# Isolation Enhancement between Ports of a Compact Ultra-wideband MIMO Antenna

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***Abstract*** **─** In this paper, a novel compact multiple-input multiple-output (MIMO) antenna with enhanced port isolation is proposed for ultra-wideband (UWB) applications. The UWB MIMO antenna contains two coplanar annular monopoles etched on the front side of the FR-4 substrate. The dielectric substrate has a relative permittivity of 4.4 and a size of 80 mm × 40 mm × 1.6 mm. The irregular ground is printed on the back side of the substrate. In order to enhance the port isolation between the two monopoles, the expanded ground is exploited in the proposed design. In addition, the ground is etched with some slots to achieve good impedance matching. Both the simulated and measured results show that the proposed antenna achieves good impedance matching as well as high port isolation over the entire UWB band. Moreover, the proposed antenna has good spatial diversity characteristics. In summary, the proposed UWB MIMO antenna can be well applied to the ultra-wideband wireless communication system.

***Index Terms*** **─** Isolation, monopole antenna, multi-input multi-output, ultra-wideband.

## I. INTRODUCTION

Compared to the traditional narrowband communications, the ultra-wideband (UWB) multiple-input multiple-output (MIMO) communication has many advantages such as high speed, large capacity and high spectrum utilization. However, there are many challenges in designing the UWB MIMO antennas, mainly the problems of impedance matching and mutual coupling reduction over the entire UWB band [1]. Some useful methods have been proposed to enhance the isolation between the elements of the MIMO antennas. One method is optimizing the layout of the antenna elements and making use of the polarization characteristics of the antennas to reduce the mutual coupling [2-6]. In [2], the MIMO slot antenna without any decoupling structure achieves a high isolation by placing the four antenna elements asymmetrically. Isolation can be improved by introducing a parasitic resonant structure to between the antenna elements. For example, a metal strip reflector was used to isolate the two array elements in [7-10]. In addition, the defective ground structures (DGS) are also very frequently used in improving the port isolation of the antennas [11-14]. In [11], the isolation between the two antenna elements is improved by adding a slot on the ground. Furthermore, other metheds including loading a ground branch are also effective to suppress the mutual coupling and enhance the port isolation between the array elements [15-22].

In this paper, a novel compact UWB MIMO antenna is proposed. Two coplanar annular monopole UWB antennas are placed side by side. The port isolation is improved by expanding the ground plane. Both the simulated and measured results show that the isolation between the array elements has been effectively increased over the entire UWB band. The details of the proposed design and the results are presented in the following sections.

## II. ANTENNA DESIGN AND ANALYSIS

The geometry of the proposed UWB MIMO antenna is illustrated in Fig. 1. The FR4 substrate is used in the design of the antenna, which has a relative permittivity of 4.4 and a thickness of 1.6 mm. Two coplanar annular monopole antennas are printed side by side on the front side of the substrate, while the ground is on its back side. The proposed antenna has a width of $W$ = 80 mm and a length of $L$ = 40 mm. The microstrip line with a width of $W_1$ = 3 mm is used to feed each element. In order to increase the port isolation between the two antenna elements, the ground plane is expanded outwards at the middle portion, as shown in Fig. 1. The antenna achieves a good impedance matching by slotting the extended ground and the portion of the ground below the microstrip feed line.

The proposed UWB MIMO antenna is simulated and optimized by using ANSYS HFSS, and the optimized dimensions of the antenna are shown in Table 1. The simulated $S$-parameters of the proposed antenna are shown in Fig. 2. Due to the symmetry of the antenna structure, only the curves of the $S_{11}$ and $S_{12}$ are plotted in the figure. From the figure, we can see that the $S_{11}$ is lower than -10 dB in the range of 2.13

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GHz to 11.03 GHz covering the entire UWB band, which indicates that the proposed MIMO antenna has been well matched. In addition, the $S_{12}$ is almost lower than -20 dB, which means that the port isolation between the two elements is kept at a high level.

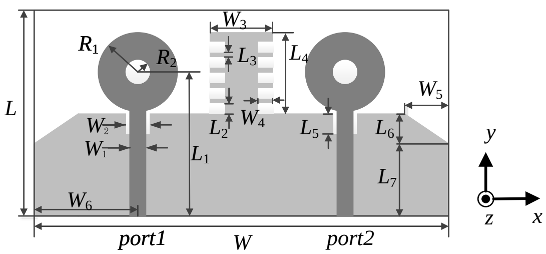



Fig. 1. Geometry of the proposed UWB MIMO antenna.

Table 1: Optimized dimensions of the antenna (unit: mm)

| Parameter | Value | Parameter | Value |
|---|---|---|---|
| $W_2$ | 4 | $L_1$ | 28 |
| $W_3$ | 12 | $L_2$ | 2 |
| $W_4$ | 3 | $L_3$ | 1 |
| $W_5$ | 8.5 | $L_4$ | 16.2 |
| $W_6$ | 20 | $L_5$ | 4.3 |
| $R_1$ | 7.6 | $L_6$ | 5.8 |
| $R_2$ | 2.5 | $L_7$ | 14 |

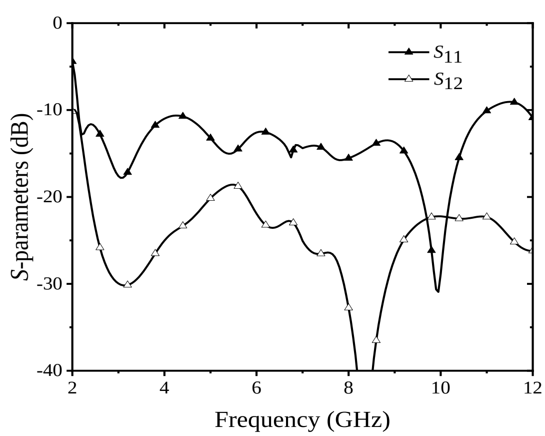



Fig. 2. Simulated $S$-parameters of the proposed UWB MIMO antenna.

Figure 3 shows the design process of the proposed UWB MIMO antenna. The $S$-parameters of the three antennas are compared in Fig. 4. As can be seen from the figure, for the initial design, antenna 1, the value of $S_{12}$ is mainly between -10 dB and -20 dB in the UWB operating band, which indicates that the two elements are not highly isolated. In the antenna 2, the ground is expanded outward with a rectangular shape between the elements, thus making $S_{12}$ below -20 dB. And this result is a solid evidence for effective isolation enhancement. However, as is shown, with the expanded ground, the $S_{11}$ of the antenna 2 is higher than -10 dB from about 4 GHz to 7 GHz, which means that expending the ground plane has a negative impact on the impedance matching and makes it worse. In order to achieve a good impedance matching again, as shown in the antenna 3, we etch slots on certain part of the ground. The slots are etched not only behind the feedlines but also within the rectangular shape expanded. The number of the slots within the expanded ground is the result of optimization. From Fig. 4, we can observe that in the UWB band, the $S_{11}$ of the antenna 3 is lower than -10 dB, and the $S_{12}$ is almost kept lower than -20 dB. It indicates that the antenna 3 achieves both good impedance matching and high port isolation.

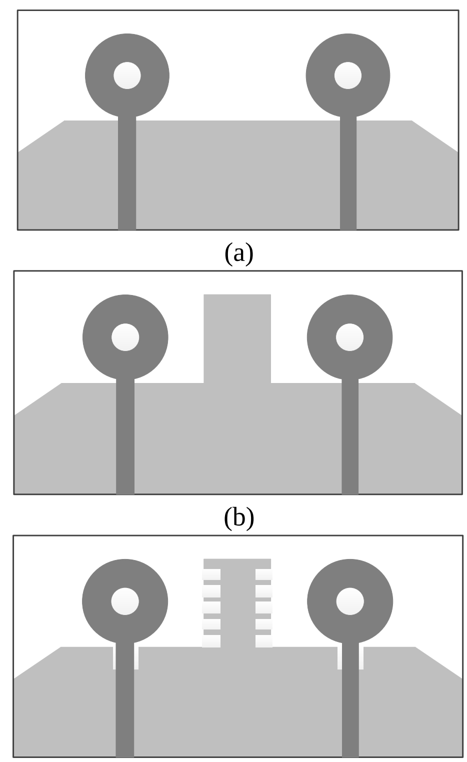



Fig. 3. Design process of the proposed antenna: (a) antenna 1, (b) antenna 2, and (c) antenna 3.

When the antenna elements are placed closely to each other, adding an excitation to one of the antenna ports will generate an induced current at the other port, which is the cause of the strong mutual coupling. Therefore, in order to reduce the coupling and enhance the isolation, it is necessary to suppress the generation of the induced current. This is the purpose of expanding the ground. The surface current distribution of the antenna 1 and the antenna 3 at the different frequencies are shown in Fig. 5, respectively. From the figure, it can be seen that when the excitation is added to the port 1 without the expanded ground, an obviously large induced current is generated nearby the port 2. Thus, there is a strong coupling between the two antenna elements. Expanding the ground plane, on the contrary, makes the induced current mainly distributed around the extended part of the ground and weak around the port 2. Therefore, the coupling between the antenna elements is effectively reduced and the port isolation is enhanced.

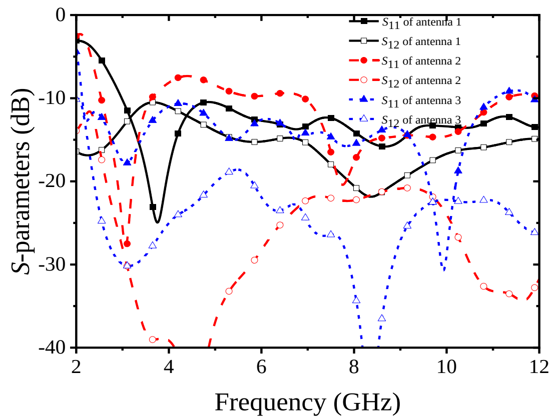
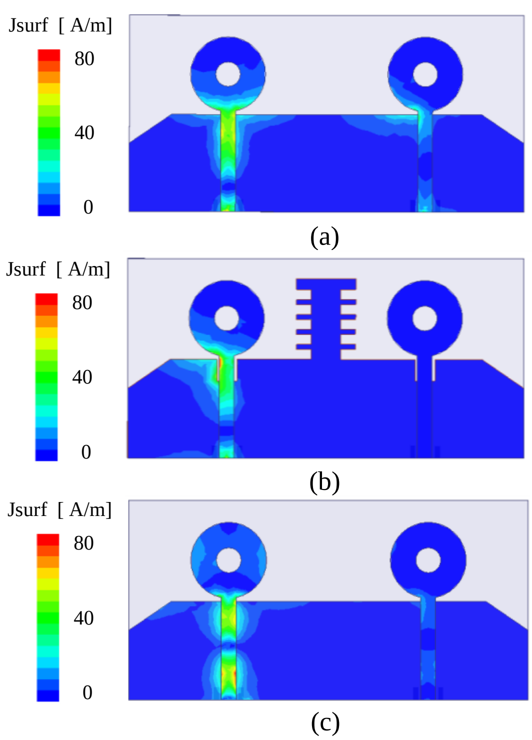



Fig. 4. The simulated *S*-parameters of the two-element monopole array.



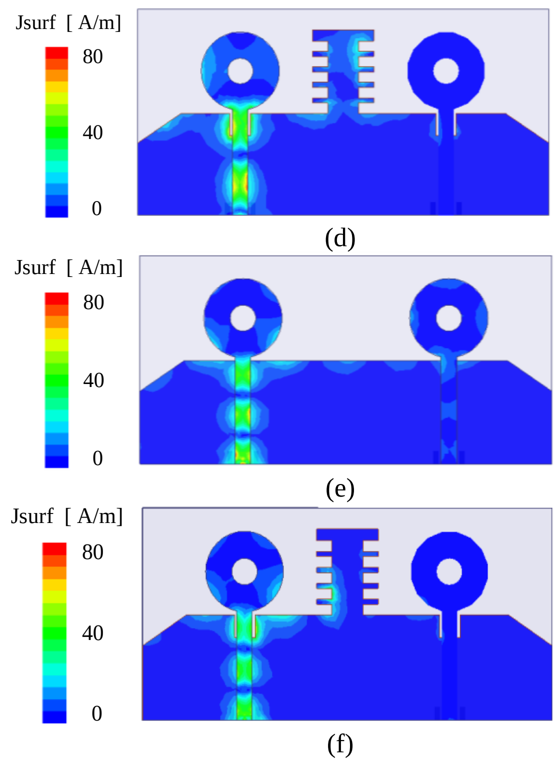




Fig. 5. Surface current distribution of antenna 1 and antenna 3: (a) antenna 1 at 3.5 GHz, (b) antenna 3 at 3.5 GHz, (c) antenna 1 at 7.0 GHz, (d) antenna 3 at 7.0 GHz, (e) antenna 1 at 10.0 GHz, and (f) antenna 3 at 10.0 GHz.

## III. RESULTS AND DISCUSSION

Both the antenna 1 and the antenna 3 are fabricated using the FR4 substrate. Figure 6 shows the photograph of the fabricated prototype.

The fabricated antennas are measured by using Keysight E5063A and the measured *S*-parameters are shown in Fig. 7. From Fig. 4 and Fig. 7. The comparison between Fig. 4 and Fig. 7 presents that the measured results correlate well with the simulated ones. The slight difference between them may be caused by the errors in the manufacturing and measurement. As seen in Fig. 7, after the ground is expanded, the measured $S_{12}$ of the antenna 3 falls below -20 dB over the entire UWB band. The result shows that the port isolation between the two antenna elements has been effectively increased. At the same time, the $S_{11}$ of the antenna 3 remains below -10 dB, indicating that the antenna 3 still has a good impedance matching. In summary, the antenna 3, as the final design of the proposed antenna, can be better applied in the UWB MIMO communication systems.

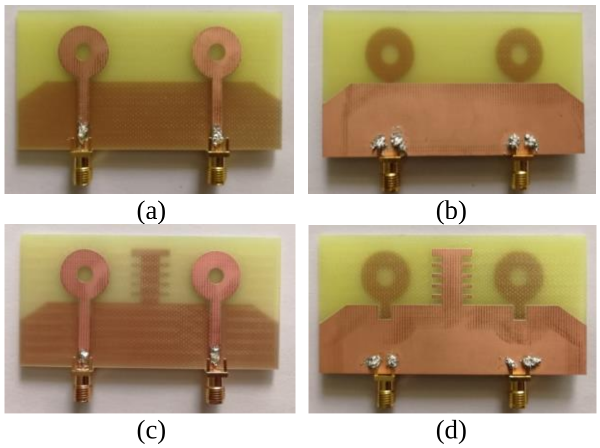



Fig. 6. Photograph of the fabricated antennas: (a) top view of antenna 1, (b) bottom view of antenna 1, (c) top view of antenna 3, and (d) bottom view of antenna 3.

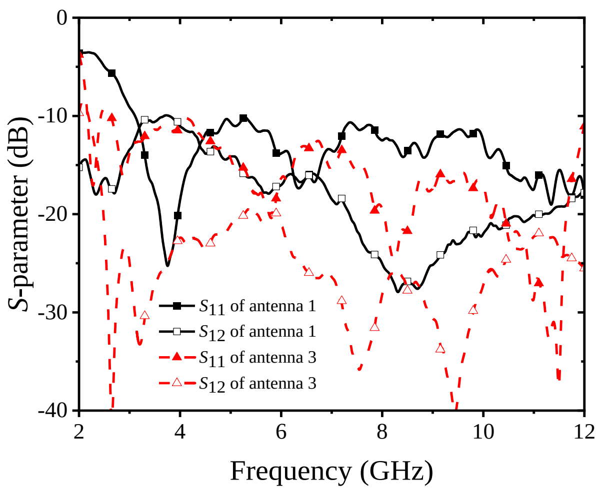
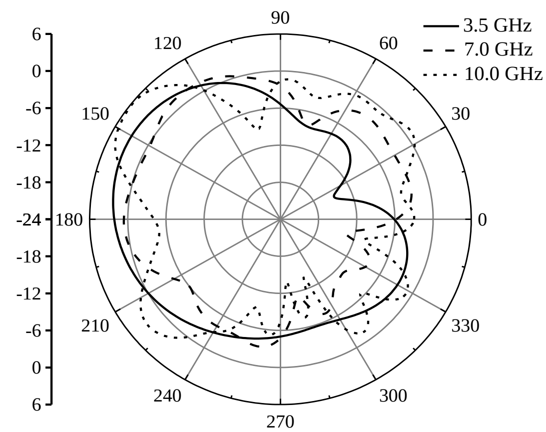



Fig. 7. Measured S-parameters of the proposed antenna.

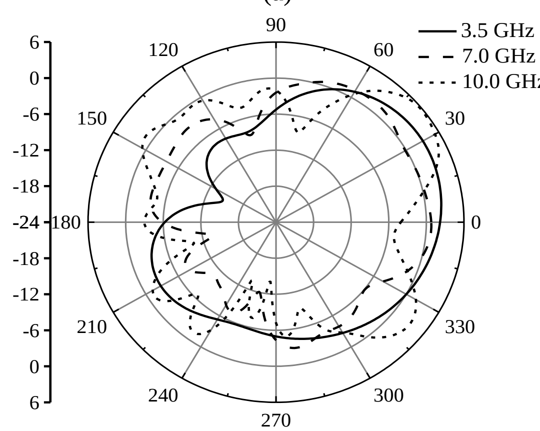
Figure 8 shows the simulated radiation patterns of the proposed antenna at the different frequencies. From the figure, it can be observed that when the two ports of the proposed UWB MIMO antenna are fed separately. It indicates that the proposed antenna has good spatial diversity characteristics. In addition, in Table 2, the overall performance of the proposed MIMO array is compared with that of some typical designs in the literature. The overall performance of the proposed antenna is comparable to or superior to that of the previous designs.

Table 2: Performance comparison with previous designs in literature

| **Ref.** | **Antenna Size ($mm^2$)** | **Bandwidth (GHz)** | **Isolation (In Most of the Band) (dB)** |
|---|---|---|---|
| [4] | 73×73 | 3-18 | >20 |
| [5] | 85×85 | 3.1-10.6 | >15 |
| [6] | 110×120 | 3.0-10.0 | >38 |
| [8] | 45×45 | 2-10.6 | >17 |
| [9] | 42×25 | 3-12 | >15 |
| [11] | 32×32 | 3.1-10.6 | >15 |
| [14] | 24×40 | 4.6-10.1 | >21 |
| [16] | 93×47 | 3.1-10.6 | >31 |
| [17] | 24×40 | 3.1-10.9 | >15 |
| [19] | 82×50 | 2.20-13.35 | >15 |
| This work | 80×40 | 2.13-11.03 | >20 |




(a)

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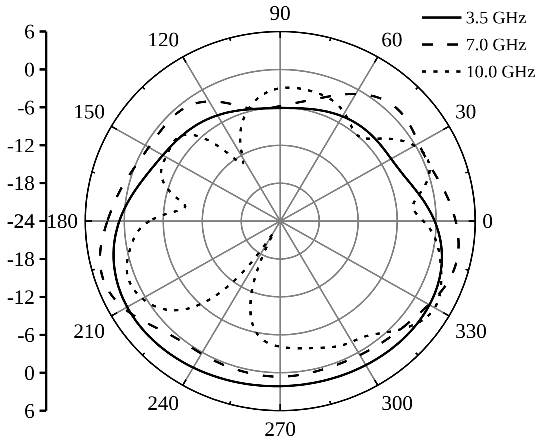
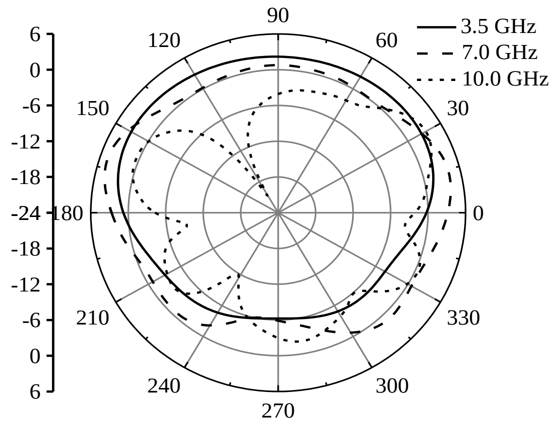



(c)




(d)

Fig. 8. Radiation patterns of the proposed antenna: (a) XOY plane with port1 excited, (b) XOY plane with port2 excited, (c) XOZ plane with port1 excited, and (d) XOZ plane with port2 excited.

## IV. CONCLUSION

A compact UWB MIMO antenna has been proposed in this paper. The primary concern for the UWB MIMO design is isolation enhancement. And this paper utilize comprehensive methods to realize the good performance. Firstly, by expanding the ground with certain shapes, the port isolation between the antenna elements has been significantly increased. Furthermore, the antenna achieves a good impedance matching over the entire UWB band through etching slots on the ground plane, not only opposite the placement of feedlines but also within the rectangular shape expanded. Based on the above results, the proposed antenna is suitable for the UWB MIMO communication systems.

## ACKNOWLEDGMENT

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