Dual-Element CPW-Fed MIMO Antenna for ISM Band Application

Ajit Kumar Singh, Santosh Kumar Mahto, and Rashmi Sinha

Abstract This article presents a dual-port circular patch CPW (coplanar waveguide)-fed multiple-input-multiple-output (MIMO) antenna for ISM band (5.8 GHz) applications. The antenna achieves an impedance bandwidth of 1.64 GHz (5.22–6.86 GHz). The optimized dimension of the MIMO antenna is 30 mm × 16 mm. The MIMO structure is obtained by putting the antenna elements orthogonally and fed independently. The matching and isolation of the MIMO antenna are improved by using a rectangular stub associated with the feed and ground plane. The individual antenna has gain and radiation efficiency of 2.52 dBi and 92%, respectively. The antenna has a stable radiation characteristic at 5.8 GHz and co- and cross-polarization are also studied. The performance characteristics of the proposed antenna are dissected as far as the envelope correlation coefficient (ECC), diversity gain (DG), mean effective gain (MEG), total active reflection coefficient (TARC), isolation between the ports, and the values are 0.28, 9.90 dB, ±3 dB, −7 dB, 12 dB, respectively.

Keywords CPW-fed · MIMO · Isolation · ECC · TARC

1 Introduction

The current scenario for wireless communication is to achieve a higher data rate, capacity, low latency, and resolution. It has been shown in [1–3] that to improve the information throughput in a multipath environment for ISM/LTE/5G operations, the MIMO antenna system should be adopted. Because of compact volume in the mobile terminal and to achieve better performance for the MIMO antenna system.

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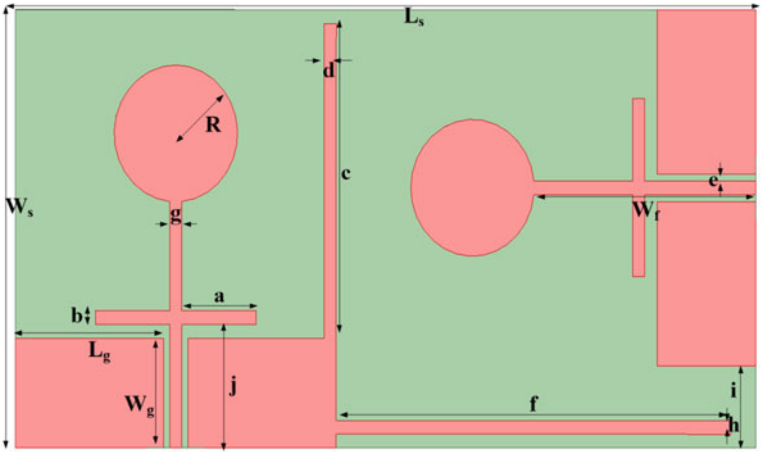


Fig. 1 CPW-fed MIMO antenna

As the number of antennas increases at the receiver, the reliability of the receiving system improves; however, space is a central issue. Likewise, the impact of isolation decreases as the distance between antenna elements diminishes, which influences the diversity characteristics of the antenna [4, 5].

Coplanar waveguide (CPW) taking care of draws in more consideration in light of more bandwidth with low dispersion and radiation spillage as compared to other feed lines [6–8].

In literature, several MIMO antennas have been proposed for ISM/WLAN applications [7–10]. In [7], a monopole printed antenna was studied for ISM band with a dimension of $44 \times 44 \times 0.5$ mm^3. A compact quad element antenna was proposed for body area networks with isolation of −25 dB and ECC of 0.02 in [8]. In [9], a compact MIMO was proposed for ISM band application (5.8 GHz) with pattern and polarization diversity. The compact antenna was proposed with a dimension of $30 \times 25 \times 1.524$ mm^3. In [10], a dual-element CPW-fed MIMO antenna was discussed for WLAN applications with an antenna dimension of $50 \times 50 \times 1.59$ mm^3.

In this article, 1×2 MIMO antenna with a dimension of $30 \times 16 \times 1.6$ mm^{3}is proposed in the frequency range 5.22–6.86 GHz by using a CPW fed along with rectangular stubs. The average isolation is 12 dB in the operating band from 5.22 to 6.86 GHz with ECC < 0.28, the peak gain 2.52 dBi, and the average radiation efficiency of 92%. Simulation is performed using commercially available software High Frequency Structure Simulator (HFSS version 2021R1).

2 Design

The proposed antenna has two circular radiators, as depicted in Fig. 1. It has an overall dimension of 30 × 16 × 1.6 mm^3 and is designed on an FR4 substrate having a dielectric constant of 4.4, and a loss tangent of 0.02. In this case, each element is orthogonally coupled with the others to utilize the polarization diversity. Matching and isolation can be improved by incorporating rectangular stubs in the ground plane and feed, which act as an open-circuit stub, and its dimension is tuned properly to compensate for the input impedance offered by the antenna as the inductance and capacitance value depends on it (Table 1).

Table 1 The optimized parameters of CPW-fed antenna

Representation	Size (mm)	Representation	Size (mm)	Representation	Size (mm)
L_S	30	W_f	9	e	0.25
W_S	16	a	3	f	16
L_g	6	b	0.5	g	0.5
W_g	4	c	11.5	h	0.5
R	2.5	d	0.5	i	3
j	4.5				

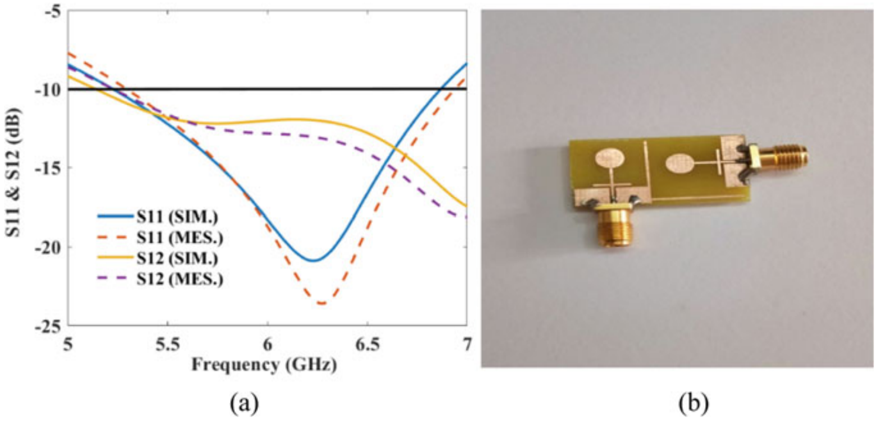


Fig. 2 **a** $S11$ and $S12$, **b** fabricated antenna

3 Results and Discussion

Simulated and experimental, Matching ($S11$) and isolation ($S12$) of the antenna, as represented in Fig. 2a are less than −10 dB, −12 dB, respectively, throughout the entire bandwidth. The fabricated antenna is shown in Fig. 2b.

The MIMO antenna has an average peak gain of 2.42 dBi in the frequency ranging from 5.22 to 6.86 GHz as displayed in Fig. 3a.

Figure 3b represents the radiation efficiency at all ports of the proposed antenna. The average radiation efficiency is 92.1% (−0.90 dB), throughout the entire bandwidth.

Figure 4 represents the 2D patterns of the antenna at 5.8 GHz and observed that at Ø = 0°, designs are similar to dipole and almost omnidirectional at Ø = 90°.

Figure 5 represents the far field patterns of MIMO antenna at 5.8 GHz frequency in x–z and y–z plane.

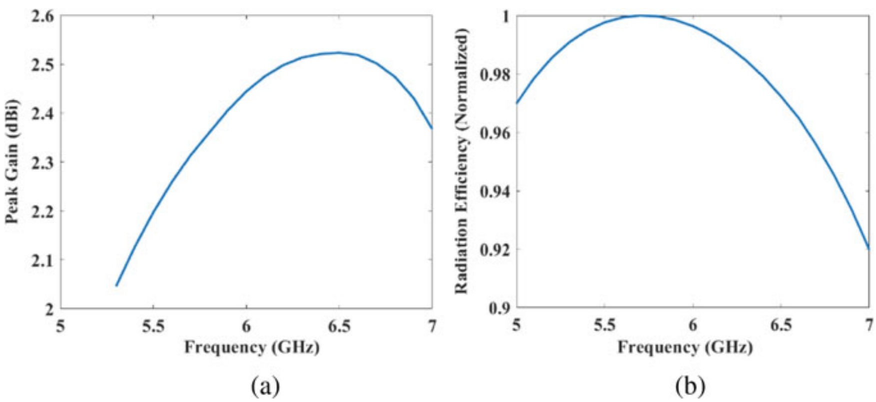
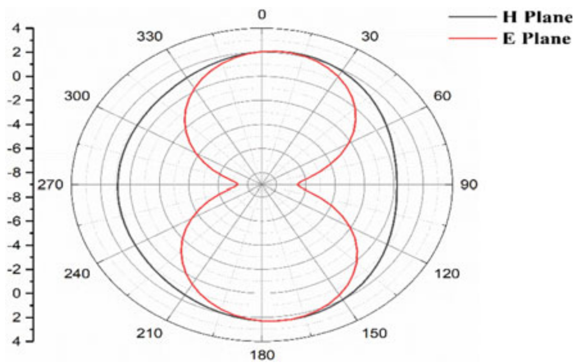


Fig. 3 **a** Peak gain, **b** radiation efficiency

Fig. 4 *E* and *H* plane at **a** 5.8 GHz, frequency for Ø = 0° and 90°



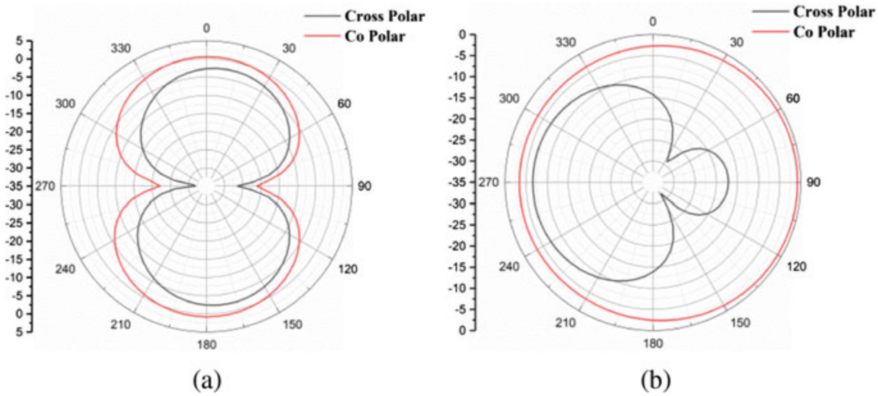


Fig. 5 Co- and cross-polarization, **a** *ZX* plane, **b** *YZ* plane

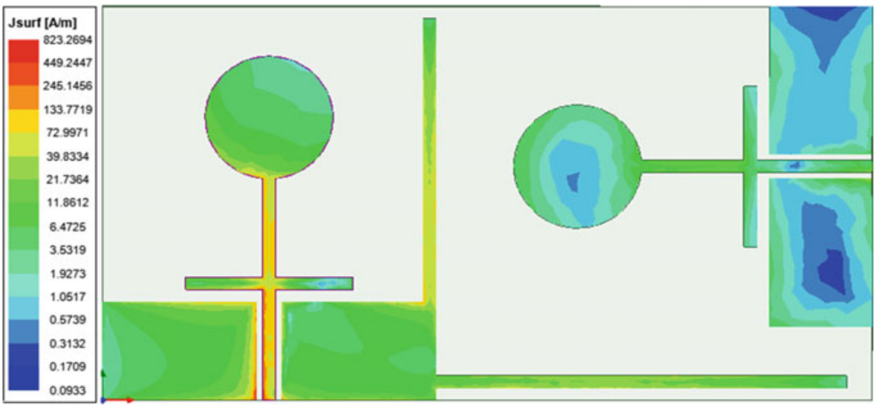


Fig. 6 Surface current density at 5.8 GHz

Surface currents flow in Fig. 6 from the stimulated port-1 to other ports is the fundamental reason behind the isolation between close antenna elements. At a time, only port-1 is excited and port-2 is matched.

4 MIMO Diversity Characteristics

The ECC which considers the correlations between the two antennas and determined using (1) [11]:

$$|\rho_e(i, j, N)| = \frac{\sum_{n=1}^{N} S_{i,n}^{*} S_{n,j}}{\prod_{k(=i,j)} \left[\sum_{n=1}^{N} S_{i,n}^{*} S_{n,k} \right]} \tag{1}$$

For ideal case, ECC is zero; however, experimental value should be ≤ 0.5.

DG of the MIMO antenna is calculated as:

$$\text{DG} = 10\sqrt{1 - \text{ECC}^2} \tag{2}$$

DG should be near to 10 dB.

The calculated values of ECC and DG are less than 0.28 and 9.90 dB, respectively, as displayed in Figs. 7a, b that show the good diversity performance.

In dual-port antenna, TARC is also an important parameter that gives the relation between radiated and received power.

For dual-element TARC can be calculated using (4) [11].

$$\text{TARC} = \frac{\sqrt{(S_{11} + S_{12})^2 + (S_{21} + S_{22})^2}}{\sqrt{4}} \tag{3}$$

Ideally, TARC should be <0 dB. The simulated value of the TARC is less than ≤7 dB in the frequency ranging from 5.22 to 6.86 GHz as depicted in Fig. 7b.

MEG is the ratio of mean received power to mean input power. For two elements, MEG can be determined using (5) and (6) [11] and shown in Fig. 8.

$$\text{MEG}_i = 0.5\left[1 - \sum_{j=1}^{N} |S_{ij}|^2\right] \leq 3\,\text{dB} \tag{4}$$

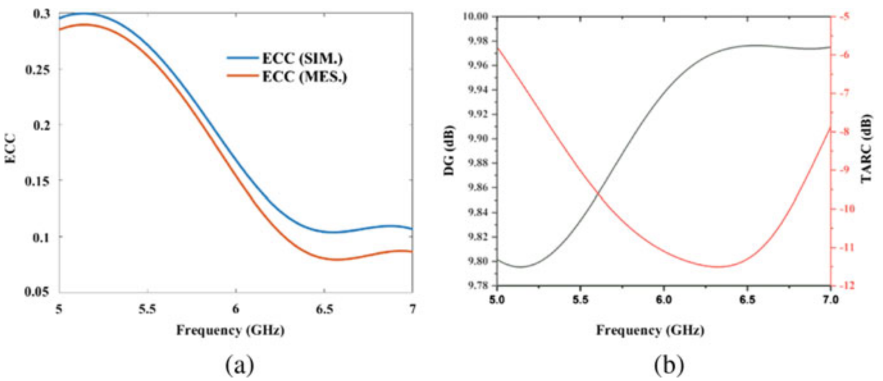


Fig. 7 **a** ECC, **b** DG and TARC

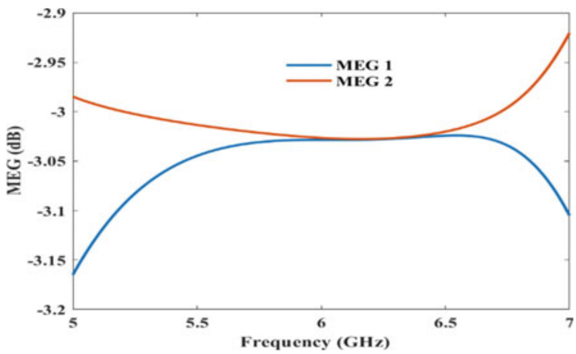


Fig. 8 MEG

Table 2 Comparative chart of proposed MIMO antenna

References	Dimensions (mm^3)	Frequency range (GHz)	Isolation (dB)	ECC
[9]	44 × 44 × 0.5	2.35–2.5	−10	NA
[10]	26 × 26 × 0.8	2.4	−25	0.02
[12]	30 × 25 × 1.524	5.8	−13	NA
[13]	50 × 50 × 1.59	2.25–3.15, 4.89–5.95	−15	0.01
[P]	30 × 16 × 1.6	5.22–6.86	−12	0.28

$$\text{MEG}_j = 0.5\left[1 - \sum_{i=1}^{N} |S_{ij}|^2\right] \leq 3\,\text{dB} \tag{5}$$

in which, i, j denote antenna elements 1 and 2, separately.

The proposed MIMO antenna is compared with other published work in Table 2. This MIMO antenna has a size of 30 × 16 × 1.6 mm^3, which is compact as contrasted to other antennas. The measured value of ECC is 0.28 which is good as depicted in Table 2, except [10, 13]. The MIMO antenna achieved isolation of 12 dB, which is better than [9], however, less than [10, 12, 13]. The MIMO antenna achieves an average radiation efficiency of 92% which is better than other reported antennas.

5 Conclusion

A CPW-fed dual-element MIMO antenna with an isolation of 12 dB is presented for ISM band application. The performance of the proposed design has been analyzed and discussed in terms of its various antenna characteristics parameters like impedance bandwidth, surface current distribution, reflection coefficient, gain, efficiency, and radiation characteristics. It also offers high DG of 9.90 dB and satisfactory TARC ≤ 7 dB. Therefore, the proposed MIMO antenna is suitable for ISM bands viably.

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