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Compact Patch MIMO Antenna With Low Mutual Coupling For WLAN Applications

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Abstract: A compact triband microstrip patch MIMO antenna is proposed for WLAN applications. The antenna consists of two patches antenna elements, which are orthogonally placed to each other for high isolation at 2.4, 2.8 and 5.8 GHz frequency bands. On its ground plane, a Complementary Split Ring Resonators (CSRRs) is etched for size reduction and multiband generation. The proposed compact MIMO antenna covers an entire size of 58 x 45 x 1.6 mm^3, with the patch size of 13.3 x 17.1 mm^2. A 79% size reduction at 2.45 GHz was achieved for miniaturization, with a very low mutual coupling (S_{21} and S_{12}) of -32 dB at all bands.

Keywords: MIMO, WLAN, CSRR, Isolation.

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1. INTRODUCTION

Recently, the technology of Multiple Input Multiple Output (MIMO) have been applied in various communications systems for significantly enhancing the channel capacity, improving the performance of data transmission [1] and mitigating the multipath fading [2]. These MIMO systems are efficiently designed for different frequency bands such as the GSM, UMTS, LTE, WLAN and UWB [3]. Due to the limited spaces available in the wireless communications devices, a multiband antenna is set to reduce the cost of antenna production [4] by meeting the given requirements of the modern communications systems and supporting multiple bands of frequencies [5-7]. Therefore, by designing a multiband MIMO antenna, high speed data and transmission rate are achieved, in addition of covering many frequency bands [1].

The design process of MIMO antenna as stated in [2] is faced with two major challenges. One is the large size of the antenna elements at lower frequency bands. While the latter is low isolation between the antenna elements. Thus, a compact MIMO antenna, which operate at multiple bands with miniaturized antenna elements and low mutual coupling is required for low cost and high performance.

Various methods of designing compact, multiband MIMO antenna with low mutual coupling have been proposed [8-12]. In [8], a two-element MIMO antenna was proposed for LTE and WiMAX. Good isolation was achieved at the lower band, but the design is characterized with large number of CSRR, which is not suitable for ease design and fabrication. The design of [9] presented a dual band MIMO antenna for WLAN application. The authors used two transmission lines and slots to obtain the high isolation. However, the design is complex for modern communication devices. Similarly in [10], two WLAN bands at 2.45 and 5.2 GHz for MIMO application were proposed. Nevertheless, the designed achieved a high mutual coupling of 14 dB.

A dual band MIMO antenna for WLAN applications is also reported in [11]. Two methods of enhancing the isolation between the antenna elements were proposed. Good isolations were achieved; however, the design process did not report other array configurations of the antenna elements. In addition, by applying more than one technique to achieve high isolation, more complexity in the design was added.

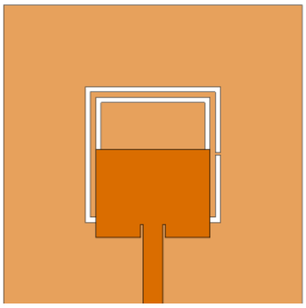
In this paper, a simple method is proposed to achieve miniaturized multiband antenna elements, high port isolation and compact size system for MIMO application. The proposed design is set to operate at 2.4, 2.8 and 5.8 GHz. The design was carried out using the CST Software with FR4 as the substrate with the thickness of 1.6 mm. The proposed MIMO antenna has a compact size of 58 x 45 mm^2 with permittivity of 4.4. When compared with the design in [12], the proposed design is smaller. The optimized designed of the single antenna element is used for the MIMO array configurations. The proposed design presented various array patterns for obtaining good isolations and low mutual coupling.

2. ANTENNA DESIGN

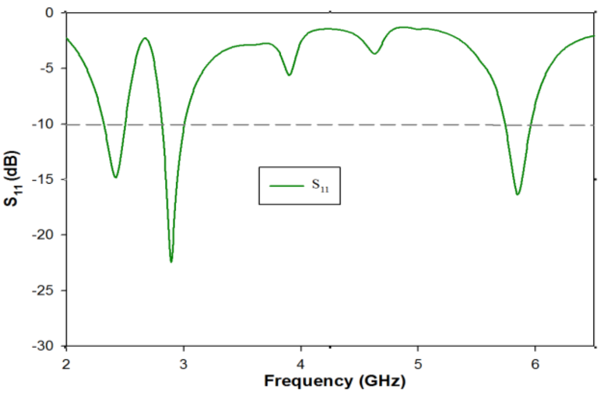
2.1 Single Antenna Design

The design of the single element antenna for the proposed multiband MIMO antenna was first proposed in [13]. Thus, the authors in this paper have extended and optimized some parameters of single antenna element. Among the numerous advantages of using the multiband antenna elements for MIMO design, size reduction and integration of more than one communication technologies are achieved. These saves installation space and production cost. Proper matching must be achieved between the antenna elements for good isolation. However, in [13] the feeding line is too large for compact and low mutual coupling MIMO antenna. Appropriate optimization and parametric studies were carried out to obtain the optimum result for the MIMO design.

Figure 1 (a) and (b) depicts the geometry of the optimized multiband microstrip moaded with CSRR Structure and simulated Reflection Coefficient respectively.



(a)



(b)

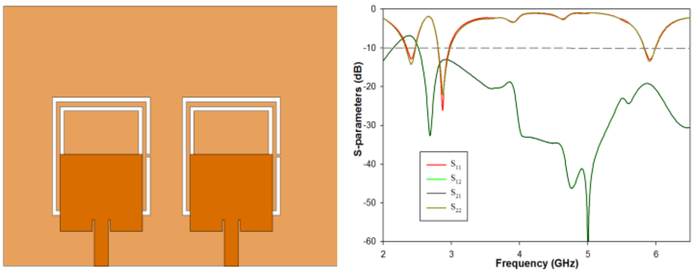
Figure 1. (a) Geometry of the optimized Multiband Microstrip Loaded with CSRR Structure. (b) Simulated Reflection Coefficient

2.2 1 x1 Patch MIMO Antenna Array with CSRR

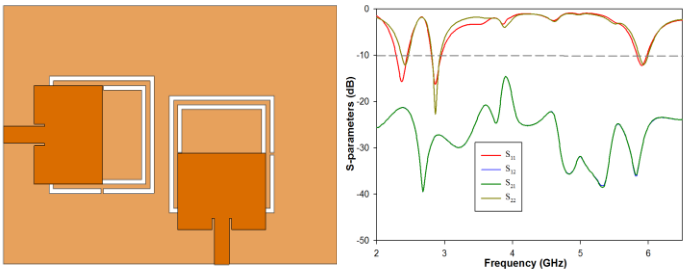
Figure 2 shows the various antenna geometries of the proposed 1x1 microstrip patch MIMO antenna for WLAN applications. The proposed design, based on the results obtained is suitable for multiband application at 2.4, 2.8 and 5.8 GHz.

For each of the antenna array designed for MIMO application, its performance is measured based on various parameters such as the, radiation pattern, mutual coupling, surface current and gain. The antenna elements are arranged beside each other with different spacing between each element. Changing the polarization, pattern and position of the antenna elements results in obtaining different mutual coupling. Thus, from the results obtained in Figure 2 (a) – (d), Figure (b) and (d) have low mutual coupling at 2.4 GHz than (a) and (c), this is because they are orthogonal. While the parallel configuration; (a) shows very high mutual coupling at the same frequency. Figure 2 (c) is slightly different with Figure 2 (d), in which, the element at port 1 is not equidistant with the width of the MIMO antenna.

Furthermore, the selection of Figure 2 (d) for the proposed multiband compact patch MIMO antenna is presented.



(a)



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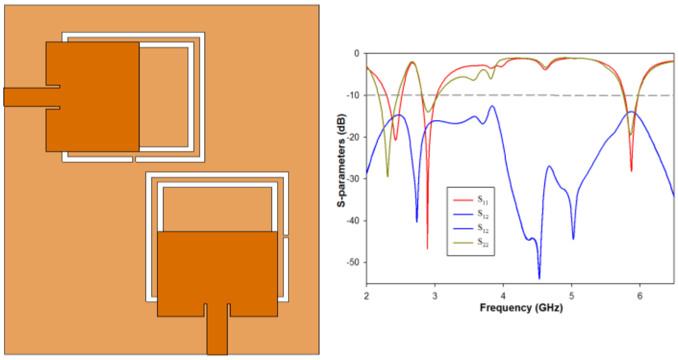
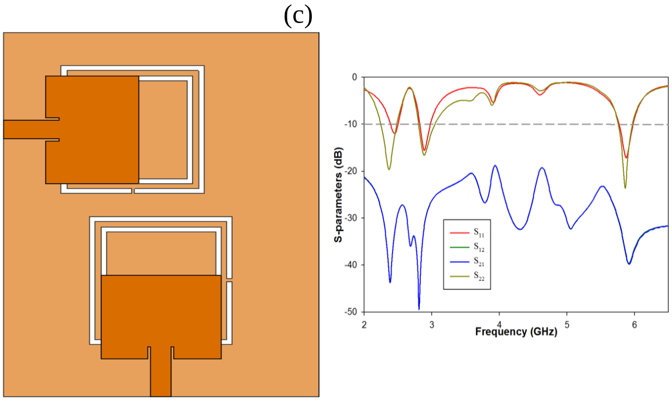


(c)



(d)

Figure 2 (a) – (d) Simulation Results of S-Parameters for the Compact Patch 1x1 Compact MIMO Antenna for different array configurations.

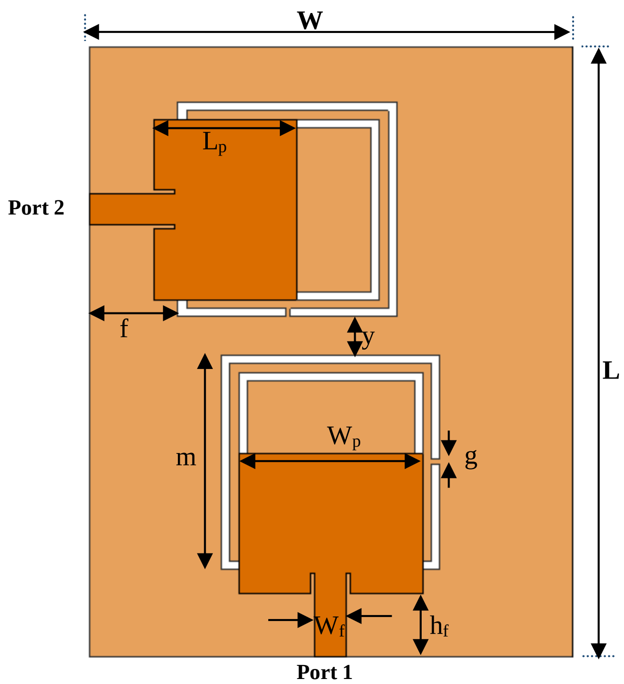


Figure 3. Geometry of the proposed MIMO antenna, top view. L = 58 mm, W = 45 mm, L_p = 13.3 mm, W_p = 17.1 mm, m = 20 mm, g = 0.5 mm, y_o = 4, W_f = 2.93 mm, f = 7, h_f = 10 mm and y = 4 mm.

The geometry of the MIMO antenna with its dimensions is shown in Figure 3. All the design parameters are shown with their respected values as presented here.

2.3 Simulated Results and Discussion

2.3.1 Mutual Coupling Between Ports and Return Loss

The proposed compact MIMO antenna is shown in Figure 3. The design is chosen after various analyses of the different configurations of the two elements antenna. In Figure 4, both the S-parameters are shown with the three 3 bands of 2.4, 2.8 and 5.8 GHz. The proposed design has satisfied the impedance matching requirement of S_{11} and S_{22} of < -10 dB.

Similarly, the mutual coupling (S_{21} and S_{12}) between the two ports are shown in Figure 4 as well. As can be seen from the individual bands of 2.4, 2.8 and 5.8, the minimum mutual coupling is < -32 dB. Since the mutual coupling is less than 32 dB, the proposed compact 1x1 patch MIMO antenna is suitable for MIMO at the designed WLAN bands.

2.3.2 Mutual Coupling Between Ports and Return Loss

Figure 5 shows the simulated 2-D radiation patterns for each port at 2.4, 2.8 and 5.8 GHz for E Plane (*yoz*) and H plane (*xoz*). It can be seen from Figure 5 (a) that at 2.4 and 2.8 GHz, the radiation patterns of E plane (*xoz*) at port 1 is dumbbell-shaped, while at port 2 is apparently omnidirectional. However, at the higher frequency, 5.8 GHz, the E plane at both the ports have quasi-dumbbell shape.

For the H plane (*xoz*) in all the frequencies, an omnidirectional pattern is observed at both ports. However, the gain at 2.4 GHz in port 1 is lower than port 2, which can be traced from the (*xoz*). On the other hand, the H plane pattern of 5.8 GHz at port 2 suffers lower gain with its corresponding port.

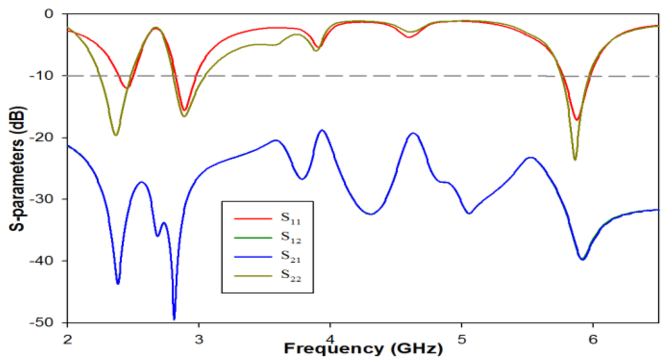
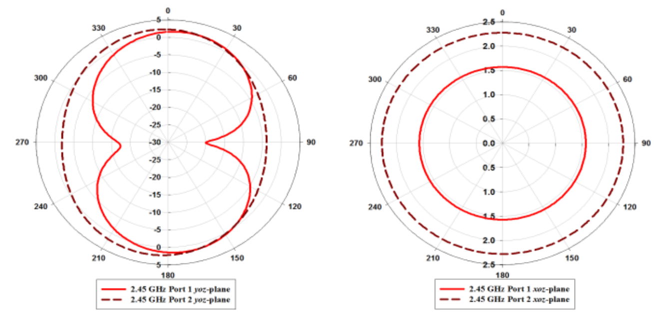
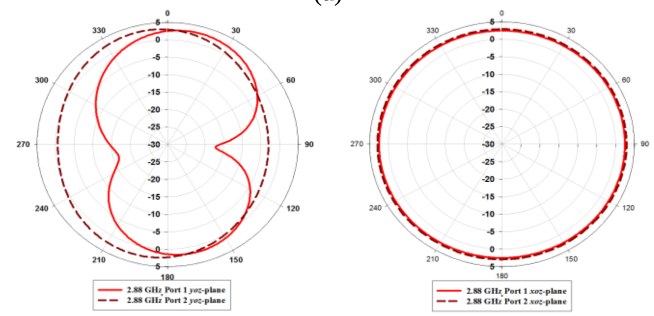


Figure 4. Simulated S-parameters for Compact Multiband MIMO Antenna.



(a)



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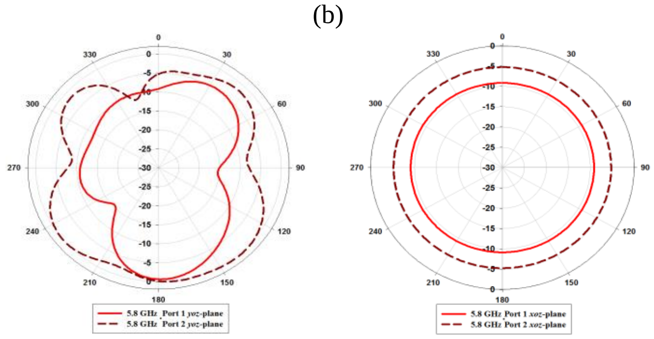


(c)

Figure 5. Simulated Radiation patterns of the proposed MIMO antenna for E and H Plane at: (a) 2.4 (b) 2.8 and (c) 5.8 GHz

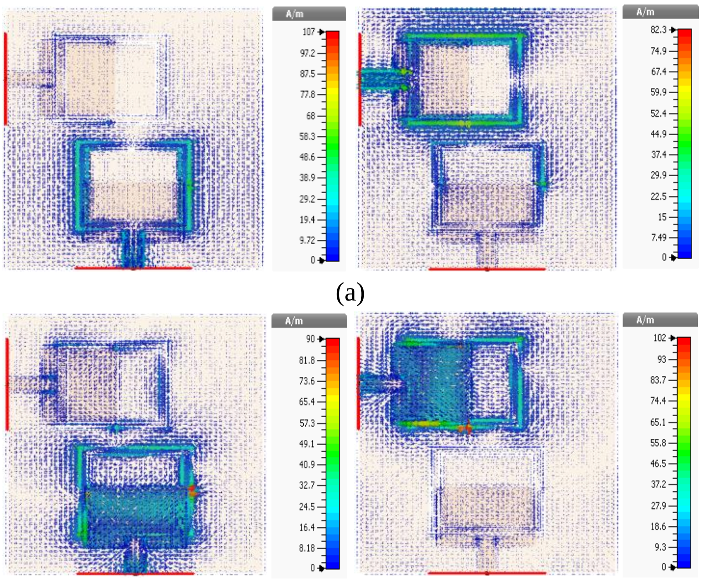
Table 1 shows the performance of the antenna at various bands with ports variation.

Table 1. Antenna Performance

Frequency Bands	Antenna Ports	Antenna Performance	
		Frequency (GHz)	*Gain (dB)*
Band 1	Port 1	*2.45*	*1.95*
	Port 2	*2.45*	*2.68*
Band 2	Port 1	*2.88*	*2.97*
	Port 2	*2.88*	*3.21*
Band 3	Port 1	*5.88*	*2.83*
	Port 2	*5.88*	*1.23*

2.3.3 Surface Currents

To explain more on the effect of CSRR structure on the microstrip antenna, Figure 6 compares the surface current distribution at 2.4 and 5.8 GHz for WLAN applications at various ports. At the 2.4 and 5.8 GHz, when port 1 is excited, the coupling current at the port 2 is less, thus a very low coupling is achieved because of the orthogonality of pattern gains of the antenna elements. Similar effect is noticed when port 2 is excited.



(b)

Figure 6. Simulated Current Distribution for WLAN Frequencies at (a) 2.4 GHz (b) 5.8 GHz

3. CONCLUSION

A compact Microstrip Patch MIMO antenna loaded with CSRR on the ground plane is presented for multiband applications. The proposed multiband antenna covers the WLAN frequency of 2.4, 2.8 and 5.8 GHz. Various array configurations of the two elements are presented to achieve appropriate diversity for MIMO application. Better mutual coupling at -32 dB was achieved with orthogonal diversity. The proposed MIMO antenna can be easily deployed in wireless communication devices due to its compact size and good isolation.

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