A Compact UWB and Bluetooth Slot Antenna for MIMO/Diversity Applications

Peng Gao and Shuang He

A novel compact pattern diversity slot antenna for ultra-wideband (UWB) and Bluetooth applications is presented. This antenna consists of two modified coplanar waveguides that feed staircase-shaped radiating elements, wherein two different fork-like stubs are placed at the 45° axis. The measured results show that this proposed antenna operates from 2.3 GHz to 12.5 GHz, covering Bluetooth, WLAN, WiMAX, and UWB. The performance of radiation patterns and the corresponding envelope correlation coefficient prove this antenna is suitable for MIMO/diversity systems. Also, the antenna's compact size makes it a good candidate for portable devices.

Keywords: Ultra-wideband, UWB, Bluetooth, slot antenna, CPW fed, diversity, MIMO.

I. Introduction

Due to their low cost and high speed rate, ultra-wideband (UWB) technologies have great potential for many wireless applications, which has motivated much research in the past decade since the Federal Communications Commission opened the permit of the 3.1 GHz to 10.6 GHz band with an emission level of –41.3 dBm/MHz [1]. Nevertheless, it is inevitable that conventional UWB technologies meet the challenges in multipath devices. To solve this problem, MIMO technology has been proposed [2].

Several types of diversity, such as space, pattern, and polarization, have been used in MIMO standards. Among them, by using multiple directional beams to obtain independent signals, pattern diversity techniques are very applicable in mobile terminals due to their easy designs and fabrications, which use different radiation patterns to improve channel fading and the transmission quality of the mobile terminals (for example, orthogonal radiation patterns and symmetrical radiation patterns) [3]. Moreover, it is an efficient way to reduce antenna size.

As key components of the UWB system, high isolation and wideband characteristics are required and studied for UWB diversity antennas, including etching a ring slot in the ground plane [4] and [5], inserting stubs between the two radiating elements [6], and extending a tree-like structure on the ground plane [7]. However, the size of these UWB diversity antennas (80 mm × 80 mm) prevents them from being easily integrated.

Recently, the rapid development of portable devices and the wireless personal area network has inspired research on the miniaturization of UWB components [8]. Although the designed antennas in [6] and [7] have compact sizes varying from 25 mm × 40 mm to 35 mm × 40 mm, they have the shortcoming of uncovering the full UWB band. At the same time, Bluetooh (IEEE 802.15.1), which has been very attractive in wireless communications, is working around 2.4 GHz. Therefore, it is necessary to develop a MIMO/diversity antenna for UWB and Bluetooth applications.

In this letter, a compact MIMO/diversity antenna for UWB and Bluetooth applications is presented. Two staircase-shaped radiating elements fed by modified coplanar waveguides (CPWs) are inserted to achieve a UWB and Bluetooth characteristic. Two decoupling fork-like stubs are placed at the 45° axis between the two radiators. This antenna has a total size of 48 mm × 48 mm, which is a significant reduction from the sizes previously reported. Measured results show that this antenna has a frequency bandwidth from 2.3 GHz to 12.5 GHz and the isolation between the two ports is better than 20 dB over the whole band.

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Peng Gao (phone: +86 18980765100, penggao@uestc.edu.cn) and Shuang He (shuanghe223@gmail.com) are with the Research Institute of Electronic Science and Technology, University of Electronic Science and Technology of China, Chengdu, China.

II. Antenna Design

1. Antenna Configuration

The geometry of the proposed antenna is shown in Fig. 1. It is printed on an FR4 substrate with an area of 48 mm × 48 mm, thickness of 0.8 mm, permittivity of 4.4, and loss tangent of 0.02. This antenna consists of two staircase-shaped radiators, which are respectively fed by a CPW. The excitation ports are modified by the staircase structures, which make them match a 50-Ω impedance. The ground plane is shaped with a quarter circular ring and two fork-like stubs, which can efficiently enhance wideband isolation characteristics.

2. Two Fork-like Stubs

The fork-like stub is performed to highlight the variations of the S-parameters by increasing the number of stubs. As a quarter-wavelength reflector, the stubs reduce the wideband mutual coupling by separating the radiation patterns of the two radiators [8]. The length of the stubs, l, can be estimated using

$$l = \frac{c}{4f \cdot \sqrt{\frac{\varepsilon_r + 1}{2}}}, \qquad (1)$$

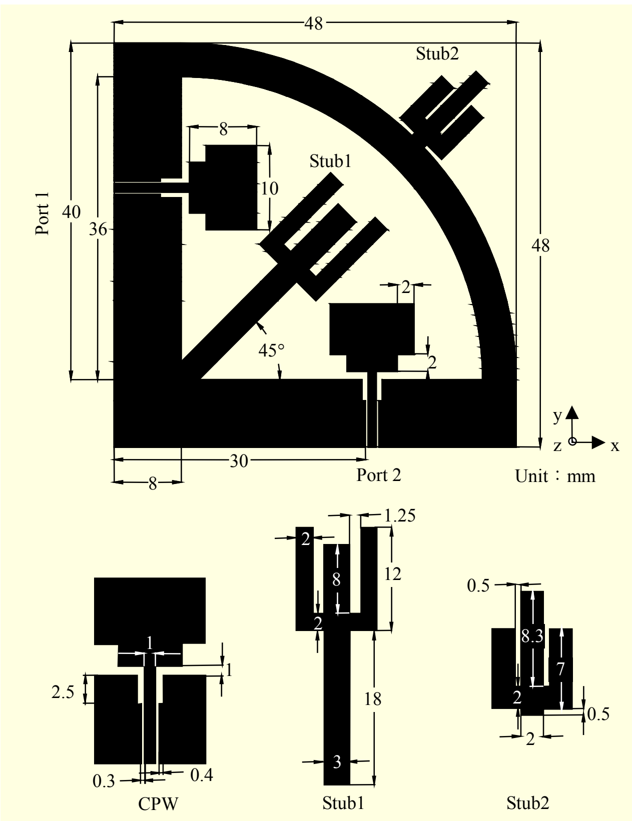

Fig. 1. Configuration and parameters of proposed antenna.

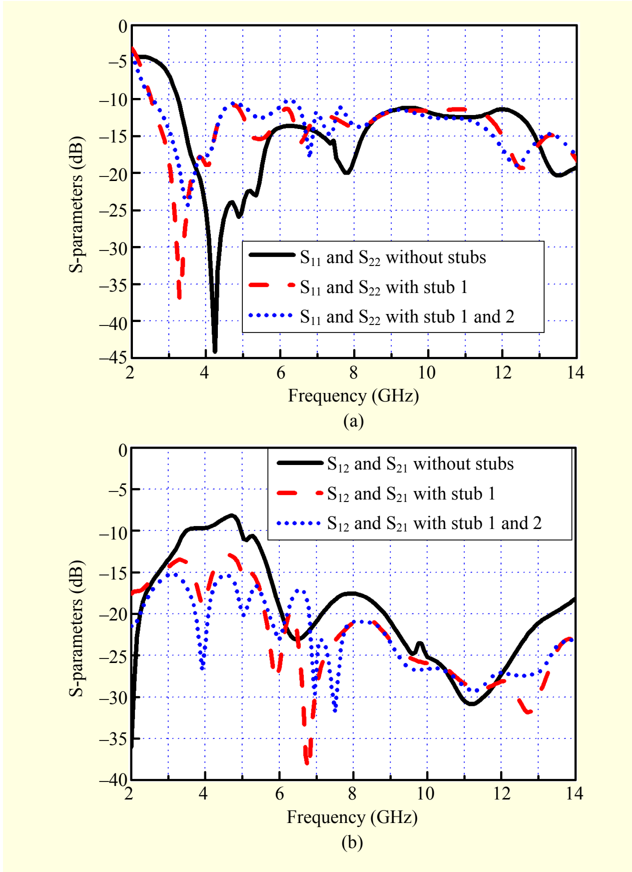

Fig. 2. Simulated S-parameters when total number of stubs varies: (a) S_{11} and S_{22}, (b) S_{12} and S_{21}.

where f, ε_r, and c are frequency of resonance, dielectric constant, and speed of light, respectively. Stub 1 and Stub 2 each obtain two different lengths: 12 mm and 8 mm ($\lambda/4$ of 4 GHz and 6 GHz) and 8.3 mm and 7 mm ($\lambda/4$ of 5 GHz and 7.5 GHz), respectively.

As depicted in Fig. 2(a), when Stub 1 is inserted in the antenna, the path of the surface current is lengthened and the lower frequency of the operating band thus shifts from 3.3 GHz to 2.3 GHz. Figure 2(b) shows the improvement of the isolation across the operating band (shift from 7 dB to 15 dB). As Stub 1 is inserted in the antenna, the additional two resonant frequencies (4 GHz and 6 GHz) are produced. Another two resonant frequencies (5 GHz and 7.5 GHz) are obtained after Stub 2 is increased. The simulation results show that Stub 1 and Stub 2 can weaken the mutual coupling, which is very useful in constructing diversity antennas.

III. Experiment Results and Discussion

1. Impedance Performance

To demonstrate aforementioned details, an antenna prototype

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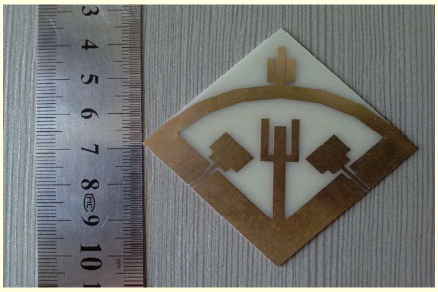

Fig. 3. Prototype of proposed antenna.

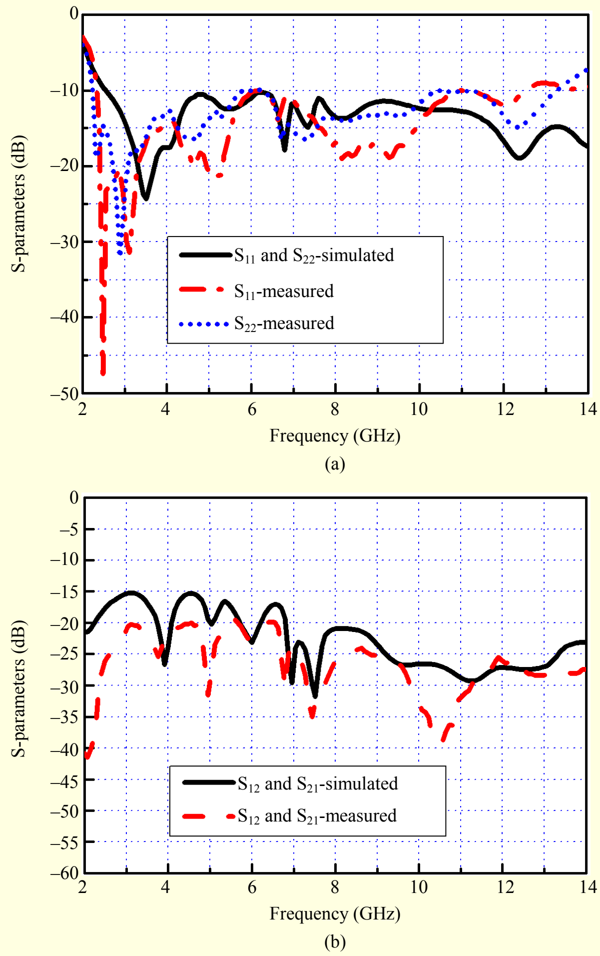

Fig. 4. Measured and simulated S-parameters of proposed antenna: (a) S_{11} and S_{22}, (b) S_{12} and S_{21}.

is fabricated, as shown in Fig. 3. The transmission characteristics are measured with the Agilent E8363B vector network analyzer. Figure 4 shows the simulated and measured S-parameters of the proposed antenna. As indicated in Fig. 4(a), the simulated return losses (S_{11} and S_{22}) are identical for both ports due to the symmetrical structures and the discrepancies in measurement are negligible. These are mainly led by the difference of soldering connectors. According to the measured results, the impedance bandwidth (defined by a return loss of no less than 10 dB) is from 2.3 GHz to 12.5 GHz, covering Bluetooth, WLAN, WiMAX, and UWB. According to the measurement shown in Fig. 4(b), the isolation of the two ports is more than 20 dB. These results indicate that this antenna is suitable for diversity systems.

2. Radiation Performance

Figure 5 shows the radiation patterns (measured with anechoic chamber SATIMO StarLab) of the proposed antenna at 2.5 GHz, 6.5 GHz, and 10.5 GHz when Port 1 is excited while Port 2 is terminated with a 50-Ω load and vice versa. Owing to the location of the radiators, the XY-planes of

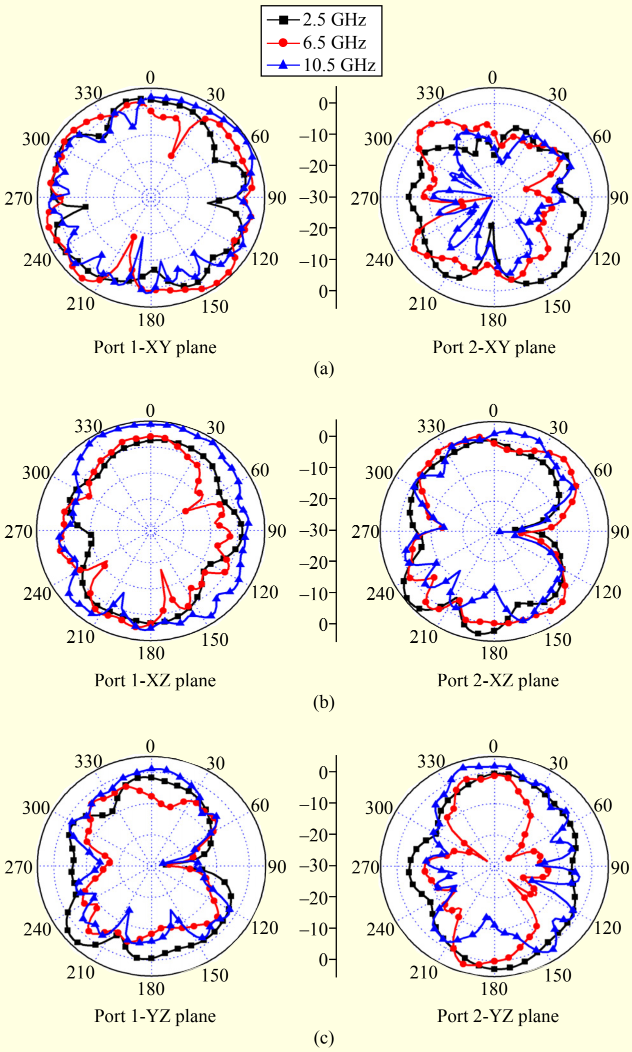

Fig. 5. Measured radiation patterns of proposed antenna at 2.5 GHz, 6.5 GHz, and 10.5 GHz: (a) XY plane, (b) XZ plane, and (c) YZ plane.

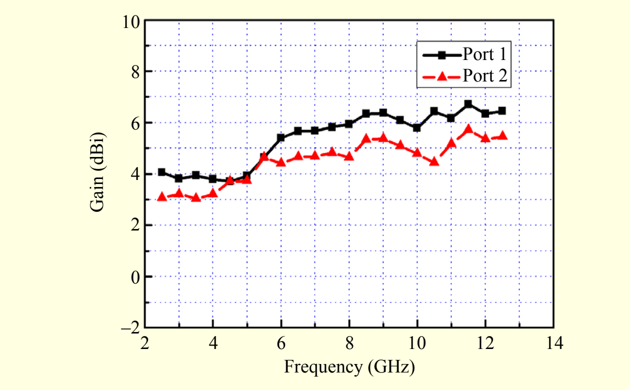

Fig. 6. Measured gain of proposed antenna.

Ports 1 and 2 are almost symmetrically placed at the 45° axis and the XZ-plane (YZ-plane) of Port 1 is similar to the YZ-plane (XZ-plane) of Port 2, which means the patterns of Ports 1 and 2 are rotated almost 90°. So, the antenna can simultaneously obtain the vertical polarization wave and horizontal polarization wave. The measurement of the antenna peak gain is plotted in Fig. 6. The peak gain increases with the operation frequency and the variation of the antenna peak gain is within 3 dB.

3. Diversity Performance

The envelope correlation coefficient (ECC) is an important parameter for evaluating the performance of the diversity system. The ECC can be calculated by using the measured S-parameters as explained in [9], and, for a two-port system, the ECC can be obtained from the S-parameters and (2). The ECC of the proposed antenna is below 0.01 across the whole operating frequency, as shown in Fig. 7, which shows that the antenna is suitable for a diversity system.

$$\mathrm{ECC}=\frac{\left|S^{*}_{11}S_{12}+S^{*}_{21}S_{22}\right|^{2}}{\left(1-\left(\left|S_{11}\right|^{2}+\left|S_{21}\right|^{2}\right)\right)\left(1-\left(\left|S_{22}\right|^{2}+\left|S_{12}\right|^{2}\right)\right)}. \qquad (2)$$

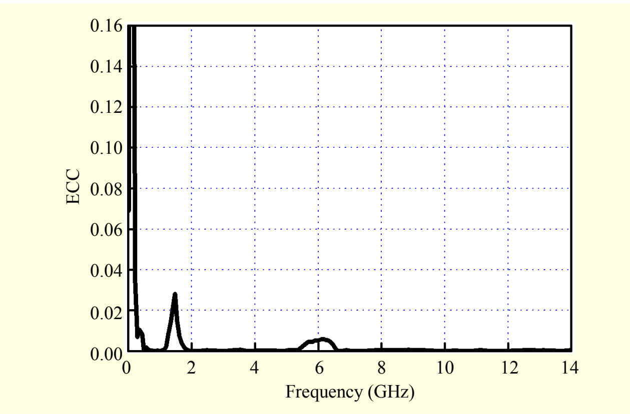

Fig. 7. Measured ECC.

IV. Conclusion

A dual port pattern diversity UWB and Bluetooth antenna was presented. The antenna is fed by two modified CPWs and two fork-like stubs are extended from the ground plane, which enhances the isolation coefficient more than 20 dB. An impedance bandwidth of 2.3 GHz to 12.5 GHz was obtained, covering Bluetooth, WLAN, WiMAX, and UWB, and measurements of radiation patterns, antenna gain, and the ECC were shown. The antenna's compact size (48 mm × 48 mm) makes it suitable for portable MIMO/diversity applications.

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