Compact Two-Port UWB MIMO Antenna System With High Isolation Using a Fork-Shaped Structure

K. Manuel Prasanna, and S. K. Behera, *Member, IEEE*

***Abstract*— A printed ultra wideband (UWB) MIMO antenna system is proposed for portable UWB applications. The MIMO antenna system consists of two semicircular radiating elements on a single low-cost FR4 substrate of a compact size of 35 mm × 40 mm and is fed by a 50-Ω microstrip line. A T- shaped slot is etched on the radiating elements to enhance the impedance bandwidth. The proposed antenna system operates over a wide frequency range from 4.4 to 10.7 GHz (almost covering the entire UWB). A fork-shaped structure is introduced in the ground plane to increase the isolation between the antennas. Simulated results of S-parameters of the proposed antenna system are obtained and a high isolation of -20 dB is achieved in most of the band, which is found suitable for MIMO applications.**

***Index Terms*— Isolation, ultra wideband (UWB), multiple-input-multiple-output (MIMO), mutual coupling, return loss.**

I. Introduction

ULTRAWIDEBAND (UWB) is a modern technology for transmitting information over a large bandwidth promising high data rates with low power consumption. The unlicensed use of 3.1 -10.6 GHz has been authorized by the Federal Communications Commission for short distance high data rate indoor applications like PAN wireless connectivity. At the same time in UWB technology, by suitable coding and integration techniques, data rate can be exchanged with range for applications like radar and imaging systems. Many printed monopole antenna systems have been proposed which operate in the required frequency band of 3.1-10.6 GHz for UWB applications [1]–[4]. Multiple-input-multiple-output (MIMO) systems transmit the same power using multiple antennas at the transmitter and receiver thereby increasing the channel capacity without the need of additional bandwidth or power. Hence ultra wideband MIMO antenna systems provide high capacity and high speed wireless communication. Recently, several MIMO/Diversity antennas have been proposed which operate in the UWB for various diversity applications [5]–[6], [11]–[13]. However, for an efficient MIMO antenna system mutual coupling between the individual antennas should be as low as possible. Since MIMO employs multiple antennas for transmission, overall size of the antenna system is also a major concern. Hence, a compact UWB MIMO antenna with high isolation of more than -16 dB is desirable for portable wireless devices.

Several studies have been carried out on various MIMO antenna systems with two and four radiating elements and various methods are proposed to improve the isolation between the antenna elements. Various structures like the mushroom–shaped EBG structures [7]–[8], defected ground plane structures [9]–[10] have been proposed to reduce the mutual coupling by suppressing the ground current flowing between the radiating elements. In [11], a two – port compact UWB MIMO antenna for USB Dongle applications is proposed in which isolation of -26 dB is achieved by a slot formed between the monopole and the ground plane. The impedance bandwidth is from 3.1 to 5.15 GHz. In another UWB Diversity antenna [12], isolation of < -20 dB is achieved by optimizing the shape of the ground plane and through slots in the radiating elements. The operating frequency range of the proposed antenna is 3.1–5 GHz. However, both of these antennas [11] and [12] can cover only the lower UWB band. In [13], a diversity antenna covering the entire UWB has been designed, in which stubs are introduced to reduce the mutual coupling. In [13], enhanced isolation is obtained at the cost of increased complexity and size of the overall antenna system.

In this paper, a two- element MIMO antenna system is presented. The proposed antenna system has a compact size of 35 mm × 40 mm, which is smaller than the antennas in [12] and [13]. Also, the MIMO system has an operating band from 4.4 to 10.7 GHz, covering almost the entire UWB. A fork-shaped structure is extended from the ground plane to enhance the isolation to < -20 dB in most of the UWB band.

II. Antenna Design

The geometry of the proposed UWB MIMO antenna system is shown in Fig.1. The antenna system consists of two radiating elements of similar geometry printed on a common FR4 substrate of thickness 1.6 mm and a compact size of 35 mm × 40 mm. The relative permittivity of the substrate is 4.4.

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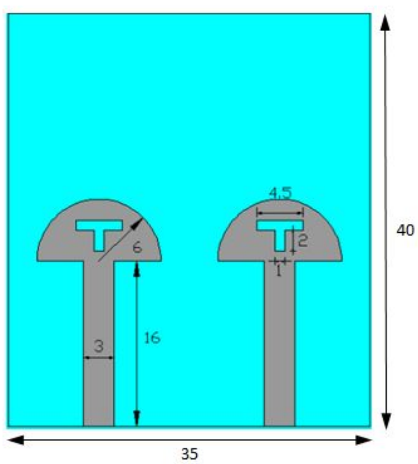
A semicircular disc monopole is chosen as the radiating element and each of the radiators is fed separately by a 50Ω microstrip line. Circular and semicircular monopole antennas have more impedance bandwidth than the rectangular, triangular, square and hexagonal monopole antennas. Semicircular geometry of the radiator provides more isolation between the radiating elements than most other existing geometries. The two radiators are placed in such a way that distance between them is more than half of the wavelength of the lowest frequency in order to achieve the isolation between the radiating elements. The gap between the radiating element and the ground plane affects the impedance bandwidth and hence the distance is optimized at 1 mm. A central T-shaped slot of 1 mm width is introduced on each of the radiators to enhance the impedance bandwidth. A fork-shaped structure along with a single branch arising from the center of the ground plane improves the wideband isolation between the radiating elements.



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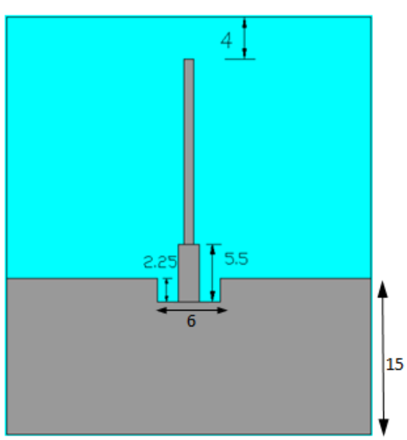

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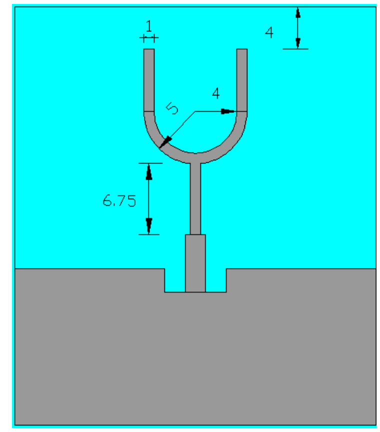

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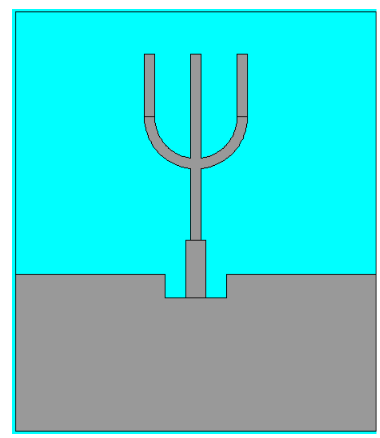


(d)

Fig.1. Geometry of the proposed antenna system.
(a) Front view, (b), (c) and (d) rear view. All dimensions are in mm

III. Proposed Isolation Mechanism

Reflecting structures are introduced in the ground plane to reduce mutual coupling between the antennas [Fig. 1(b-d)]. A single branch of length 16.75 mm extends from the center of a notched block in the ground plane [Fig. 1(b)], which acts as a reflector, thereby providing isolation between the antennas. Then a fork-shaped structure is introduced instead of the center branch [Fig. 1(c)]. When one of the ports feeding the radiators is excited, the designed structures extending from the ground plane obstruct the surface current flowing to the other radiator through the ground plane, thereby weakening the coupling between the radiators. Finally, the fork-shaped structure is introduced along with the center branch [Fig. 1(d)]. The resulting isolation structure has a center reflector and two branches, introduced due to the fork-shaped structure. More resonances will be introduced when the number of branches or structures increase, and hence isolation is enhanced throughout the UWB.

IV. Results and Discussions

The proposed antenna with the various ground plane structures is simulated using the commercial software CST MICROWAVE STUDIO. The simulated results of S-parameters and radiation pattern are obtained in the frequency range of 3-11 GHz and analyzed for isolation and bandwidth performance characteristics.

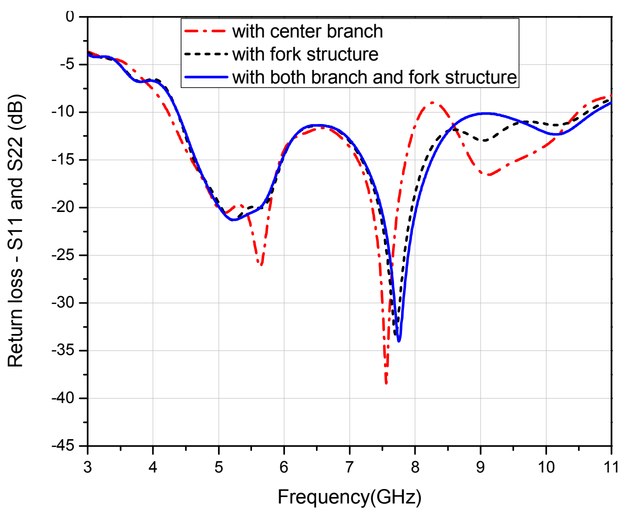


Fig.2. Simulated S_{11} and S_{22} of the proposed antenna system.

A. Bandwidth characteristics

Simulated results of S_{11} and S_{22} of the MIMO antenna system with and without the fork-shaped structure are shown in Fig. 2. Both S_{11} and S_{22} are found to be same due to symmetry of the antennas. According to the simulated results, S_{11} (Return loss) is found to be less than -10 dB from 4.4-10.7 GHz after the addition of the fork-shaped structure. Hence the bandwidth is increased to cover almost the entire UWB by introducing the fork-shaped structure.

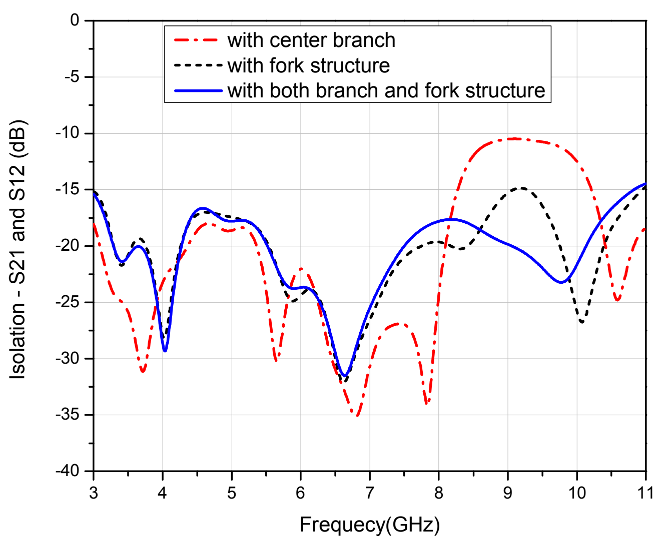
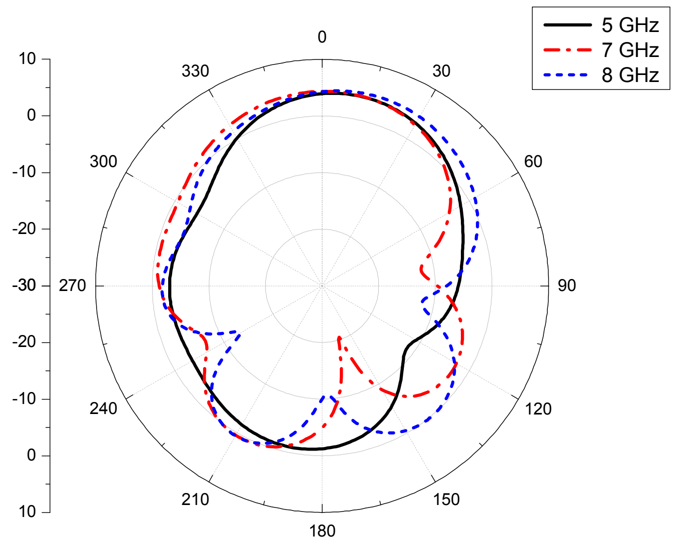


Fig.3. Simulated S_{21} and S_{12} of the proposed antenna system.

B. Isolation characteristics

Simulated results of S_{21} and S_{12} are shown in Fig. 3. S_{21} is found to be less than -15 dB throughout the band after introducing the fork-shaped structure. With the center branch and the fork structure together, better isolation of more than -17 dB is achieved throughout the UWB and more than -20 dB in most of the band. This result satisfies the required condition that the mutual coupling between the antennas is to be lower than -15 dB for proper operation of the MIMO system in the UWB range.



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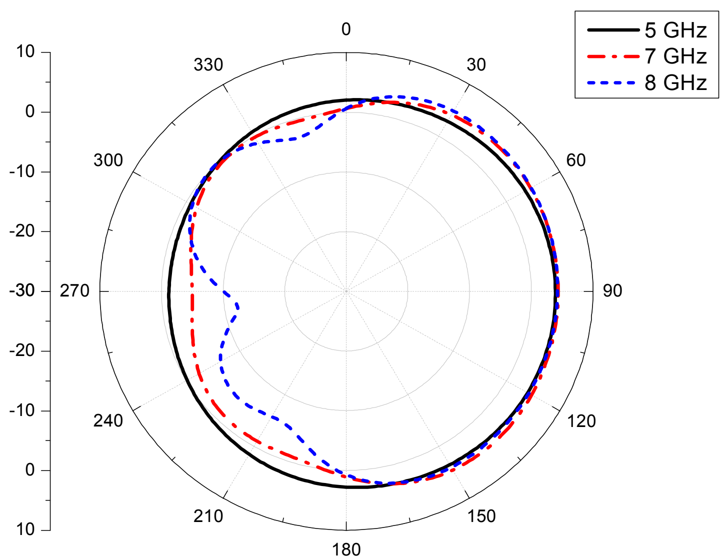

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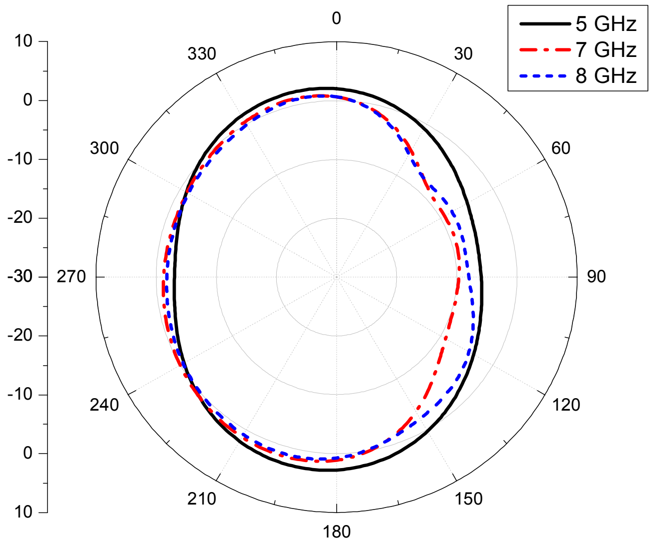

(c)

Fig.4. Simulated radiation patterns of the proposed antenna system: (a) x-y plane, (b) x-z plane, (c) y-z plane.

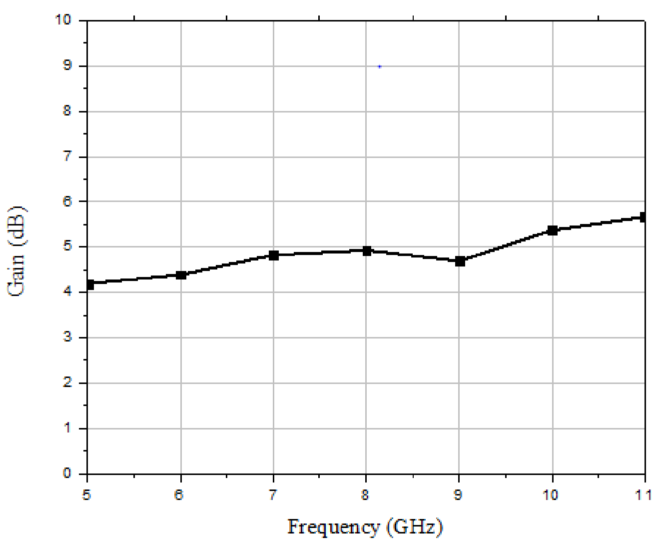

Fig.5. Simulated antenna gain.

C. Radiation performance

The radiation characteristics of the proposed antenna system are investigated in the operating frequency range of 4.4-10.7 GHz. Simulated radiation patterns for one port are shown in Fig. 4 at frequencies of 5,7 and 8 GHz, in the three principal planes at $\theta = 90^0$, $\varphi = 0^0$ and $\varphi = 90^0$, corresponding to the x-y, x-z and y-z planes respectively. The radiation pattern is found to be nearly omni-directional at 5 GHz and more directional at 7 GHz. The radiation patterns are stable across the UWB. The antenna gain at one port is also plotted for a frequency range of 5-11 GHz as shown in Fig. 5. The gains of both the antennas are same due to symmetry of structure of the radiating elements. The gain is found to be relatively constant throughout the UWB.

V. Conclusion

A novel compact UWB MIMO antenna system with high isolation has been proposed and investigated. Good isolation performance was achieved through the proposed fork-shaped structure. Isolation was found to be better than -17 dB throughout the UWB. The bandwidth of the proposed antenna covers almost the entire UWB from 4.4 to 10.7 GHz. The obtained results of isolation and bandwidth characteristics show that the proposed MIMO antenna system can work well in extremely wideband range and it is found suitable for application in UWB portable devices.

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