Compact Ellipse Shape Antenna for UWB Application

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Abstract— **The proposed antenna has very compact size of 18×18 mm² is used for ultra wideband applications. The antenna substrate thickness 0.8mm. The proposed antenna consists of two symmetrical half slot antenna elements with coplanar waveguide – fed structures and y shaped slot that is cut at the bottom center of the common ground plane. The slot efficiently prevents the current from directly flowing between two ports at low UWB frequency. The antenna covers 1.6 to 14 GHz. The proposed antenna also contains relatively stable radiation pattern and gains.**

Keywords— CPW; half slot; UWB antenna; compact size.

I. Introduction

INCE the Federal Communications Commission (FCC) allotted the unlicensed frequency band from 1.6 to 14 GHz as the UWB communication [1], UWB technology gained lots of concerns and remarkable developments due to its high data rate and low-spectral-density radiated power. A multiple number of works have been studied for compact UWB antennas that contain wide bandwidth, stable radiation patterns and band-notched characteristics. However, UWB communication systems also suffer from the multipath fading problem. Multiple -input-multiple-output technology utilizes multiple transmitting and receiving antennas to provide multiplexing gain and diversity gain, which significantly reduces multipath fading and increases transmission capacity. However, placing multiple antennas in a small space will cause strong mutual coupling among different antennas. Thus, designing compact antenna with weak mutual coupling is the challenge for current works.

A number of UWB antennas have been proposed in the past few years. In [2]-[5], various extended stubs, which were added between symmetrically or orthogonally antenna elements, worked as $\lambda^g/4$ resonators as well as reflective components that reflect the radiations of adjacent ports. Antennas in [6] -[7] enhanced isolation by notching rectangular or T-shaped slot on the ground, which suppressed the surface currents flowing between adjacent ports. Antennas with aforementioned decoupling structures normally introduce orthogonally feeding structure to further improve the isolation and realize diversity performances. Furthermore, EBG[8] and neutralization line [9] also are the efficient method to improve isolation. But they occupied considerable space and augmented the complexity of the antenna design, which are not suitable for very compact antenna.

In this paper, a very compact CPW-fed antenna with half-slot structure is proposed, operating in UWB frequency. Owning to its superiority of the structure, the antenna obtains a very compact size of only 18×18 mm² that is smaller than most proposed UWB antennas (only 52.3% of [10], 72.3% of [7]). Ground plane of the proposed antenna has three different functions: 1). matching circuit; 2). radiating element around 3 Hz; 3). reflective component for high frequency. Y-shaped slot is employed to improve the isolation performance at low UWB frequency band. At high frequency the surface currents mainly concentrate on the edge of the half slot. Thus, a good isolation, which is with S12/S21 < -15 dB of 3-4 GHz and S12/S21 < -20 dB of 4 -12.4 GHz, is achieved. The ellipse-shaped radiator and ground plane jointly generate multiple resonant frequencies, which makes the antenna completely cover the UWB frequency.

II. DESIGN AND ANALYSIS OF UWB ANTENNA

A. Double CPW-fed Half Slot Antenna

Fig. 1 shows the geometry of the proposed single half-slot antenna that is fed by CPW structure. It is printed on the F4 b-2 substrate with compact size of 18×18 mm^2, relative dielectric constant of 2.65 and thickness of 0.8 mm. The half slot structure is employed in our design due to its advantages of compact size, wide impedance bandwidth and good directional property [11]. The CPW-fed structure, which contains the strip line of 2mm width and gaps of 0.7 mm, connects the radiator to SMA connector for wide impedance bandwidth. The ground plane is the matching network for the half-slot antenna, but its width has slight influence on the reflection coefficients. Because around 3GHz strong currents mainly concentrate on the edges of the slot. Thus, changing ground width has slight impact on its currents distribution, current path and resonant frequency. To achieve the compact size, the width is chosen to be 11.4 mm. When the ground plane is fixed, the shape of the radiator has significant effect on the impedance bandwidth as depicted.Three half-slot antennas with different radiators obtain similar resonant frequencies. But only the half slot antenna, which possesses ellipse-shaped radiator with semi-major axis of 4.8mm and semi-minor axis of 3.74 mm, achieves preferable impedance bandwidth. The antenna with rectangular or ellipse-shaped radiator can't match very well from 3 to 4.4 GHz due to its large input impedance . However, a distinct resonant trend can be found at 3 GHz owning to the protuberant ground. Thus, the single half slot antenna can cover the low frequency of UWB through improving the impedance matching network. By synthetically considering, the half slot antenna with ellipse-shaped radiator is employed as the basic structure to build the antenna because of its wide bandwidth and good impedance characteristic.

B. Design and Measurement of UWB MIMO Antenna

We found that the input impedance of 3 GHz can be significantly decreased by combining two half-slot antennas into one MIMO antenna. Thus, the initial MIMO antenna, denoted as Ant 1, is simply combined with two symmetrically placed half-slot antennas and its compact size is only 18×18 mm2. Increasing the width of the ground can improve. The isolation and slightly influences the impedance bandwidth. But the improvement of isolation is finite and the all size also increases. To simultaneously achieve wide impedance bandwidth and minimum size of the antenna, the width of the MIMO antenna is decided to be 18 mm that is 0.2 mm longer than double single half-slot antennas. The openings of half slots gape toward opposite y-axis directions, and then a T-shaped protuberant ground is obtained. As for mentioned, the protuberant ground of single half slot antenna is the main radiating element at 3 GHz, and thus it can be equivalent to a RLC shunt circuit. For Ant 1, the T-shaped protuberant ground can be considered as a shunt circuit that is combined with two the RLC shunt circuits in parallel because of its perfectly symmetric structure. At 3 GHz, the simulated input impedance of Ant 1 is 72+34j Ohm that is almost one half of the input impedance (130+75j Ohm) of single half slot antenna. As illustrated in Fig. 4, the impedance bandwidth of Ant 1 is from 2.9 to 15 GHz, which is completely satisfied with the applications of UWB communications. However, the mutual coupling of 2.9-4.8 GHz is above -15 dB and the peak value is -7.4 dB at 3.17 GHz. To achieve acceptable isolation of low UWB frequency, a Y-shaped slot is added at the bottom center of the ground plane of Ant 1, which is denoted as Ant 2.the peak value of mutual coupling of Ant 2 decreases by approximate 5 dB and the mutual coupling of3.8-11.8 GHz is below -20 decibal. For Ant 2, the impedance bandwidth of 3.16-4.18 GHz slightly deteriorates resulting from that the Y-shaped slot causes the impedance mismatching. It can be easily improved by employing two quadrate patches to the corners of each slot, and the isolation is further improved. For the proposed MIMO antenna, the high resonant mode of12.9 GHz is vanished due to the impedance mismatching. The impedance performance of the proposed antenna is measured by Agilent E5071C vector network analyzer. When one port is excited, the other port is terminated with a 50 Ohm load. As depicted in Fig. 4, the measured impedance bandwidth (S11/S22 < -10 dB) is from 3 to 12.4 GHz and the measured mutual coupling is below -15 dB (-20 dB for 5-12.4 GHz).

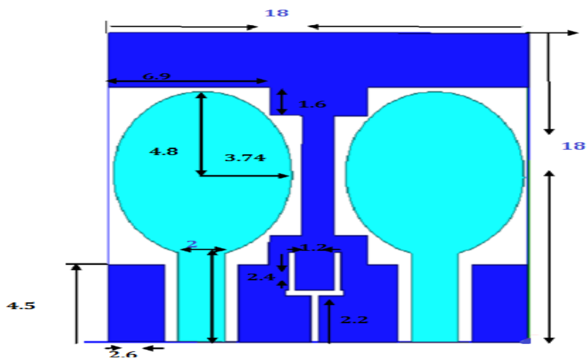

Fig.1 Proposed Double CPW-fed half-slot antenna

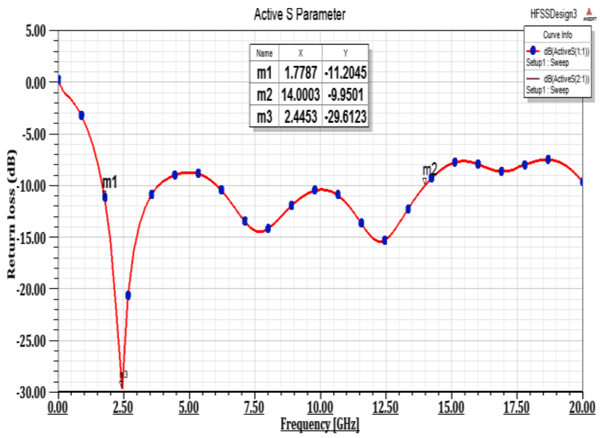

Fig. 2. Return Loss of the proposed Antenna

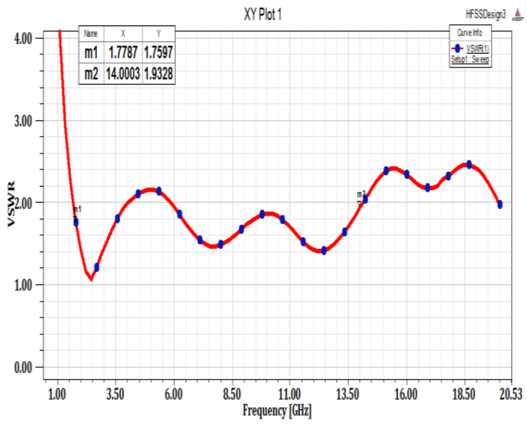

Fig.3 VSWR

C. Studies of UWB MIMO Antenna

To study the radiation mechanism of the proposed UWBMIMO antenna, the surface current distributions of Ant 1 and proposed MIMO antenna at their resonant frequencies

are. Two antennas possess similar current distributions. But the slight shift of resonant frequencies happens due to the influence of different matching circuits.
Around 3 GHz, the currents mainly concentrate on the protuberant ground and the quarter-wavelength current can be found along it., lots of currents flow directly to the adjacent port via the connected ground, which leads to the dissatisfactory isolation performance. The ellipse-shaped radiator operates as a typical monopole antenna resonating around 5.6 GHz and the length of current path is about 13.9 mm that is half perimeter of the ellipse-shaped radiator and approximate 0.33 λg corresponding to its resonating frequency. 9.7/10.5 and 12.9 GHz are the high-order modes currents of 9.7/10.5 GHz mainly concentrate on the ringent part of the slot, while the currents of 12.9 GHz mainly concentrate on the edge of the protuberant ground. Thus, the protuberant ground well reflects the radiations from two close radiators, which achieves good isolation from 5 to 15GHz.To improve isolation and impedance matching of low UWB frequency, a Y-shaped slot is cut at the center of the ground plane and two quadrate patches are added to the corner of each half slot. The added Y-shaped slot lengthens the current path between two ports and its slot length in the vertical direction significantly influences the isolation and impedance bandwidth of the MIMO antenna. The geometry of the slot is obtained through multiple simulations and parameters optimizations.

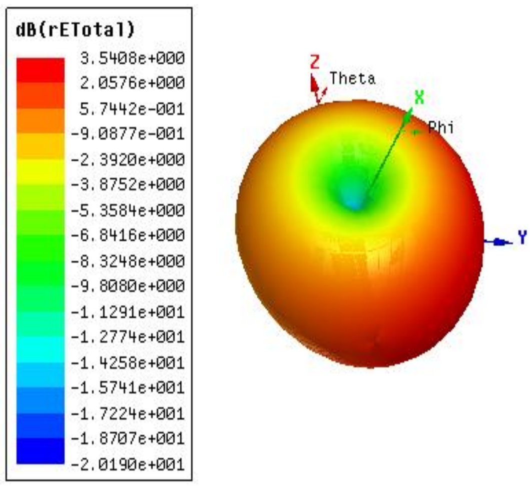

Fig 4 3D Radiation pattern

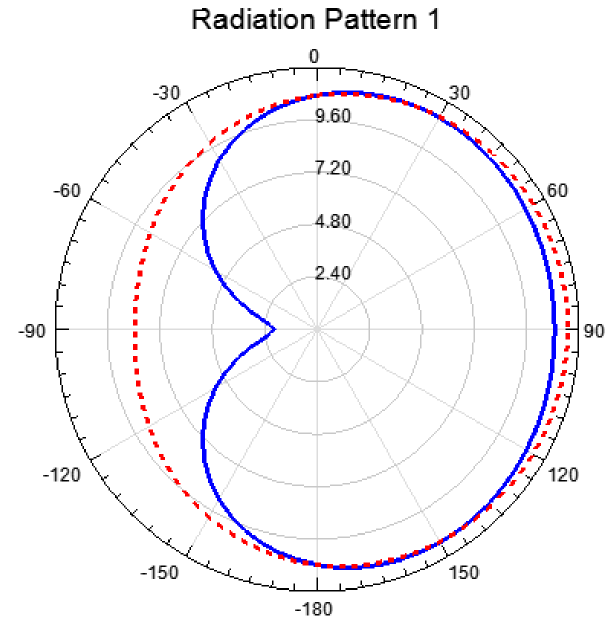

Fig.5 2D radiation pattern

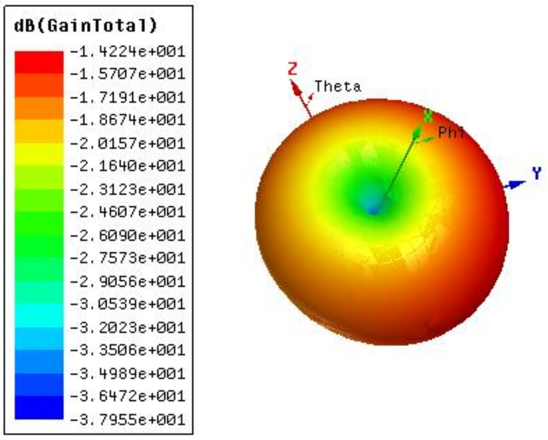

Fig 6.Gain

IV. CONCLUSION

UWB antenna with a very compact size of 18×18 mm2 has been fabricated and measured. Two CPW-fed half-slot antenna elements generate multiple resonant frequencies, which provide a wide impedance bandwidth from 1.6 to 14 GHz. The natural T-shaped protuberant ground, employed Y-shaped slot and quadrate patches improve the isolation performance over the whole UWB frequency spectrum. Approximately quai-omnidirectional radiation patterns,

relatively stable gains and low ECC values guarantee The antenna with superior radiation performance. These superiorities of the proposed UWB MIMO antenna indicate it is competitive e for portable devices.

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