MIMO Based Multi Band Antenna for Wireless Communication in C-Band, X-Band, K-Band and Ku Band

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Abstract. This paper presents a design of a multiband MIMO microstrip patch antenna. The isolation between the two ports varies from 12.5 dB to 44 dB for all the available bands. Proposed antenna is useful for C-Band, X-Band, K-Band and Ku-Band applications. The proposed antenna shows the circular polarization behavior at 5.27 GHz (5.26 GHz–5.31 GHz), 6.20 GHz (6.18 GHz–6.22 GHz), 11.89 GHz (11.72 GHz–12.24 GHz), 13.56 GHz (13.46 GHz–13.61 GHz), 16.68 GHz (16.55 GHz–16.85 GHz), 21.17 GHz (21.17 GHz–21.20 GHz) and 22.84 GHz (22.28 GHz–22.93 GHz). The proposed antenna is designed on FR-4 substrate with relative permittivity 4.4 and thickness 1.59 mm.

Keywords: Antenna · Multiple-input–multiple-output (MIMO) · Mutual coupling · Multiband · Micro strip patch

1 Introduction

Emerging technologies in the modern wireless communication systems require products that are capable of providing multiple services within a single device. Multiple-input-multiple-output (MIMO) technology is used to increase the capacity and quality of the channels, which are used in communications. Recently, MIMO antennas have been widely studied and used in wireless local area network (WLAN), mobile communication, wireless broadband network and other mobile communication networks. MIMO antennas aim to produce a high isolation among the multi-antenna elements used in the transmitter and receiver; thus in a limited space the channel capacity of the communication system can be increased without increasing bandwidth [1–5].

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The data rate, operating distance and link reliability can be highly improved without using extra spectrum and transmission power in MIMO technology. It helps to handle large data, video and voice stream. MIMO systems are useful for both Line Of Sight (LOS) and non-LOS (NLOS) indoor wireless communications; they reduce the channel's multipath and increase the data throughput [3, 4]. To date, huge R&D has been done to improve underground MIMO channel performances [3–5].

In recent years, lot of work has been done on integrated and multifunctional wireless communication systems. Multi-band antennas play an important role and are extremely desired, as they can be simultaneously used for different signal frequencies [3, 4]. To the best of our knowledge the work done on the multi-band MIMO antennas is very less in the open literature.

This paper presents new design method to design a multi-band antenna with MIMO for C-Band, X-Band, K-Band and Ku-Band applications.

2 Antenna Design

Proposed antenna has been designed on the FR-4 substrate with relative permittivity $\epsilon_r = 4.4$, thickness 1.59 mm and loss tangent 0.02. A 3-dimensional EM simulator HFSS (v.11) has been used to design the antenna. The dimensions of the antenna are: a = 19.5 mm, b = 11.5 mm, c = 6.5 mm, d = 1.5 mm, e = 13.1 mm, f = 3.0 mm, g = 10.46 mm, h = i = 4.0 mm, j = 5 mm, and w = L = 40 mm as shown in Fig. 1. The proposed antenna has a unique combination of two opposite face C-type rings. The radius of the outer ring is 19.5 mm, ring width is 3 mm and gap between two rings is 2 mm. The width of the 50 Ω line is 10.46 mm, which has been used for feeding the antenna and also for impedance matching. The gap between two rings plays a major role in optimizing the resonant frequency and

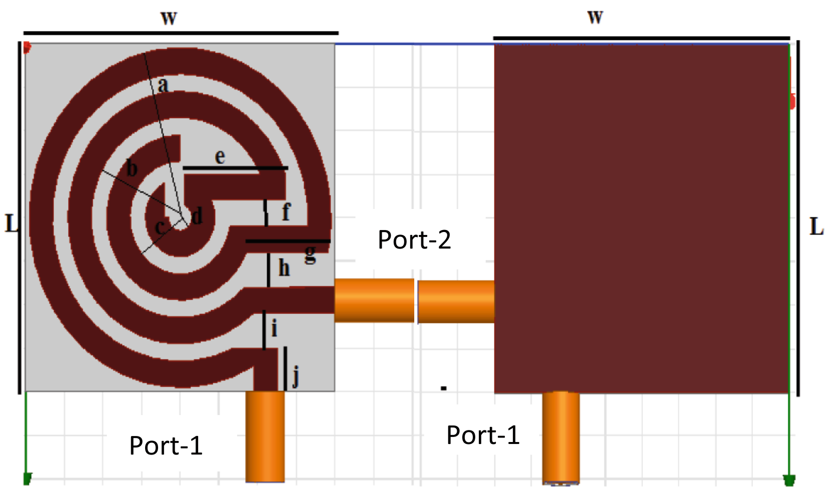

Fig. 1. Layout with dimensions of the proposed antenna (a) Top side (b) Bottom side

isolation between two ports. By changing the gap between the two rings, one can increase the isolation and shift the position of resonant frequency.

Figure 2 shows the |S11| of the antenna while Fig. 3 shows the isolation between two ports. The resonant frequency, bandwidth and % fractional bandwidth are shown in Table 1. From the Fig. 2 it is clear that the antenna is useful for different frequencies between 4.5 GHz to 25 GHz, which cover the C-Band, X-Band, K-Band and Ku-Band. Figure 3 shows the isolation between the Port 1 and Port 2 which is found to vary from 12.5 dB to 44 dB. This shows its effectiveness for the MIMO antenna as well as for multi-band application.

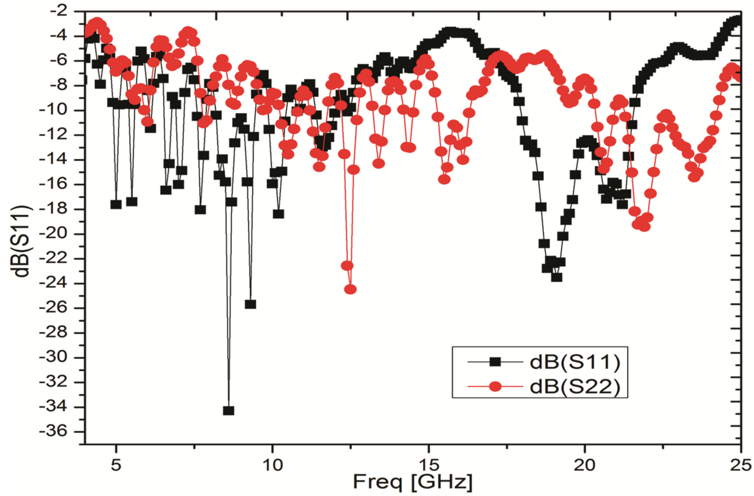

Fig. 2. |S11| and |S22| frequency response of the proposed antenna

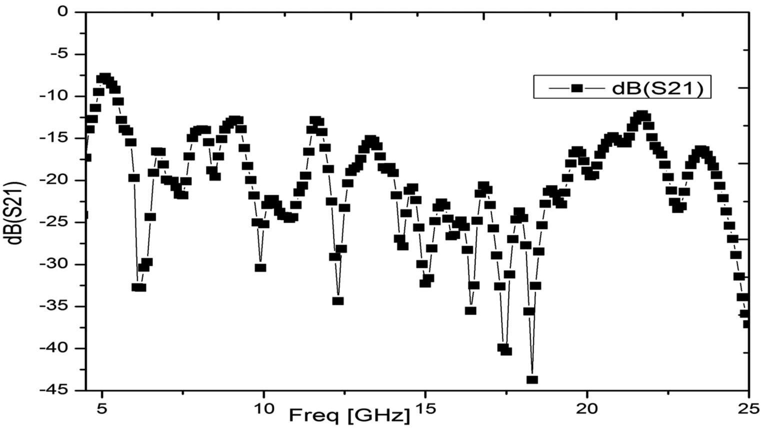

Fig. 3. Isolation between two ports of the antenna |S21| (dB)

Table 1. Performance of the Proposed antenna

Resonant Frequency (Fr) (GHz)	Lower Cutoff of B.W (Fl) (GHz)	Upper Cutoff of B.W (Fh) (GHz)	Bandwidth (GHz)	Percentage Bandwidth ((Fh – Fl)/ Fr)*100
S11				
4.96	4.89	5.08	0.19	3.83
5.47	5.39	5.58	0.19	3.47
6.08	6.04	6.13	0.09	1.48
6.57	6.52	6.77	0.25	3.80
6.96	6.90	7.17	0.27	3.87
7.64	7.58	7.88	0.30	3.92
8.57 & 9.28	8.17	9.45	1.28	14.93 & 13.79
10.14	9.84	10.44	0.60	5.91
11.63	11.37	12.02	0.65	5.58
19.06 & 21.18	17.93	21.56	3.63	20.24 & 17.13
S22				
10.45	10.21	10.80	0.59	5.64
11.46	11.18	11.76	0.58	5.06
12.48	12.19	12.72	0.53	4.24
13.39	13.20	13.59	0.39	2.91
14.29	14.19	14.50	0.31	2.16
15.46 & 16.08	15.27	16.31	1.04	6.72 & 6.46
20.57	20.32	20.96	0.64	3.11
21.77 & 23.50	21.25	24.22	2.97	13.64 & 12.63

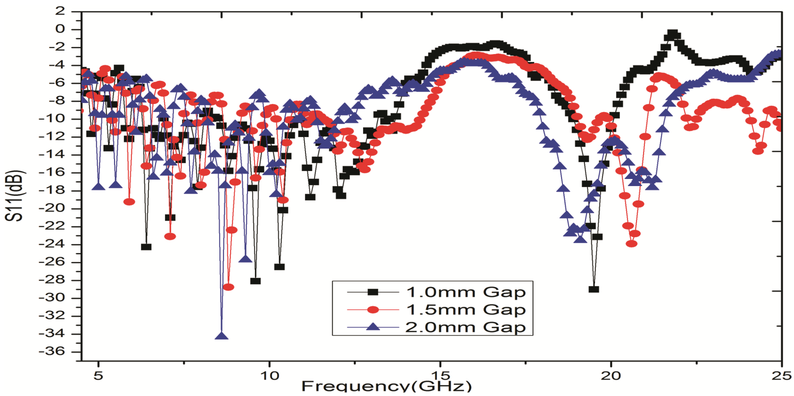

Fig. 4. |S11| of the Proposed Antenna for different gaps.

3 Parametric Study

The effect of the gap between the strips of the rings from 1 mm to 2 mm is shown in Fig. 4. Impedance bandwidth and isolation between the two ports are shown in the Figs. 4, 5 and 6.

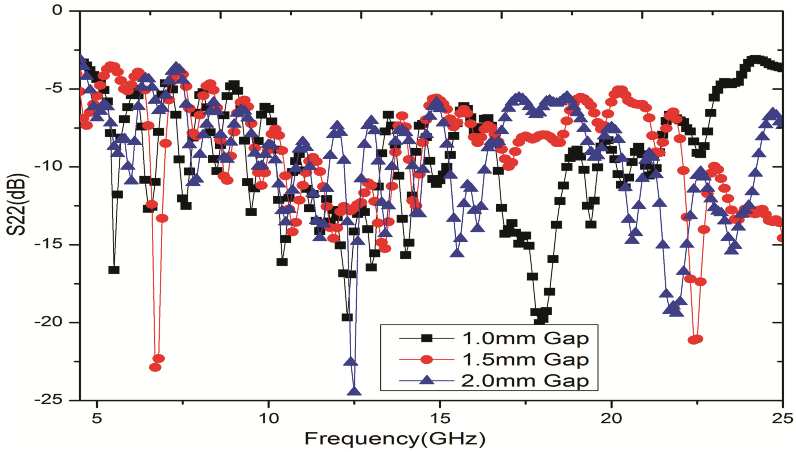

Fig. 5. |S22| of the Proposed Antenna for different gaps.

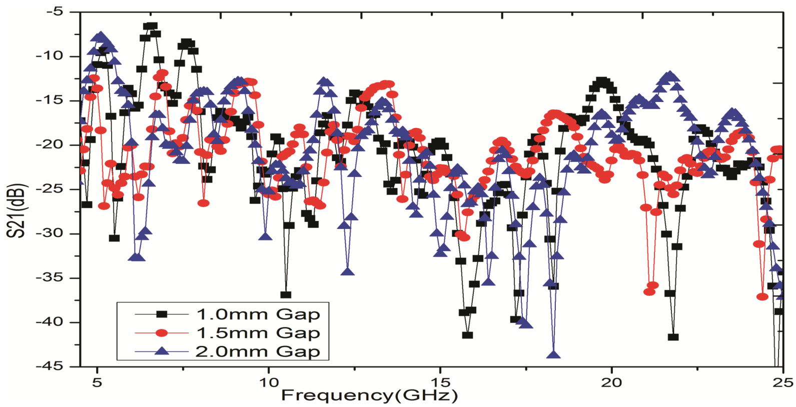

Fig. 6. |S21| of the Proposed Antenna for different gaps.

From Fig. 4 it is seen that the resonating frequencies of the antenna of port 1 are shifted towards the higher frequency side by increasing the gap. From the Fig. 5 it can be seen that the resonating frequencies of port 2 are also shifted toward the higher frequency side while from Fig. 6 the isolation between the two ports are increased by increasing the gap between the strip rings.

For more depth analysis of antenna only Port 1 with patch and Port 2 with patch have been used the individual antenna structures is shown in Fig. 7. The simulated response is shown in Fig. 8.

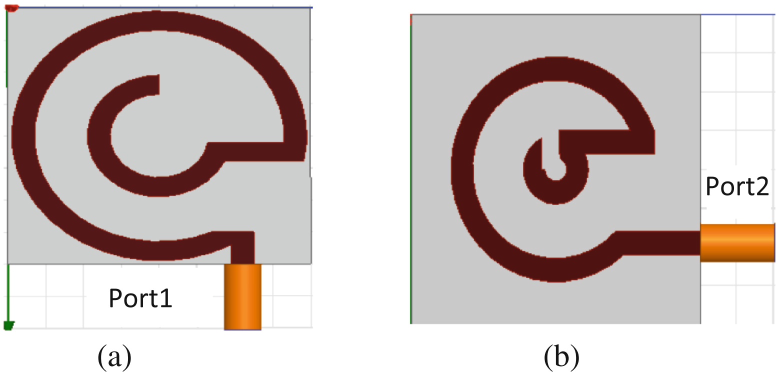

Fig. 7. Proposed Antenna structure (a) with Port 1 (b) with Port 2

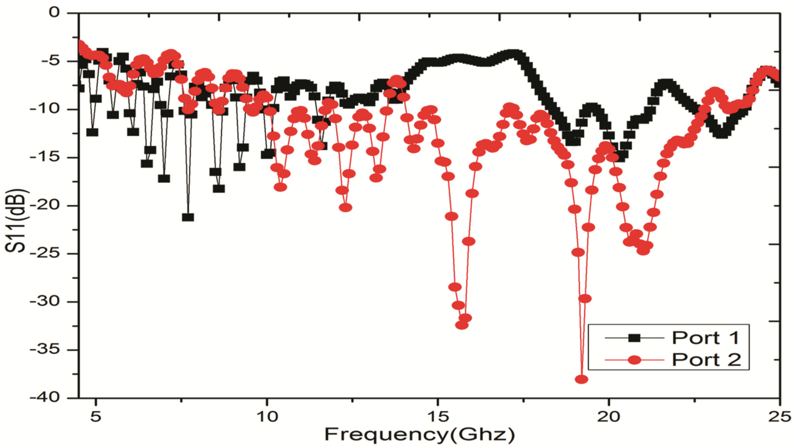

Fig. 8. Antenna structure with Port 1 and Port 2

From Fig. 8 it is clear that the antenna with individual Port 1 resonates in lower frequency range from 4.5 GHz to 12 GHz while antenna with Port 2 resonates from 10 GHz to 22 GHz. As both the ports are connected to the patch, the antenna starts resonating at both the lower frequency as well as higher frequencies, shown in Fig. 2 and Table 1.

This antenna supports ten frequency bands at Port 1, and eight frequency bands at Port 2. Thus, it shows the usefulness for multi-band applications. Most of the multi-band antennas are known to suffer with low gain problems [6, 7] this proposed multi-band antenna, however, is seen to overcome the low gain problems. Gain of the proposed antenna is shown in the Fig. 9. It varies from 1 dB to 24 dB for the entire spectrum of the antenna. This antenna also exhibits the circular polarization for different bands, which is very useful for wireless communication. The axial ratio response of the proposed antenna is shown in the Fig. 10. The axial ratio at resonant frequencies, bandwidth and percentage bandwidth are given in Table 2.

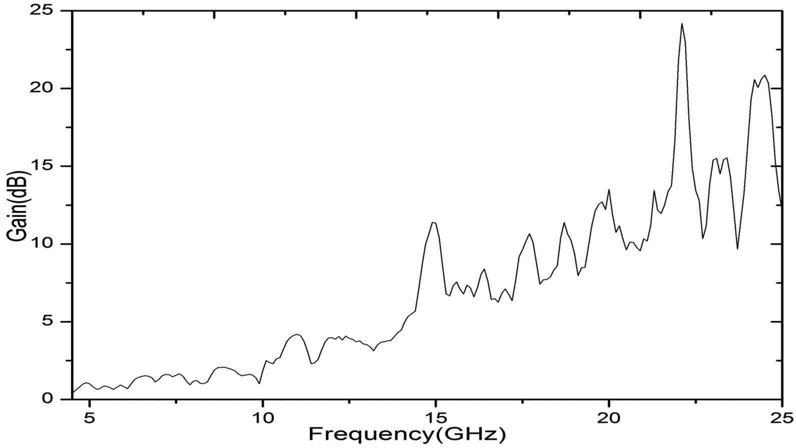

Fig. 9. Gain of the proposed antenna

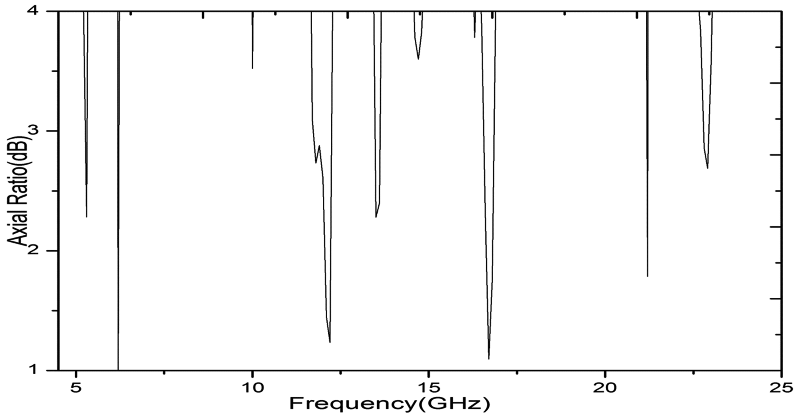

Fig. 10. Axial ratio of the proposed antenna

Proposed antenna shows the circular polarization behavior in C-Band, X-Band, K-Band and Ku-Band. This behavior is suitable for satellite communications, radar, terrestrial broadband, space communications, amateur radio in X-band; satellite communications in K-band; and radar, satellite communications and astronomical observations. The radiation pattern of the proposed antenna for the different frequencies are shown in Fig. 11.

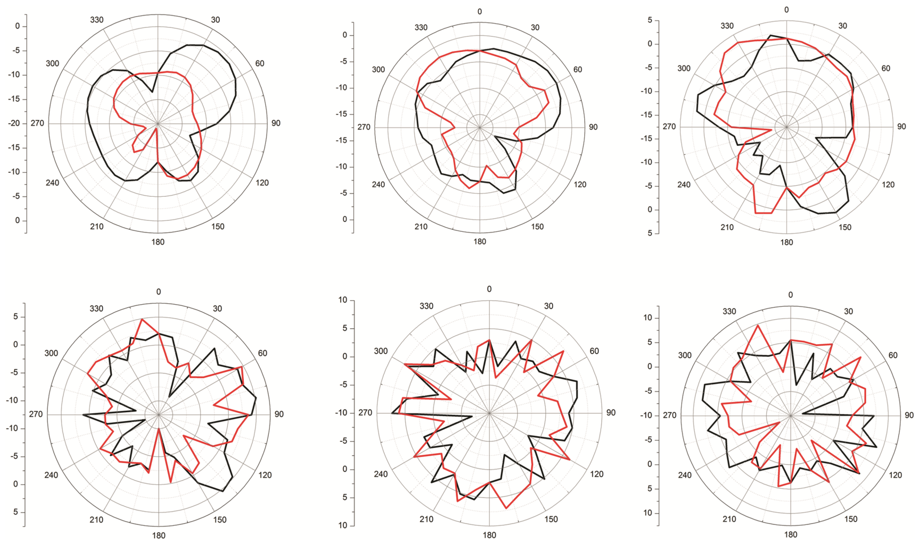

Fig. 11. Radiation pattern of proposed antenna at (a) 5.5 GHz (b) 8.6 GHz (c) 10.5 GHz (d) 14.3 GHz (e) 19.0 GHz & (f) 21.8 GHz

Table 2. Axial Ratio and bandwidth.

Resonant Frequency (Fr) (GHz)	Lower Cutoff of B.W (Fl) (GHz)	Upper Cutoff of B.W (Fh) (GHz)	Bandwidth (GHz)	Percentage Bandwidth ((Fh – Fl)/ Fr)*100
5.27	5.26	5.31	0.05	0.94
6.20	6.18	6.22	0.04	0.64
11.89	11.72	12.24	0.52	4.37
13.56	13.46	13.61	0.15	1.106
16.68	16.55	16.85	0.30	1.79
21.17	21.17	21.20	0.03	0.14
22.84	22.28	22.93	0.65	2.84

From the figure it is clear that at lower frequency and higher frequency antenna shows co-polarization. Moreover, at lower frequency E-plane shows unidirectional properties and H-plane show omni-directional properties but at higher frequency it shows some distorted behavior.

4 Conclusion

A multi-band MIMO microstrip patch antenna has been presented. The parametric study has been presented to see the effect of various parameters on the performances of the antenna. The isolation between the two port is varies from 12.5 dB to 44 dB for all the available bands Proposed antenna could be useful for C-Band, X-Band, K-Band and Ku-Band applications. Antenna also show the circular polarization behaviors at 5.27 GHz, 6.20 GHz, 11.89 GHz, 13.56 GHz, 16.68 GHz, 21.17 GHz and 22.84 GHz.

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