URSI AP-RASC 2019, New Delhi, India, 09 - 15 March 2019

Pattern Diversity and Polarization Diversity Wide Band Circularly Polarized MIMO Antenna

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Abstract

This paper presents pattern and polarization diversity, planar wideband circularly polarized (CP) Multiple-Input and Multiple-Output (MIMO) antenna. 3dB axial ratio bandwidth (ARBW) is 2.45 GHz (8.11-10.56) while its impedance matching bandwidth (IMBW) is 3.52 GHz(8.07-11.59). Proposed antenna structure is simple and useful for X-band communication, and it has both pattern diversity and polarization diversity within the entire axial ratio band. The isolation between the antennas without using decoupling mechanism are high or better than -20dB within the entire impedance matching and axial ratio band. The antenna structure has been fabricated on FR-4 substrate and its simulated and measured results are in good agreement, which verify the design concept.

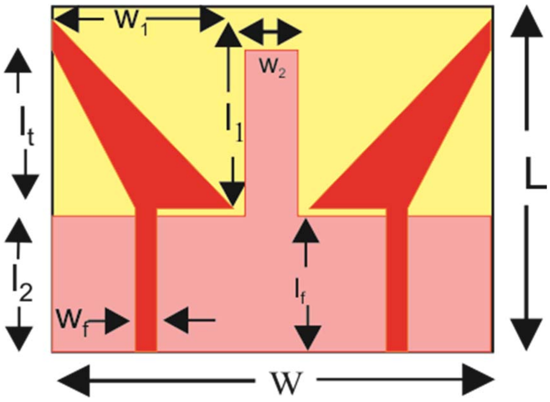
1. Introduction

In modern communication system, Multiple-Input and Multiple-Output (MIMO) is used to increase the capacity of a communication link by employing multiple transmitting and receiving antennas [1-8]. Nowadays, MIMO antennas specifically are used for receiving and sending many data signal instantaneously over the same radio channel. The diversity gain and multiplexing gain improves the capacity and quality of the communication link. Pattern diversity antennas can discriminate a large portion of the angular space while the polarization diversity antennas are useful to immunize the system from polarization mismatches, that would source of fading in the signal [1-8]. Isolation is a big issue in the MIMO antennas; it can be improved by the suggested method in [1-3]. However, by using such methods the antenna size increased and antenna structure becomes more complex. MIMO antenna which has both polarization and pattern diversity is essential choice for realizing low far-field correlation between the antennas without using any decoupling mechanism [4-7]. MIMO ultra-compact antenna using three-port with good isolation and pattern diversity for WLAN band (2.4GHz) is proposed in [3]. However, in [4], polarization and pattern diversity (LP/CP type) is achieved by using two element MIMO antennas. Arrays using printed dipole antenna with pattern diversity for dual band operation by using complementary split-ring resonator is reported in [5]. In [6], both diversity pattern and polarization for WLAN applications with three-element MIMO Antenna is reported while [7] presents the circularly polarized MIMO antenna using dielectric resonator based with polarization diversity. Above suggested polarization and pattern diversity antennas are good; however, these antennas suffer with the narrow circular polarization or axial ratio band, which limit the application for narrow band.

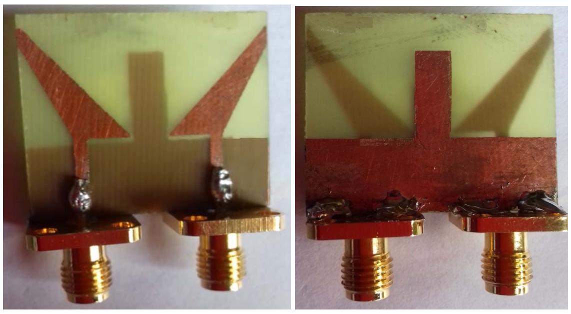
The objective of this work to *design pattern and polarization diversity wideband circularly polarized (CP) Multiple-Input and Multiple-Output (MIMO) antenna*. The 3dB axial ratio bandwidth (ARBW) is 2.45 GHz (8.11-10.56), impedance matching bandwidth (IMBW) is 3.52 GHz (8.07-11.59) and high isolation in the antennas which is better than -20dB, without using extra decoupling structure. Proposed antenna structure is simple and useful for X-band communication, and it has both pattern diversity and polarization diversity within the entire axial ratio band. All the simulations are carried out using 3D EM simulator ANSYS HFSS.

2. Antenna Design

The proposed MIMO antenna has been designed on FR-4 low cost substrate having $\varepsilon_r = 4.4, loss\ tangent = 0.02\ and\ thickness\ h = 0.8m$. The detailed dimensions with layout and fabricated antenna structure is shown in Fig.1. Antenna design starts from the rectangular patch which is antenna-1, and then by truncating diagonally from the upper side of the antenna-1 which is antenna-2. Next, we truncate the lower portion of the patch to obtain the antenna-3, which provides impedance matching and narrow band circular polarization at 10.82GHz. The diagonally truncation in both the antennas (Antenna-A and Antenna-B) from the lower side is to excite simultaneously two orthogonal horizontal mode and vertical mode with a 90^0-phase difference for obtaining better axial ratio bandwidth as well as impedance matching. Finally, a stub has been added to the ground plane at the middle to further improving the impedance matching, isolation and to widen the axial ratio bandwidth. Final antenna is antenna-4, which is designed in four systematic steps, illustrated in details in Fig.2.



(a) **Layout with dimension**

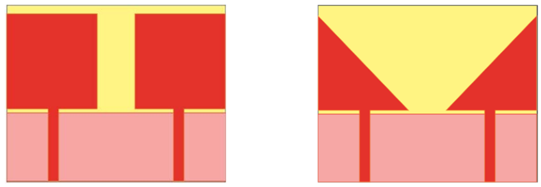


(b) Top View **(C) Bottom View**

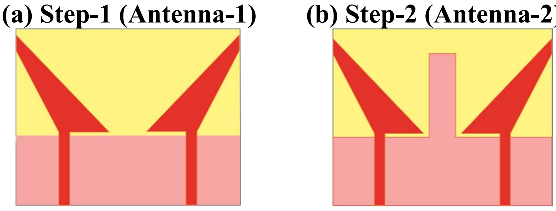
Fig.1 Proposed Antenna Structure

Proposed MIMO antenna has two monopole antennas, which are facing each other with a small spacing of 5 mm. Both the antennas are fed by microstrip line of width (w_f) and length (l_f). The dimensions of the proposed antenna structure are as follows: *W=29mm, L=23mm,* w_1*=12mm,* w_2*=3.5mm,* l_1*=12.5mm,* l_2*=9mm,* w_f*=1.4mm,* l_f*=9.5mm* and l_t*=10.5mm*. These diagonal truncation and ground stub change the radiation pattern to directional radiation pattern. Since, these antennas are facing each other, hence their radiation pattern are in opposite direction thus pattern diversity is observed.

The simulated performances of the proposed antennas (from antenna-1 to antenna-4) are compared in Fig.3. The impedance matching bandwidth (S11) comparison of antennas Antenna-1(step-1), Antenna-2(step-2), Antenna-3(step-3), and Antenna-4(step-4), among all of them matching of Antenna-4 is good which 3.52 GHz (8.07-11.59 GHz) is shown Fig.3.a. Fig.3b shows isolation (S21) between two monopoles of an Antenna-4 is higher than all other antennas, which is better than -20 dB. Isolation (S21) of antenna-4, further improves with frequency. Axial ratio is improved, as we move from antenna-1 to antenna-4. A wide axial ratio band is observed for Antenna-4, which is 2.45 GHz (8.11-10.56 GHz). Axial ratio bandwidth is mainly controlled by the truncation of lower side length l_t. The axial ratio bandwidth increases with increase in length. The comparison of the axial ratio bandwidth (ARBW) is presented in Fig.3c. Gain variation from 0.3 dB to 2.97dB with frequency within the axial ratio band of the antenna-4 is illustrated in Fig.4c.



(a) Step-1 (Antenna-1) **(b) Step-2 (Antenna-2)**



(c) Step-3 (Antenna-3) **(d) Step-4 (Antenna-4)**

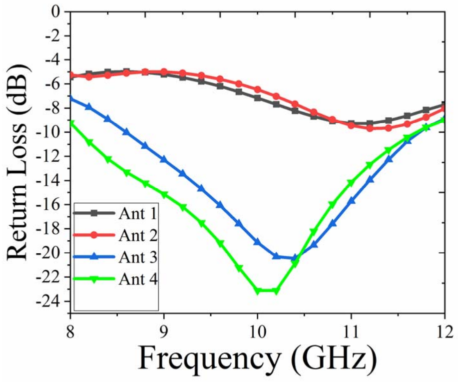
Fig.2 Design steps of the proposed MIMO antenna

3. Simulated and Measured Results

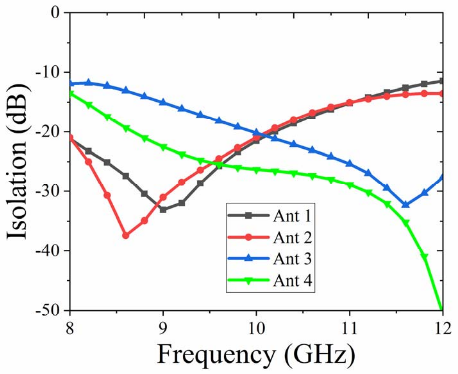
Both simulated and measured results are compared in Fig. 5. It can be note that the isolation is high which can be seen in Fig5a. It is better than -20 dB, obtained without employing extra decoupling structure. The isolation and pattern diversity are achieved by simply adding the one stub in the ground plane which can be seen in Fig.2d. There is no electric field coupling between both the antennas, hence it provides the pretty well pattern diversity within the axial ratio band as shown in Fig.4. Both measured and simulated axial ratio bandwidth (ARBW) is 2.45 GHz (8.11-10.56) while its impedance matching bandwidth (IMBW) is 3.52 GHz (8.07-11.59) as shown in Fig.5b and Fig.5a. The gain of the antenna varies 0.3dB to 2.97dB as shown in Fig.5c.

The 2D simulated radiation pattern shows the pattern diversity phenomena in the proposed antenna structure. Fig.4 shows the pattern diversity. The simulated surface current distribution on the surface of antenna-A and antenna-B is shown in Fig.6. The rotating surface current verify the circular polarization of both the antennas, when each port of the antennas is excited individually. Antenna-A radiate LHCP while antenna-B radiates RHCP when both of them excited separately.

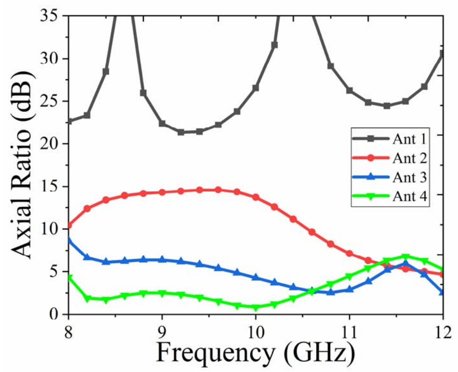
The envelop correlation coefficient (ECC) and Diversity Gain (DG) are the key parameters for the MIMO antenna. ECC mostly preferred to find the correlation in the received signals while DG provides enhancement in the system with several antennas compared to a system with single antenna. ECC is calculated from the far field pattern [6]. The ECC of the proposed antenna is nearly *equal to zero* while the acceptable ECC is less than 0.5 and DG is *20dB*. Hence our antenna has pretty well ECC and DG. The measured radiation pattern for frequency 10GHz is shown in Fig.7. Our proposed antenna is compared with the earlier published work in table-1, which shows its performance is comparable. It has wide band axial ratio and impedance matching bandwidth.



(a) **S11**

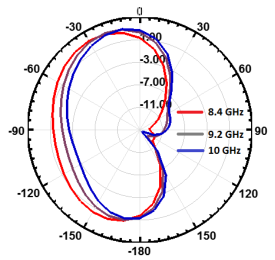


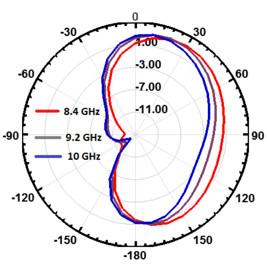
(b) S21



(c) Axial Ratio

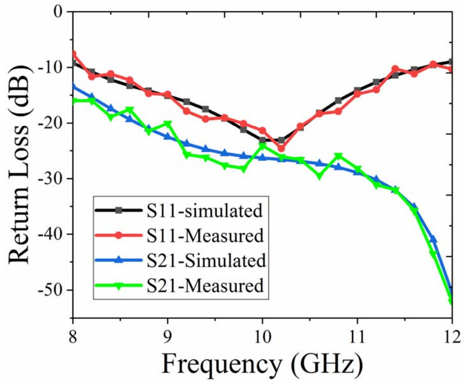
Fig. 3 Performances comparison of antennas (for step-1 to step-4)



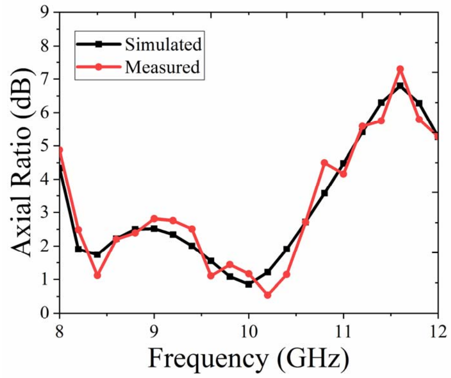


(a) Excitation at port-1 **(b) Excitation at port-2**

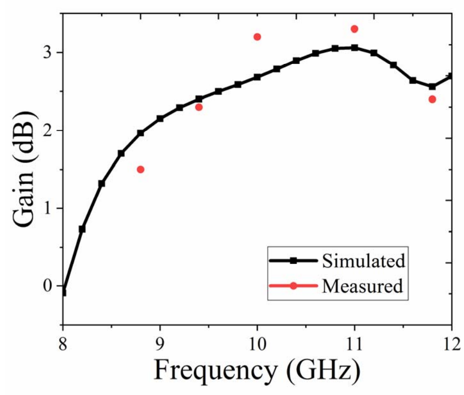
Fig. 4 Radiation pattern showing pattern diversity



(a) **S11 and S21**



(b) Axial Ratio

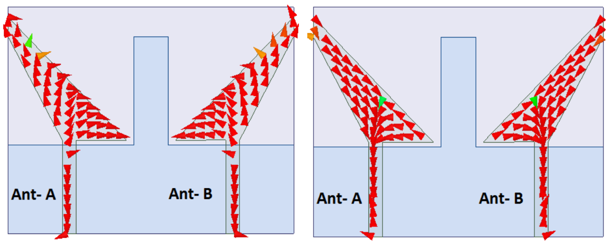


(c) Gain

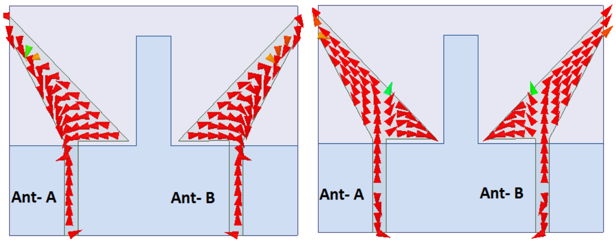
Fig. 5 Simulated and measured performances of the proposed MIMO antenna

Table 1

Ref.	IMBW	ARBW	Pattern Diversity	Polarization Diversity
3	1.3 GHz	250 MHz	Yes	Yes
4	100,250 MHz	NA	Yes	No
5	90 MHz	80 MHz	Yes	Yes
7	180,470MHz	NA	Yes	No
8	84MHz	NA	Yes	No
Our	**3.52 GHz**	**2.56 GHz**	**Yes**	**Yes**

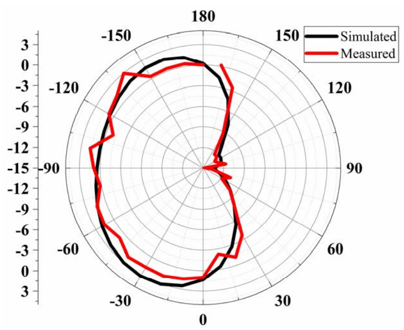


(a) $\omega t = 0^0$ (b) $\omega t = 90^0$

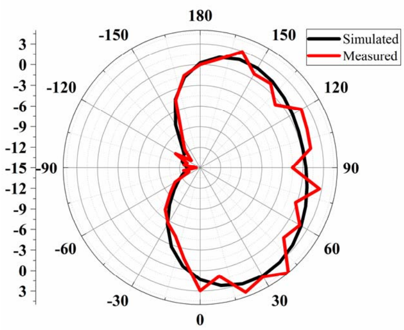


(c) $\omega t = 0^0$ (d) $\omega t = 270^0$

Fig.6 Surface current distribution at 8.4 GHz



(a) Excitation at port-1



(b) Excitation at port-2

Fig. 7 Measured Radiation pattern at 8.4 GHz showing pattern diversity

4. Conclusion

A wideband circularly polarized (CP) MIMO antenna with pattern and polarization diversity has presented in this paper. The axial ratio bandwidth (ARBW) is 2.45 GHz (8.11-10.56) while its impedance matching bandwidth (IMBW) is 3.52 GHz (8.07-11.59). Proposed antenna structure is simple and useful for X-band, and it has both pattern diversity and polarization diversity within the entire axial ratio band. The isolation without using extra decoupling structure between the antennas is high, which is better than -20dB. The performance of the proposed antenna has been compared with those of the recently published works and is shown to be favorable. Compared to legacy circularly polarized MIMO antennas, the proposed antenna has better impedance matching, 3dB axial ratio bandwidths and both pattern and polarization diversity. The antenna structure has been fabricated on FR-4 substrate and agreement in the simulated and measured results, verify the design concept

5. References

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