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Compact MIMO Antenna System with Slotted Ground Structure for Ultra-Wide Band Applications

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***Abstract*—A new ultra-wideband MIMO antenna with good isolation is proposed. An antenna system is explicitly intended to operate at frequency bands ranging from 3.1 GHz to 10.6 GHz. The design is extremely miniaturized using the slotting technique. The mutual coupling between the two elements is less than -10 dB. The maximum gain of the antenna is estimated as 4.16 dB.**

Keywords- MIMO; ultra-wideband; miniaturization; s-parameter; radiation pattern

I. INTRODUCTION

The perspective of Ultra Wide Band (UWB) technology is tremendous because of its remarkable advantages, for examples, the ability to provide high-speed data rates at short transmission distances with low power dissipation [1]. The hardest challenge in designing a UWB antenna is to accomplish wide impedance bandwidth with high radiation efficiency. The concurrent surge of wireless devices, with a high level of miniaturization and high frequency of operation, has upgraded the interest in designing high-performance antenna types. In this way, there is a growing demand for small and low-cost UWB antennas that are able to provide satisfactory performance in both time and frequency domains [2]. In addition to the needs of high-speed data transfers, there is additionally an issue of quality control, which incorporates low error rate and high capacity. So as to keep up certain Quality of Service (QoS), the multipath fading effect has to be dealt with. Hence multiple antennas are to diminish the error rate as well as to improve the quality and capacity of wireless transmission. This is done by directing the radiation only to the intended direction and altering the radiation as per the traffic condition and signal environment.

Recently, there is an interest to increase the data rate of existing wireless communication systems. The application of diversity techniques, most usually assuming two antennas in a mobile terminal, can increase the data rate and reliability without sacrificing additional spectrum or transmitted power in rich scattering environments. MIMO UWB systems can further increase the channel capacity when contrasted with conventional MIMO systems for narrowband applications [3]. To battle, the multipath fading problem in an indoor UWB wireless communication system, a UWB diversity antenna system is a promising candidate. With the increase of demand for wireless communication systems, personal communication devices are required to operate at multiple frequencies to cater to different applications. In addition to multiband operation, it is necessary that the antenna is small with a lightweight, low profile and easy integration with other circuit structures.

The basic concept of MIMO is to use multiple antennas to transmit or receive signals with different fading characteristics. Since it is impossible that all the received signals will experience profound fading at the same time, the system reliability can be increased by appropriate selection/combining of the received signals. However, installing multiple antenna elements on the small space available in portable devices will definitely cause severe mutual coupling and significantly degrade the diversity performance. Thus, one of the fundamental difficulties to employ MIMO technology in portable devices is the design of the small MIMO antennas with low mutual coupling. Some MIMO antennas for UWB applications were proposed in a previous couple of years [4]–[5]. In order to accomplish the best performance of the MIMO systems, high isolation is obtained by symmetrically feeding [4]–[6], introducing DGS to stifle surface wave [6], [7], utilizing directional antenna elements [7], adding protruding ground stub as reflective component [4], [5], [8], and adopting a neutralization line to offset the original coupling [9]. A miniaturized UWB antenna with improved band rejection characteristics in 5 GHz band [9] is used for ultra-wideband applications. A novel compact UWB antenna with high impedance bandwidth with the possibility of a rectangular waveguide has been introduced [10].

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A planar dipole antenna comprising of two semielliptical-ended arms connected by a shorting bridge equipped for enhancing the antenna's impedance and gain throughout UWB operating bandwidth is studied [11]. A few methodologies concerning miniaturization are self-similar and space-filling fractal geometries [12], defected ground structure [13], slots and notches [14], reactive impedance surfaces [15], short circuits to the ground plane, loading antenna with lumped elements, etc. Slots can enhance miniaturization in terms of electrical length of the patch to obtain wider bandwidth and directivity too [16-17]. So as to obtain the ultra-wide bandwidth, omnidirectional radiation pattern, and small size antenna, four matching techniques are applied to the proposed UWB antennas, such as the use of slots, the use of notches at the bottom of the patch, the truncation ground plane, and the slotted ground plane[18].

This paper presents a MIMO antenna in a compact volume using slotted ground with UWB ability. The proposed antenna in this paper would have the accompanying upgrades:

1) The operating frequency bands cover 3.1 GHz to 10.6 GHz.

2) The mutual coupling between the antenna elements can be avoided by utilizing a slotted ground plane.

3) The return loss is beneath -10 dB over the operating bands with a peak gain of 4.16 dB.

II. ANTENNA DESIGN

UWB technology has been viewed as one of the most encouraging wireless technologies that guarantee to reform high data rate transmission and empowers the personal area networking industry prompting to new developments and more prominent quality of services to the end users. Wireless communication systems with multiple transmitting and receiving antennas are well known for accomplishing a greater system capacity than the traditional ones employing only a single antenna at two sides of a communication link. Thus, MIMO technology can be used as a proficient innovation to solve the multipath fading problem in UWB systems. The UWB and MIMO technologies have been incorporated into the proposed antenna design for enhancing the performance in terms of high data rates. By consolidating the UWB wireless communication system with the MIMO technique, the multipath issue is treated as a favorable factor and the channel capability of the UWB communication system can be improved without additional bandwidth consumption.

The proposed antenna configuration is illustrated in fig I. The design was built on an FR4 substrate with relative dielectric constant of 4.4 and a thickness of 0.8mm. The antenna comprises two C-shaped symmetrical face-to-face radiating elements printed on the upper part of the substrate.

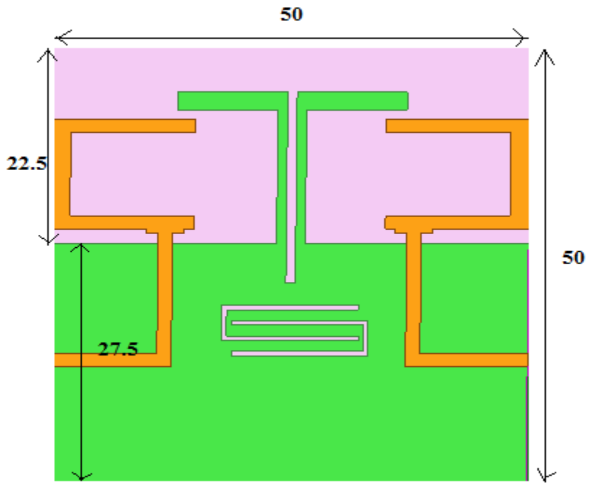

Fig 1. Proposed antenna design

Antenna design contains double U slots, two inverted L protrude branches and a line slot on the ground plane. Detailed dimensions of the element and slots are shown in fig II. The slotted ground plane is utilized to obtain ultra wide bandwidth, omnidirectional pattern, and miniaturization of an antenna. The size of the slots influences the impedance bandwidth of the antenna. Another preferred advantage of using slots on the ground plane is to reduce mutual coupling between antenna elements.

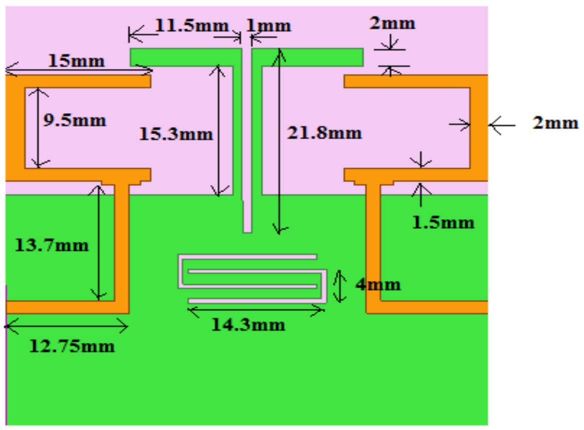

Fig 2. Detailed dimensions of the proposed antenna

III. PRINCIPLE OF OPERATION

Two antenna element with and without slotted ground was first dissected. Fig 3 demonstrates the simulated S-parameters of the proposed antenna and two antenna element without slotted ground. S-parameter depicts the input-output relationship between terminals.

Fig 3.a illustrates reflection parameters s(1,1) and s(2,2), and fig 3.b shows transmission parameters s(1,2) and s(2,1) of the proposed antenna and antenna without slotted ground.

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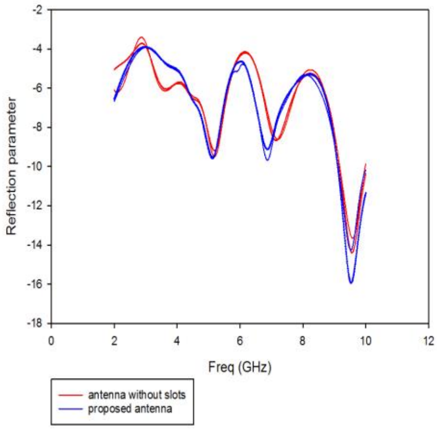
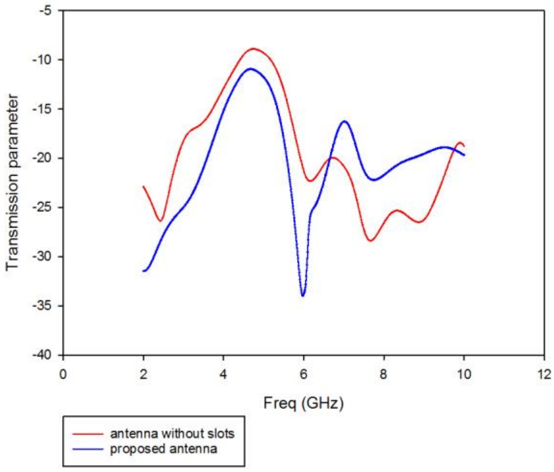


(a)



(b)

Fig 3. Simulated S-parameters of proposed antenna and antenna without slotted ground

S(1,1) would be the reflection coefficient of antenna 1 and S(2,2) is the reflection coefficient of antenna 2. Reflection coefficient describes the amount of power reflected from the antenna. From fig 3.b antenna without ground plane has return loss greater than -10 dB, that means mutual coupling is higher.

IV. SIMULATION RESULTS

Fig 4 shows the deliberate and simulated S parameters for the design prototype. The antenna geometry is resonant at the wide range of frequency bands starting from 3.1 GHz to 10.6 GHz. The most minimal values of reflection coefficients are observed as -9.8dB at 6.8 GHz and -14.5 dB at 9.8 GHz respectively. The return loss is estimated as well under 10 dB for an overall band. While designing a MIMO antenna system, the principle exertion achieved a lower value of transmission coefficient between antennas and this is viewed as a key factor in design. The mutual coupling between two antenna elements in operating bands is well under -10 dB.

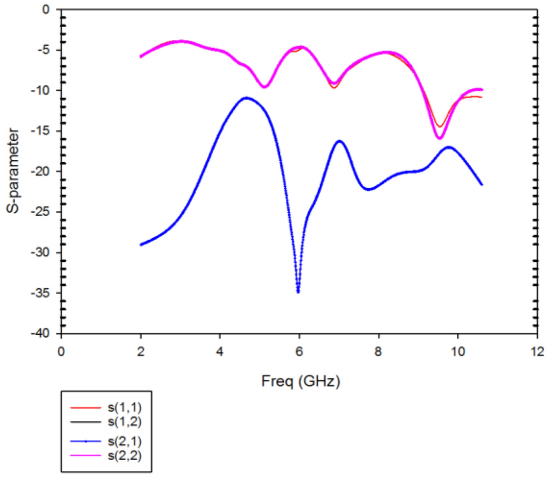
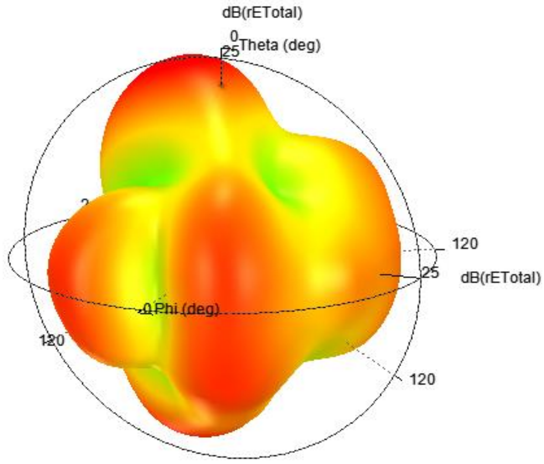
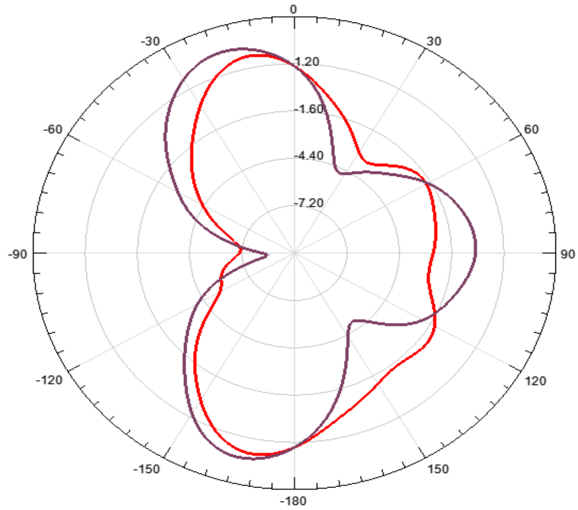


Fig 4. Simulated S-parameter of proposed antenna



(a)



(b)

Fig 5. Simulated (a) 3 dimensional and (b) two dimensional radiation pattern of proposed antenna

The radiation pattern of the proposed antenna as shown in fig 5. Fig (5. a) and fig (5. b) shows the 3D plot and the 2D plot of the radiation pattern respectively. The radiation pattern of an antenna is a plot of the far field radiation properties of an antenna as a function of the spatial coordinates which are

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determined by the elevation angle and azimuth angle. The gain of the design prototype is 4.16 dB.

The current distribution of the proposed design as appeared in fig 6. On account of antenna design without slotted ground, a strong surface current can be observed on the antenna on the right-hand side when the left side antenna is excited. This surface current stifled by the introduction of slots on the ground plane. The slots altogether disturb the fields and induced currents between the two antenna elements and reduce their mutual coupling. The current flow of UWB antenna with two slot structure is fundamentally diminished as compared to the UWB antenna with a conventional ground plane.

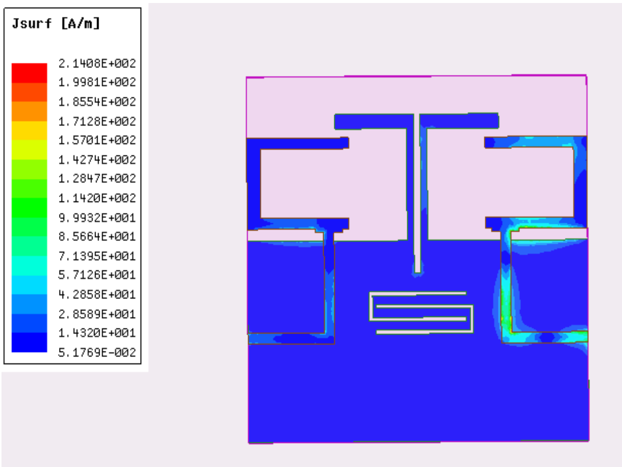

Fig 6. Current distribution of proposed antenna

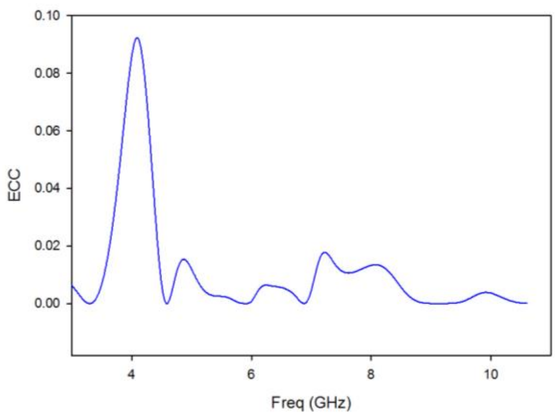

Fig 7. ECC plot of proposed antenna

The simulated envelope correlation coefficient (ECC) of the proposed prototype has appeared in fig 7. It is seen that the ECC is very small and under 0.10 within the entire operating frequencies. Which indicates that proposed MIMO has better diversity characteristics.

V. CONCLUSION

A novel compact UWB MIMO antenna system has been developed in this paper. The MIMO antenna system consisted of two symmetric antenna structure with an exceptionally compact fractured ground plane. By implementing the proposed double-u slot and a line slot, the impedance bandwidth and isolation can be enhanced significantly. The coupling between both elements over the total transmission bandwidth is under -10 dB. Simulated results show that the proposed antenna guarantees an entire UWB bandwidth with high isolation. The maximum gain of 4.16 dB has been observed.

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