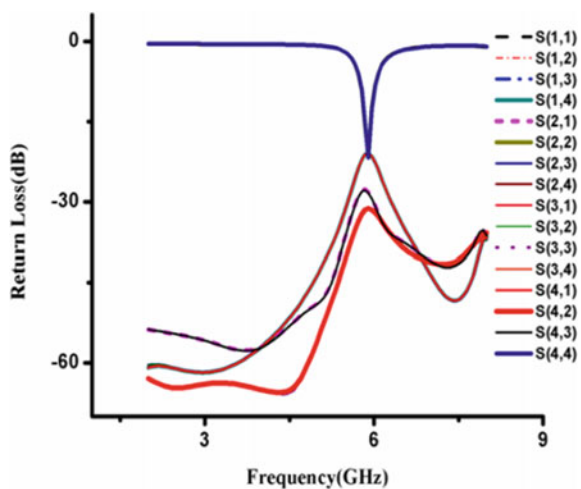


Fig. 9 Mutual Coupling Coefficient of PMMA

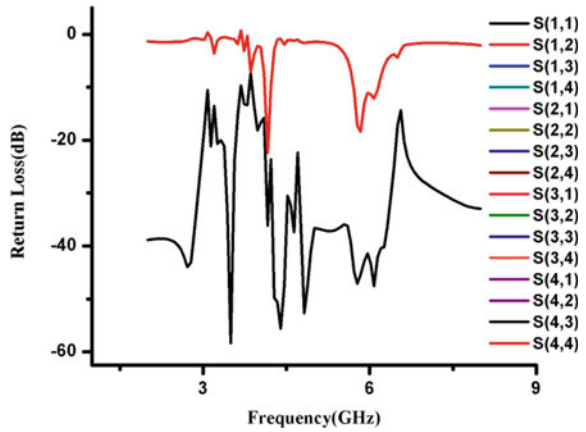


Fig. 10 Envelope Correlation Coefficient of CMMA

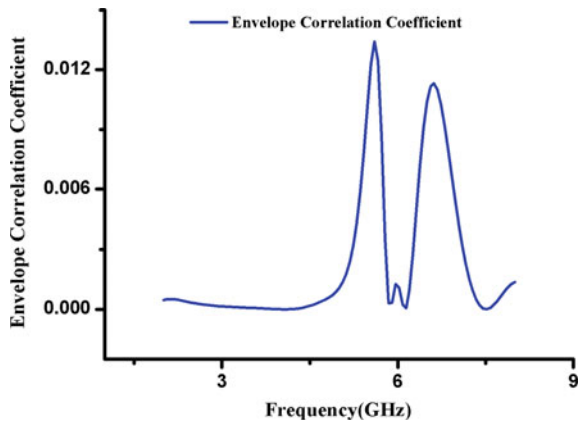
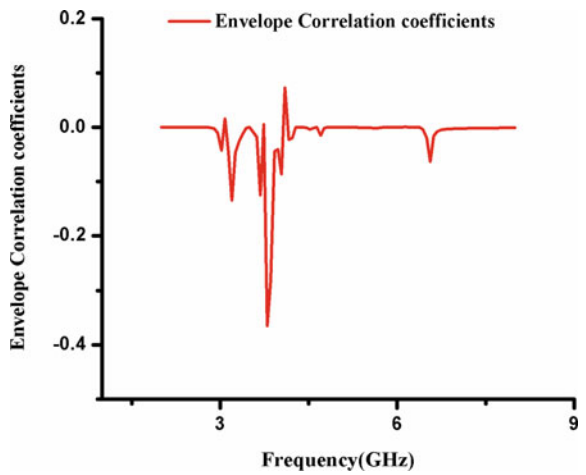


Fig. 11 Envelope Correlation Coefficient of PMMA



The diversity gain is a critical parameter that must be taken into account while evaluating the MIMO antenna performance. The diversity gain (DG) has been calculated using the mathematical equation (3) using ECC. The obtained diversity gain of the CMMA is 9.9dB and PMMA is 9.53dB and 9.9dB, respectively.

$$DG = \sqrt[10]{(1 - |\rho|^2)} \tag{3}$$

Therefore, the value of ECC and DG can confirm PMMA is acceptable for MIMO operation.

The total peak gain of antenna defines the area of coverage and link budget of the wireless system. Figure 12 shows the realized peak gain of CMMA is 5.69dB at 5.9GHz. Figure 13 shows the realized peak gain pattern of PMMA. The designed antenna has peak gain dual band frequency points 1.07dB at 4.1GHz and 4.14dB at 5.9GHz, respectively.

The radiation pattern decides how antenna propagates the electromagnetic energy. The radiation pattern is studied at CMMA resonating frequency of 5.9GHz which is a broadside radiation as shown in Fig. 14. The PMMA radiation pattern is also studied for the respective resonating frequency points. The radiation pattern at dual resonating frequency of 4.1GHz and 5.9GHz which is a broad side radiation as shown in Fig. 15.

All the results of the CMMA and PMMA are summarized in Table 3. From the Table 3, it is seen that PMMA parameters shows that there is an acceptable limit across the dual operating bands.

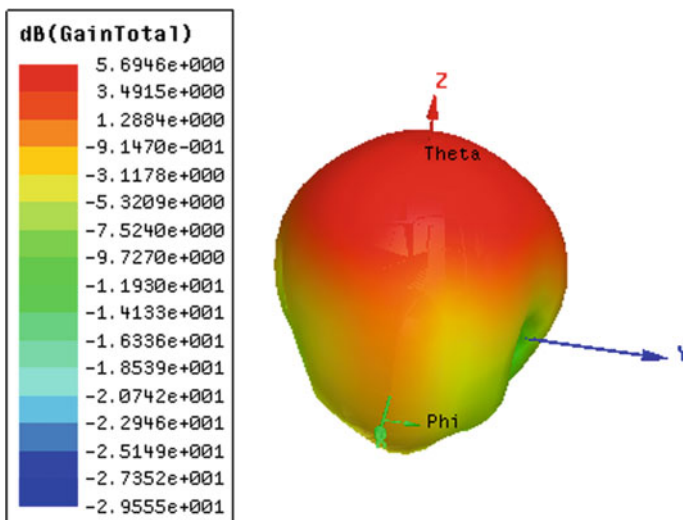


Fig. 12 Total Peak Gain of CMMA

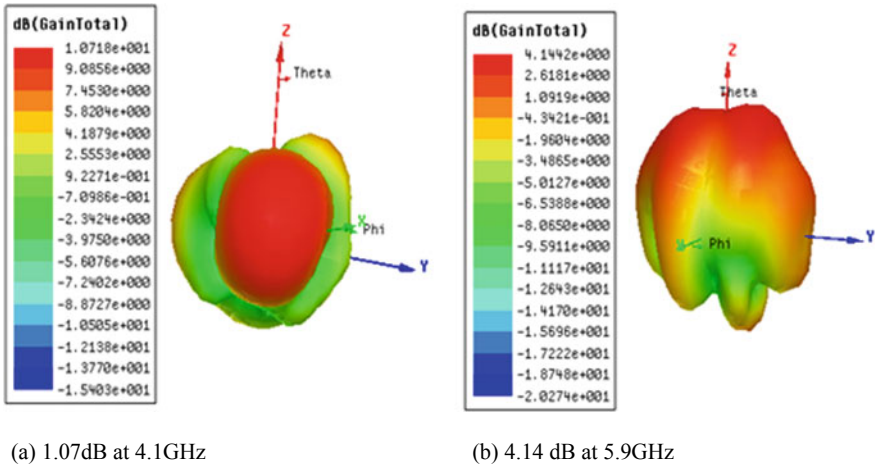
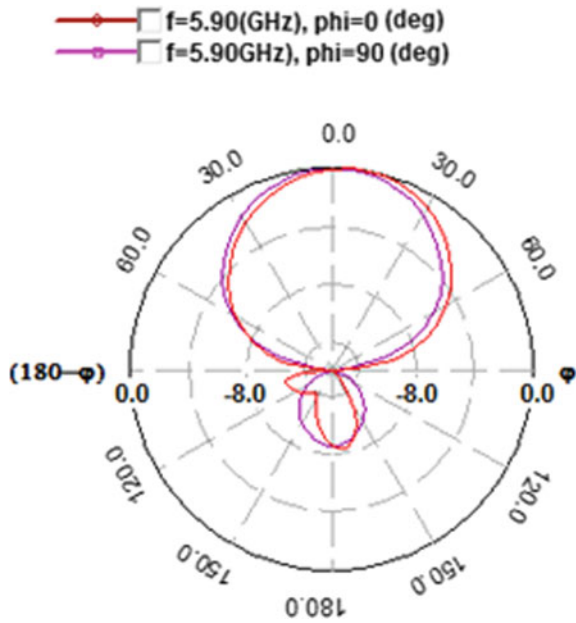


Fig. 13 Total Peak Gain of PMMA

Fig. 14 Radiation Pattern of CMMA



4 Conclusion

A periodic split ring slot defected ground structure of MIMO microstrip antenna is presented. The antenna resonates at 4.1GHz and 5.9GHz frequency. The antenna offers 88MHz bandwidth at 4.1GHz with a total peak gain of 1.07dB and 454MHz

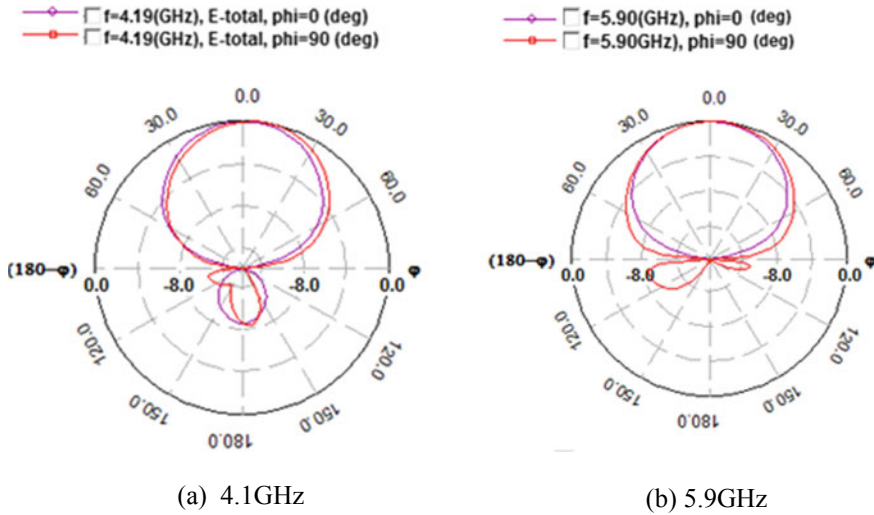


Fig. 15 Radiation Pattern of PMMA

Table 3 Summarized results of the CMMA and PMMA

Parameters	CMMA	PMMA	
Resonating Frequency (GHz)	5.9GHz	4.1GHz	5.9GHz
Return Loss (dB)	-21.3dB	-22.7dB	-19.02dB
Bandwidth (MHz)	204MHz	88MHz	454MHz
MCC(dB)	-20.9dB	-36.21dB	-42.93dB
Total Peak Gain (dB)	5.69dB	1.07dB	4.14dB
Virtual Size Reduction (%)	-	30.5%	
ECC	0.001	0.35	0.01
DG(dB)	9.9dB	9.53dB	9.9dB

bandwidth at 5.9GHz with a gain of 4.14dB. Mutual coupling coefficients and envelope correlation coefficients at both operating frequencies are significant. This configuration also gives 30.5% of virtual size reduction. The proposed MIMO microstrip antenna (PMMA) is lightweight low profile, planar configuration, low fabrication cost, and ability to be integrated with other microwave circuits. Hence the designed antenna parameters shows that, PMMA is ideal for wireless communication applications.

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