Triangular-Arranged Planar Multiple-Antenna for UWB-MIMO Applications

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Abstract **─** A triangular-arranged (TA) planar multiple-antenna is proposed. It consists of three ultra-wideband (UWB) planar monopole antenna elements, with the centers and the ports of the elements arranged at the vertexes of two regular triangles, thus the polarization of each element is 120° different. The performance of the TA multiple-antenna is investigated by simulation and measurement, and the measured results agree with the simulated ones in reasonable precision. Within the ultra-wide bandwidth of 3.4 GHz – 12 GHz, the return loss at each port is better than 10 dB, and the isolation between any two ports is higher than 20 dB. Furthermore, good omni-directional radiation pattern is obtained over the interesting frequency band. A linear-arranged (LA) three-element multiple-antenna is compared with the proposed TA antenna. Comparison between the TA antenna and the LA antenna validates the advantages of the proposed one, which consequently is suitable for UWB-MIMO applications.

Index Terms – Antennas, isolation, multiple-input multiple-output (MIMO), and ultra-wideband (UWB).

I. INTRODUCTION

Due to the large bandwidth, ultra-wideband (UWB) possesses a lot of advantages, such as enabling high data rates transmission, providing high reliability for the wireless communications. It has become a hot topic in wireless communication fields over the past decade. Moreover, the advantages of UWB can be further improved by combining multiple-antenna techniques. Multiple-input multiple-output (MIMO) systems, which have multiple-antenna units at both transmitter and receiver sides, can take advantage of the multipath components sufficiently to enhance the performance of wireless systems. Consequently, UWB combined with MIMO technique (UWB-MIMO) is a feasible method to achieve extremely high data rates and high robustness for wireless communication systems [1]. Besides, UWB-MIMO is suitable for obtaining high-precision localization and radar imaging.

As a key component of UWB system, UWB antenna has attracted a lot of research interests in both the academic and industrial fields [2-3]. For some applications, directional antennas, which radiate energy in a fixed direction, are requisite. However, the antennas with omni-directional radiation characteristics are usually more attractive. This is due to the particular requirements of UWB, especially the limits on equivalent isotropically radiated power (EIRP) imposed by many spectrum regulators, as well as the need of some applications, such as ranging and radar, which have signals arrive from any unpredictable direction. As a result, ultra-wide pattern bandwidth becomes an important design requirement for UWB antennas, i.e., the radiation pattern remains approximately omni-directional over the ultra-wide bandwidth. However, many existing UWB antennas have ultra-wide impedance bandwidth, but not pattern bandwidth.

For an UWB-MIMO system, not only the characteristics of the antenna elements, but also the mutual coupling between elements, will affect the performance of the system. The mutual coupling, which exists between any closed antenna elements, will deteriorate the pattern characteristic

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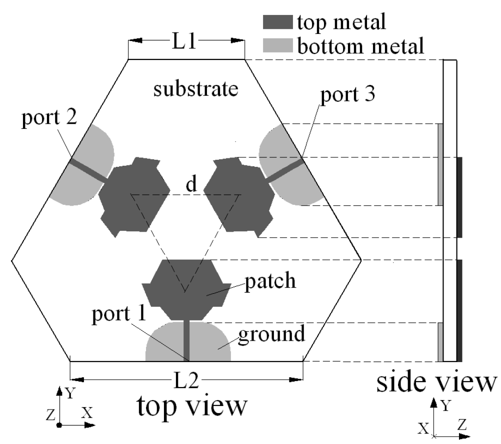
and is a very important factor when designing an UWB-MIMO antenna system. In order to improve the isolation between UWB antenna elements, some researches have been performed. For example, closed radiators are arranged orthogonally, thus the neighboring elements are orthogonally polarized [4], which will decrease the mutual coupling remarkable. Besides, elements with different dielectrics or with different radiation characteristics are put together to form a multiple-antenna, which also decrease the mutual coupling between elements [2, 5]. In some cases, structures with high isolation characteristics are placed between antenna elements, which are also helpful for the reduction of mutual coupling [6, 7]. Since the UWB-MIMO system is in the start stage, a lot of effort is needed to improve the performance of the antenna system.

In [3], a series of planar monopole antennas using genetic algorithm (GA), with the goal to achieve omni-directional pattern and uniform gain over the ultra-wide frequency band have been designed. In this paper, one of the optimized planar monopole antennas, i.e., antenna E in [3], is used to form a planar multiple-antenna. Antenna E in [3] has very good impedance matching performance and omni-directional radiation pattern over 2.6 GHz – 10.6 GHz bandwidth. Since the multiple-antenna structure has important influences on the performance of MIMO systems, such as fading correlation (and thus capacity) of a communication system, as well as ability to resolve directions of multipath components. Linear-arranged (LA) antenna are the simplest structure, we show that they have significant drawbacks, in particular related to mutual coupling between the antenna elements. We thus propose a triangular-arranged (TA) multiple-antenna, and analyze its performance.

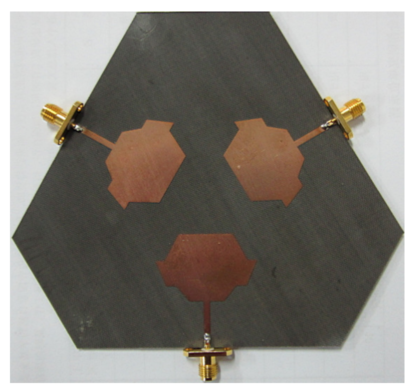
The rest of the paper is organized as follows: in section II, the multiple-antenna structure is depicted. Section III describes the simulated and measured results of the TA antenna and the LA antenna. Section IV gives the conclusion.

II. ANTENNA STRUCTURE

The element of the proposed triangular-arranged (TA) multiple-antenna is an optimized planar monopole antenna with rounded-corner-rectangular ground plane, which is antenna E in [3]. The structure of the TA multiple-antenna is shown in Fig. 1. Three identical elements are printed on a hexagon substrate, with a thickness of 0.76 mm and dielectric permittivity of 2.94. The patches and microstrip feed lines are printed on the top side and the grounds are on the bottom side. The centers of the patches and the feed ports of the elements are arranged at the vertices of two regular triangles, thus the polarization of each element is 120° different. The distance between any two patch centers *d* is set to 40 mm, which is the free space half wavelength at 3.75 GHz. A prototype is fabricated and three SMA connectors are used to feed the antenna, as shown in Fig. 1 (b).



(a)



(b)

Fig. 1. The proposed triangular- arranged (TA) planar antenna; (a) schematic diagram, left: top view, right: side view; L_1=47 mm, L_2=76.9 mm, d=40 mm and (b) the fabricated antenna.

A linear-arranged (LA) planar multiple-antenna is designed and fabricated to compare with the TA antenna. The elements and the substrate of the LA antenna are the same as that of the TA antenna. As shown in Fig. 2, three identical elements are aligned on a rectangular substrate. The distance between the adjacent elements centers is also 40 mm, the same as that of the TA antenna.

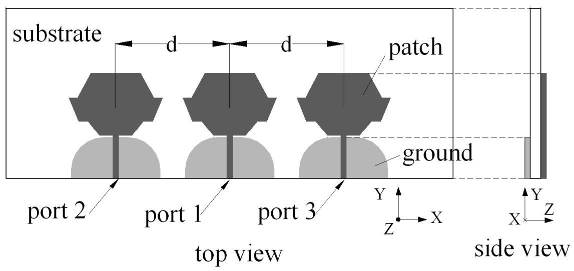
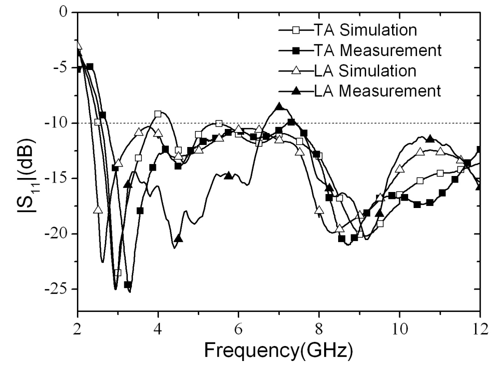


Fig. 2. Geometry of the linear-arranged (LA) antenna, d=40 mm; left: top view, right: side view.

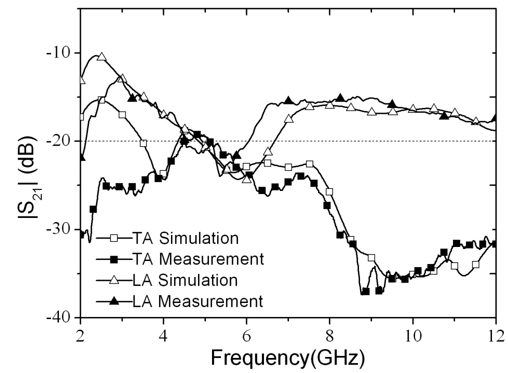
III. SIMULATED AND MEASURED RESULTS

The characteristics of the two antennas are investigated by both simulation and measurement. The simulation is performed with the Ansoft's HFSS. The measurement of S-parameters is carried out by means of a vector network analyzer, Agilent 8363B, and that of the radiation pattern is implemented by a SATIMO near field antenna testing system.

The simulated and measured S-parameters of the two antennas are shown in Fig. 3. As shown in Fig. 3 (a), the $|S_{11}|$s of both TA and LA antennas are nearly below -10 dB within the bandwidth of 2.6 GHz − 12 GHz, which indicates good impedance matching performances. The $|S_{21}|$s of both TA and LA antennas are given in Fig. 3 (b). Within the bandwidth of 3.4 GHz − 12 GHz, the measured and simulated isolations of the TA antenna are higher than 20 dB, while those of the LA antenna are only higher than 14 dB. Obviously, the isolation of TA is better than that of LA, especially at the higher frequency. This characteristic is very appropriate for the UWB-MIMO communication system, which requires lower correlation between different antenna elements. The simulated and measured results agree with each other in reasonable precision.



(a)



(b)

Fig. 3. Simulated and measured S-parameters of the TA and LA antennas, (a) $|S_{11}|$ and (b) $|S_{21}|$.

Figure 4 shows the simulated and measured radiation patterns of both TA and LA antennas at frequencies of 3.0 GHz, 5.5 GHz, and 9.5 GHz. The pattern is normalized with respect to the peak value of each case. In the simulation and measurement of radiation pattern, only one port (e.g., port 1) is excited while the other two ports are terminated with 50 Ω impedance loads. It can be seen that, in the H-plane, over the interesting bandwidth, the TA antenna has better omni-directional patterns than the LA antenna, even at higher frequency, which is very helpful for UWB applications. Simulated and measured results agree with each other in reasonable precision.

Besides, the simulated antenna gain is plotted, as shown in Fig. 5. It can be seen that the peak gain over the frequency band of 3 GHz − 10 GHz is stable, and the maximum fluctuation is about 3 dB.

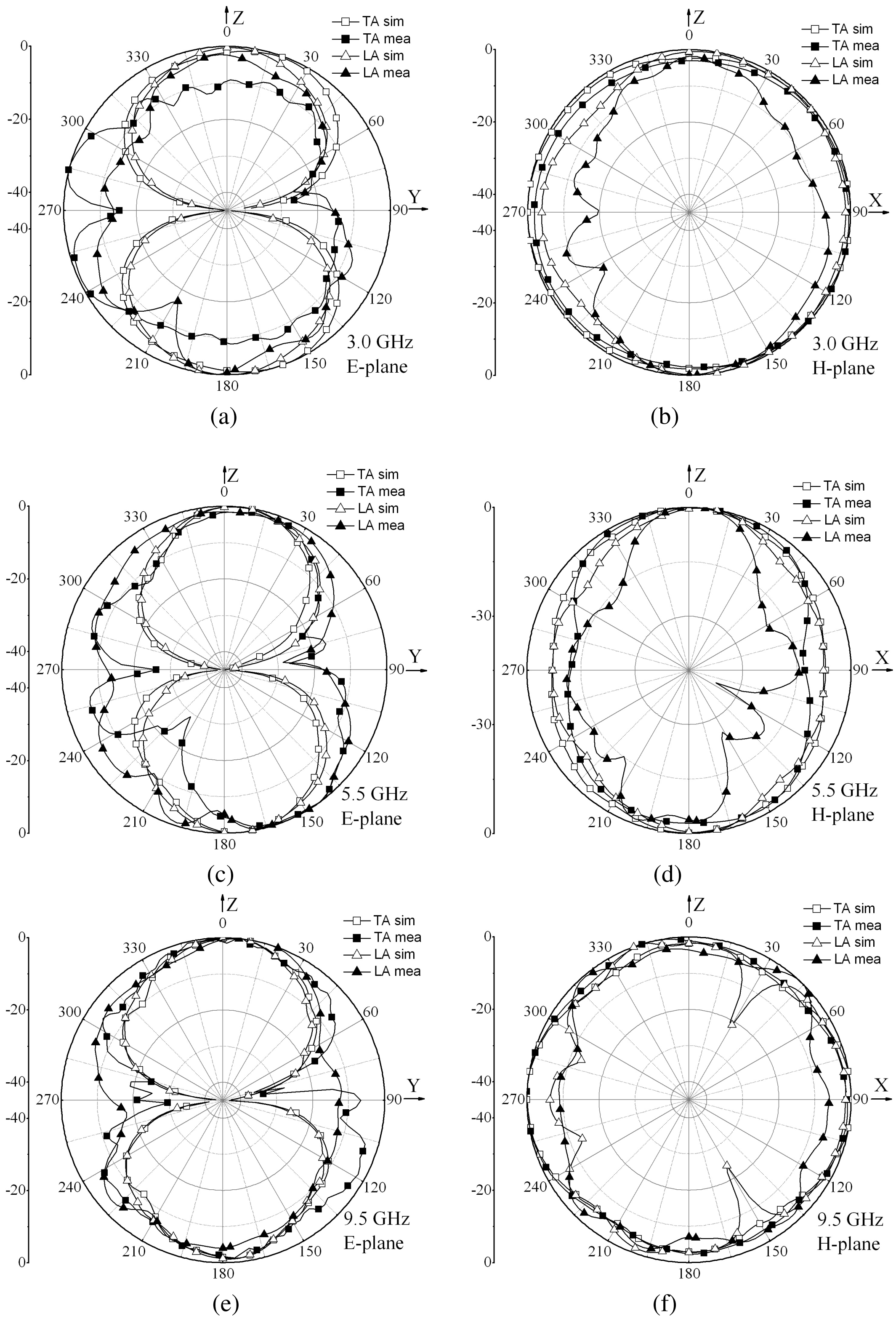


Fig. 4. Simulated and measured radiation patterns of the TA- and LA-arranged antennas at different frequencies, (a) 3.0 GHz, H-plane, (b) 3.0 GHz, E-plane, (c) 5.5 GHz, H-plane, (d) 5.5 GHz, E-plane, (e) 9.5 GHz, H-plane, and (f) 9.5 GHz, E-plane.

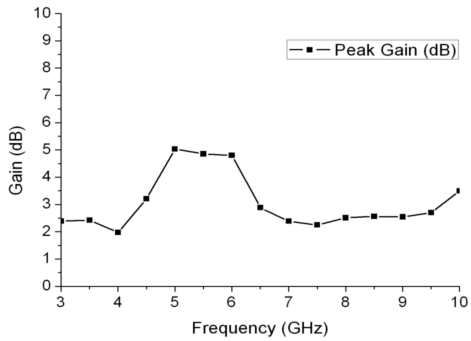


Fig. 5. Simulated peak gain of the TA-arranged antenna with one element active.

IV. CONCLUSION

A novel triangular-arranged (TA) three-element planar UWB multiple-antenna has been proposed for UWB-MIMO applications. The antenna has very good impedance and radiation characteristics over 3.4 GHz – 10.6 GHz frequency band. Compared to a linear-arranged (LA) planar multiple-antenna, the TA antenna has lower mutual coupling between different ports, especially at higher frequency, which results in better omni-directional pattern for each element. It is the excellent performance and the special arrangement of the elements, that makes the good performance of the propose TA antenna.

It is true that the TA antenna is a little larger than the LA antenna, which is an obvious weak point for the application in portable devices. However, it can be used in fixed UWB-MIMO wireless devices, and it provides a feasible choice for three-element multiple-antenna. For the portable UWB-MIMO devices, more compact structure must be adopted.

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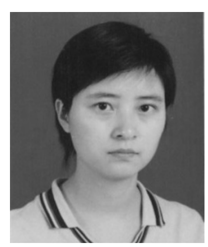

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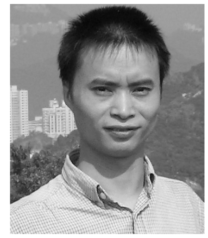

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