Design a Four Dual polarizations MIMO System Based a Serrated Chord with Right Angle Triangle Shape

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Abstract. MIMO antenna is the future elements which will operate with the 5G smartphone devices. In this research, a model of MIMO system of four elements each has a dual-polarized port is proposed. In order to approach a preferred model to match the future application of wireless, two right-angle triangles with chord have a serrated shape is proposed. The partial ground is segmented to four elements corresponding to each proposed single antenna with a suitable shape. The results show that the operating frequency of each single antenna is 6.27 GHz and can cover 590 MHz (5.97 GHz-6.56 GHz) at -10dB with good isolation -26dB while the MIMO system operated at 6.13 GHz with 500 MHz covered a range of (5.9 - 6.4) GHz.

**Keywords:** Serrated, dual-polarized, right-angle triangle, MIMO array, partial ground.

1   Introduction

Lately, as the fourth generation of mobile communications (4G) have fully developed physically, the concentration of many institutions have moved out forward fifth-generation of mobile communication (5G) [1]. As it is known, the essencely index of the future 5G communication is the hugely amount of the data transfer [2]. So, the main challenge of the designer is to improve the data rate for 5G smartphone applications. To improve the efficient spectrum without increasing input power, multiple-input multiple-output (MIMO) is a good choice to investigate such enhancement [3]. Antenna diversity with MIMO system can also provide an improvement in coverage and quality. Because of the printed circuit board (PCB) of the smart phone favored to be as small as possible, polarization techniques have been introduced. The power of the received signal is increased by utilizing the dual-polarization at the same time can mitigate the fading effects of the multipath [3]. However, with MIMO system the surface currents and due to its radiation resulted in a mutual coupling problem [4]. To address the mutual coupling problem, many techniques are proposed for example neutralization lines [5], parasitic geometry [6], and ground plane modifications [7]. In microstrip antenna, there

must be a ground layer with a distinct geometry, which has a significant effect on the performance of such antenna [8]. As in [9], a discussion of the partial ground effect is presented. Also, in [10] and [11] improved the isolation with using tree shape and serration edge of the ground, respectively. On the other hand, the use of serration edge with patch antenna can improve antenna gain, radiation pattern effect and frequency performance which depends on its dimensions [12]. Accordingly, this research will try a patch microstrip with serrated edge having special geometries and band frequency to match the future smartphone applications.

2　Single antenna geometry

The proposed prototype consists of three layers as shown in **Figure 1.** The first one contains a dual-polarized right-angled triangle with serrated chord feeding by 50 Ω microstrip line and used a "Sub Miniature version A" (SMA) as a connector. The second layer with a height of 1.5 mm acts as a substrate which made of Rogers RO3003 (lossy) with permittivity 2.2 and 0.001 of tangent. The third layer which considered as a ground layer concerned with partial geometry. All details of the proposed single antenna are summarized in Table 1.
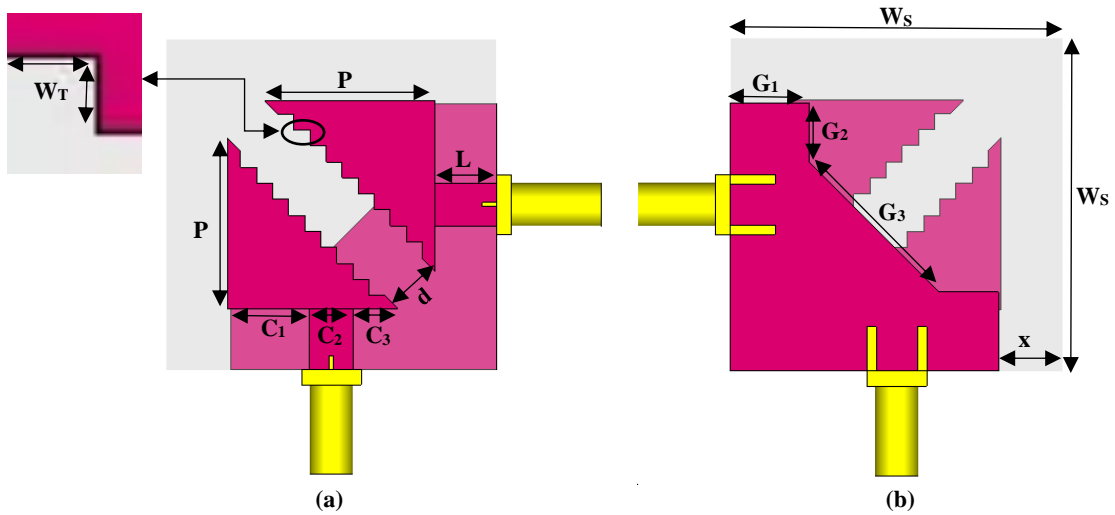

Fig. 1. Single antenna element (a) Front view and (b) Back view.

**TABLE 1**. Parameter values of the antenna design.

Parameter	Value (mm)	Parameter	Value (mm)
P	18.04	W_T	1.70
L	6.48	W_S	35
d	5.60	G_1	8.30
C_1	8.70	G_2	6.23
C_2	3	G_3	19.33
C_3	4.74	X	6.80

The procedure of the current design is started with choosing the shape of microstrip similar to the proposal in [10], but our modification is detailed by using polarization diversity instead of spatial diversity and study the effect of distance between the two triangles in order to investigate a better mutual coupling between them. furthermore, this research applied the serrated chord and partial ground geometry.
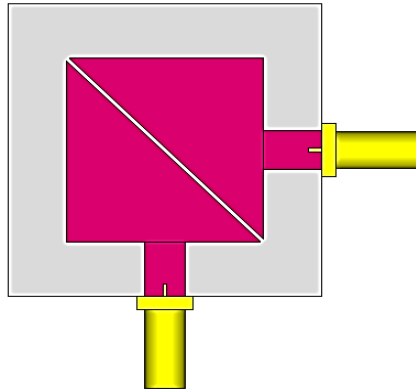

Fig. 2. First step of design with no serrated edge.

Figure 2 shows the first step of a single antenna element design. The distance between the two corresponding triangles is studied to show the effect of separation distance on its performance, the four results which have been chosen are illustrated in **Figure 3**.
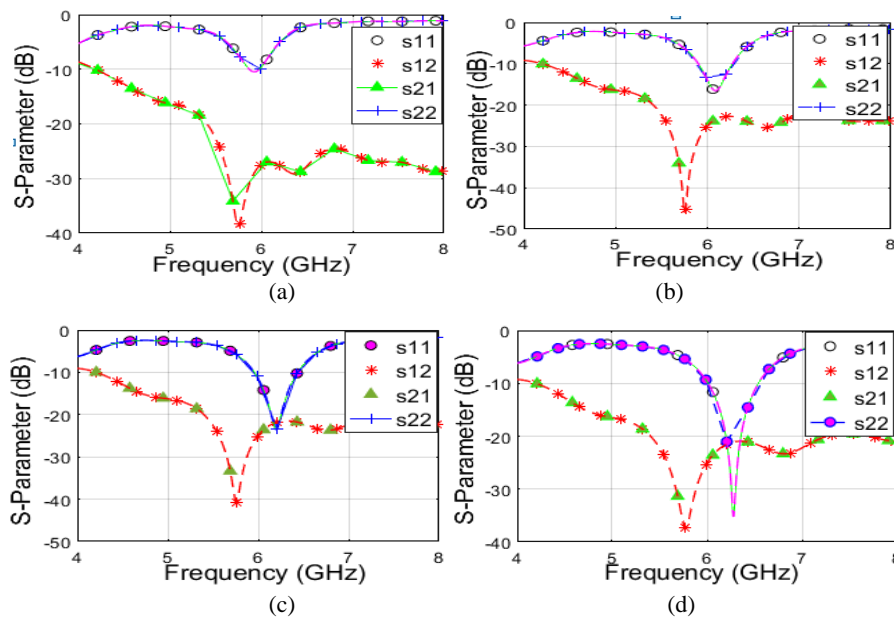

Fig. 3. S-Parameter results for first step of antenna with different *d* in mm (a) *d* = 4, (b) *d* = 5, (c) *d* = 5.6 and (d) *d* = 6.

The result of **Figure 3 (C)** shows mostly suitable with return losses of approximately -24 dB and a mutual coupling about -23dB. From other view, a survey of many researches whose deal with serrated design in [12-13] show that the serrated shape has improved the gain and frequency performance. Accordingly, this research applies such shape in order to approach prefer performance in term of antenna gain and frequency response. The effect of W_T length with the same d, G_2 and G_3 is tried with multiple values that obtained the results shown in **Figure 4**.


(a)   (b)

(c)   (d)
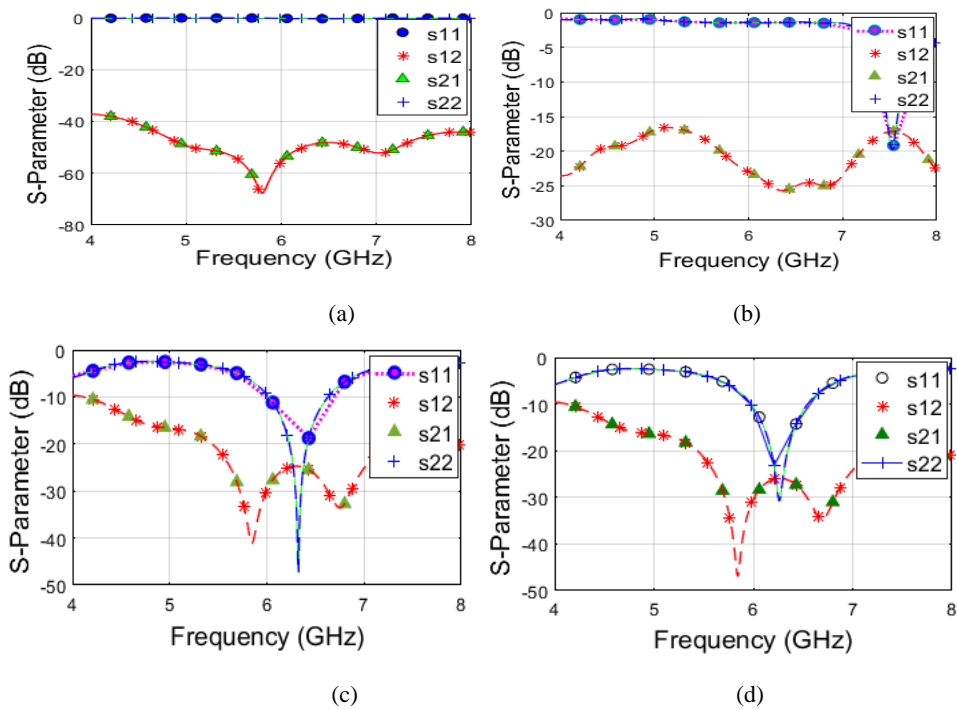
FIG. 4. Results of S-Parameter for different serrated dimensions in mm (a)W_T = 1.41, (b)W_T =1.98, (c)W_T = 1.90, and (d) W_T = 1.70.

The results of **Figure 4 (d)** with a return loss of about -32 dB and isolation -26 dB confirms that the better length of W_T is 1.7 mm. Although the result of **Figure 4 (c)** shows return losses can be approach -50 dB but the isolation is -25 dB, so that, **Figure 4 (d)** is still as the best result. On the other hand, the dimension of the partial ground has direct effect on the result. **[5]** Figure shows four samples among many trying dimensions, we choose four among them.
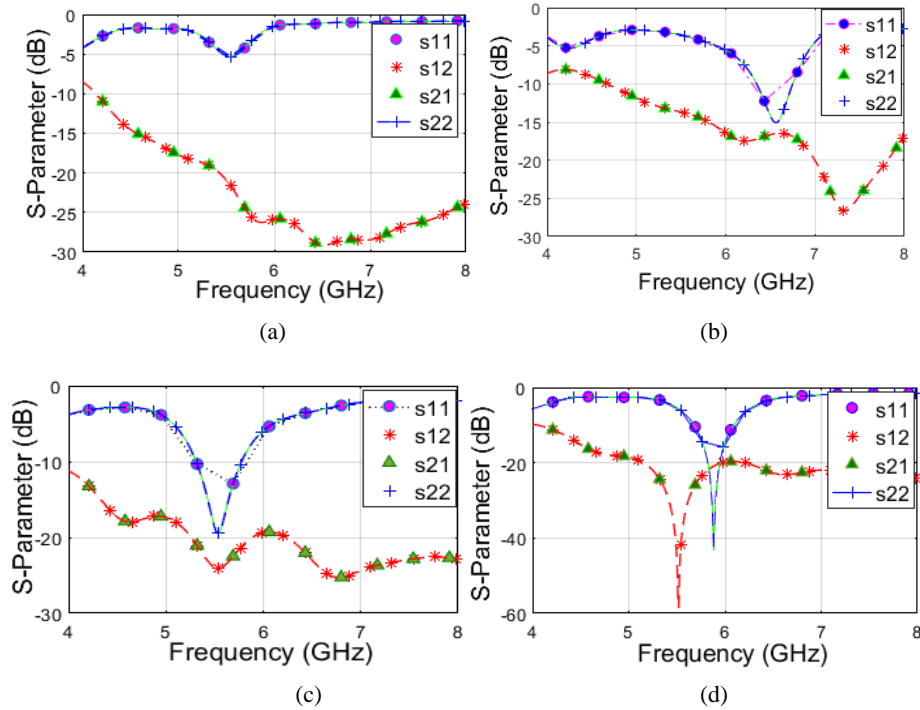
Fig. 5. The effect of G2 and G3 on S-Parameter (a) 28.14, 0, (b) 12, 15, (c) 7.44, 8.33, and (d) 6.60, 23 respectively.

The result shows that the proposed single antenna element is operated at 6.243 GHz and can cover 590 MHz (5.97 GHz-6.56 GHz) at -10dB, while the bandwidth has wider at -6 dB about 1.03 GHz in the range of (5.75-6.78) GHz. Also, the result of VSWR shows that it doesn't approach 2 dB for both exciting ports as illustrated in **Figure 6**.
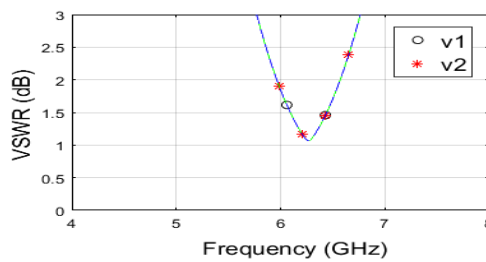
Fig 6. VSWR for the proposed antenna

In term of the radiation pattern, **Figure 7** determined the radiation shape for each port, which form an oval shape covering all direction of the antenna with a gain of 4.85 dBi for both ports.
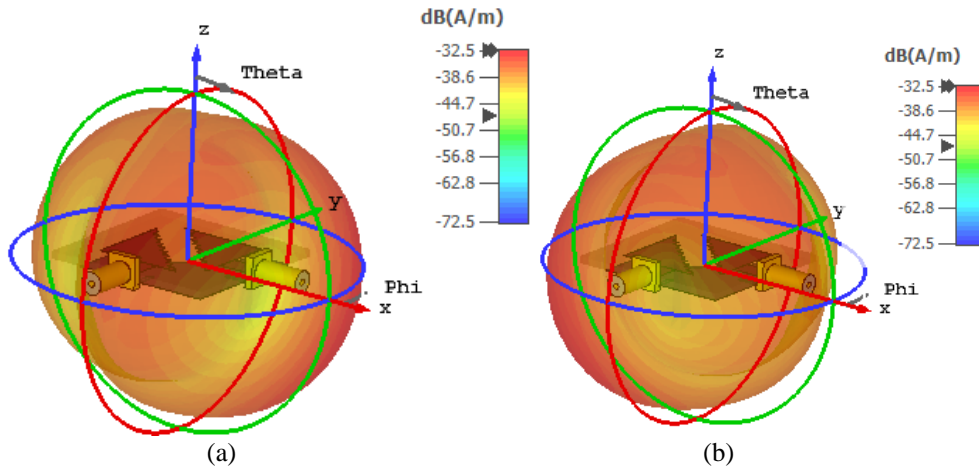
Fig. 7. Radiation pattern for single antenna element (a) Port1 and (b) Port (2).

3   MIMO antenna array

For the purpose of the smart mobile applications which need to cover all directions of the device body, an antenna array is proposed to install four antenna elements which were designed in section 2. At first, trying design steps, each antenna element installed in a corner of a PCB which made of Rogers RO3003 (lossy) with permittivity 2.2 and 0.001 tan δ. In this research, the ground layer is separated only with the corresponding of the antenna elements in order to improve the reflection coefficients S_{ab} and mutual coupling S_{rk}. Now, the final proposed MIMO paradigm is obtained a better result in terms of S_{ab} and S_{rk} as shown in **Figure 8**.
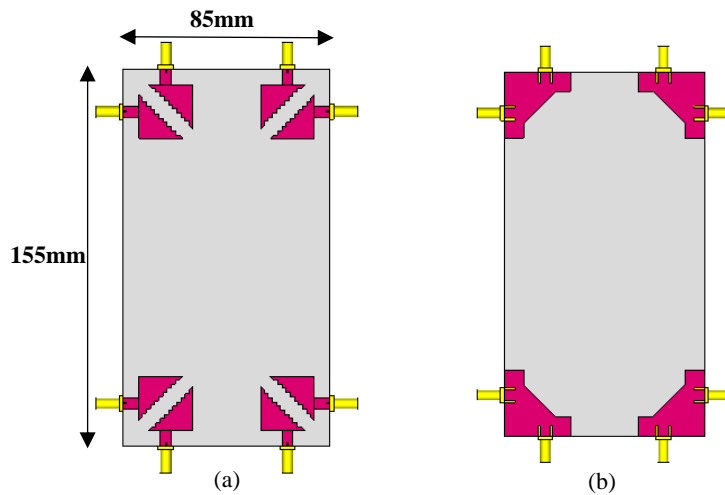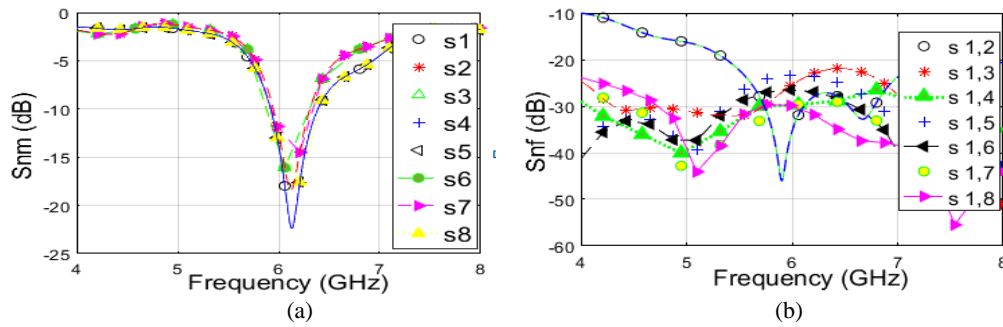

Fig. 8. The proposed smartphone antenna system (a) Front view and (b) Back view.

When all ports excited simultaneously, the system can obtain an operating frequency of 6.123 GHz with S_{rk} under -20 dB as in Figure 9.



(a)   (b)

Fig. 9. Results of smartphone antenna system (a) Return losses and (b) Mutual coupling.

On the other hand, **Figure 10** shows the VSWR for all excited ports in MIMO antenna array.
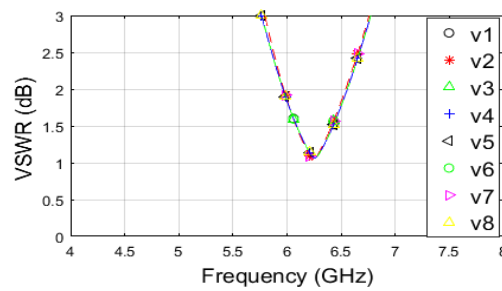
Fig. 10. VSWR of MIMO antenna array.

Also, **Figure 11** shows the radiation pattern when all port operated at the same time, it obviously appears the distribution for all ports can over all directions of device body.
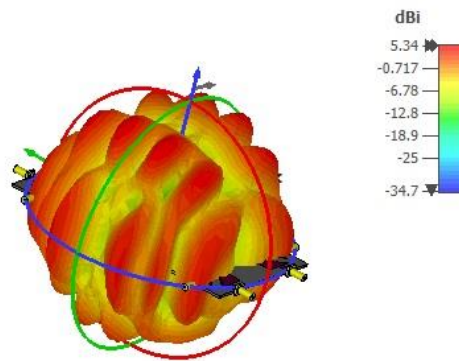
Fig. 11. Radiation pattern for MIMO antenna array.

4   **Conclusion.** In this research, a model of MIMO array of dual polarized four elements is proposed to match the future smartphone. Such model is obtained after a

procedure of trying several dimensions started with the separation between two right-angle triangles. The chord of each triangular has a serrated shape which affects the radiation pattern, improves gain and enhances the frequency performance. Several trying to choose an optimum of serrated length to obtain a better response. Also, several dimensions of partial ground are experienced to achieve better overall results. The final proposed MIMO prototype shows that the operating frequency is 6.13 GHz with a bandwidth of 500 MHz (5.9 - 6.4) GHz at -10dB while the single element operated at 6.27 GHz and cover 590 MHz (5.97 GHz-6.56 GHz) at -10dB.

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