Compact UWB MIMO Antenna with Asymmetric Coplanar Strip Feeding Configuration

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***Abstract*— A compact UWB MIMO antenna composed of two elements is presented in this paper. The two antenna elements are fed by asymmetric coplanar strip (ACS). The radiator of the single antenna consists of half elliptical shape radiator. The two antenna elements are located side by side on FR4 substrate with size equal to 48 × 28 mm2. The edge to edge distance between the antenna elements is 0.23 λ_0 at 3 GHz. The two antenna elements are designed to operate in the UWB frequency band from 3 GHz to 11.5 GHz with return loss lower than -10 dB and isolation lower than -15 dB without using decoupling structures between the elements. The envelope correlation coefficient, diversity gain, and capacity loss which define the performance of MIMO antenna are within the required limits. The proposed antennas has been fabricated and measured. Experimental measurements were obtained and are in good agreement with simulation results, which verify that the proposed antenna is a good candidate for UWB MIMO applications. Moreover, the performance of the MIMO antenna is verified by computing the envelope correlation coefficient (ECC), diversity gain (DG), and channel capacity loss (CCL).**

***Index Terms*—UWB antenna, MIMO antenna, asymmetric coplanar strip -fed, MIMO performance.**

I. Introduction

High capacity and reliability are considered the main requirements of wireless communication systems. These requirements can be achieved by adopting multiple input multiple output (MIMO) technology in the wireless system. The use of multiple antennas through MIMO technology allows to increase the system capacity without the need of additional power or spectrum [1-2]. The performance of the MIMO system depends on receiving signals that have low cross-correlation. Hence, there is an essential need for designing MIMO antennas with high isolation between antenna elements [3-5]. One of the common techniques that have been adopted to increase the isolation between MIMO antenna elements uses electromagnetic band gap (EBG) structures [6–7]. However, EBG structures occupy a large area and increase antenna complexity. Defected ground structure (DGS) have also been used as a decoupling structure to increase the isolation between MIMO antenna elements [8-9].

A compact-size MIMO antenna with low correlation is necessary for portable devices. The spacing between the wo antennas elements should be at least half-wavelength at the lowest operating frequency of the UWB band. The design of a MIMO antenna should result in an isolation coefficient that is better than -15 dB, in order to overcome possible multipath fading effects encountered in MIMO systems [3-5].

The unlicensed band for UWB technology from 3.1 to 10.6 GHz has been set by the Federal Communication Commission (FCC) [10]. UWB technology has several advantageous such as low power consumption and high data rate transmission. Several antennas which meet the high demand of UWB applications have been proposed in literature [11-14].

This paper presents the design of a compact two-element UWB MIMO antenna with asymmetric coplanar strip (ACS) feeding configuration. The antenna operates in the UWB frequency band from 3 to 11.5 GHz, with better than -15 dB insertion loss and without using any decoupling structures between the elements. The UWB MIMO antenna is designed, simulated, fabricated, and measured. The performance of the designed antenna has been validated using commercial software CST microwave studio. Experimental measurements have been obtained and are in good agreement with simulation results. Moreover, the performance of the MIMO antenna is verified by computing the envelope correlation coefficient (ECC), diversity gain (DG), and channel capacity loss (CCL).

II. UWB MIMO Antenna Configuration

The configuration of UWB MIMO antenna is shown in Fig. 1. The ACS feeding structure has a single strip that is 3 mm in width and a slot that is 0.3 mm in width. The main block is a monopole antenna with a semi-elliptical radiator. The two antenna elements are aligned on the substrate side-by-side. A ground plane with a rounded edge is used to achieve the desired impedance bandwidth. The ACS feeding structure in the UWB antenna enables to reduce size. The proposed antenna has a compact size with a total area equal to 48 × 28 mm^2. The distance between the two antenna edges is 25 mm, which is equal to 0.23 λ_0 at 3 GHz. Simulation results of the proposed antenna structure are obtained using CST Microwave Studio for both return loss and insertion loss, and plotted in Fig. 3. The antenna operates in the UWB frequency band from

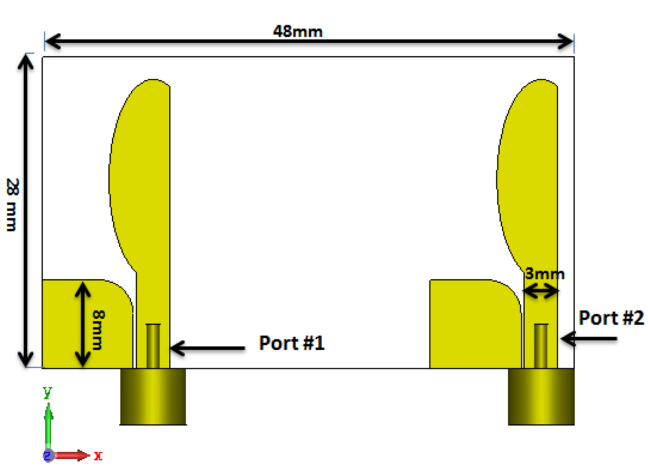

Fig. 1. 2D layout of UWB MIMO antenna.

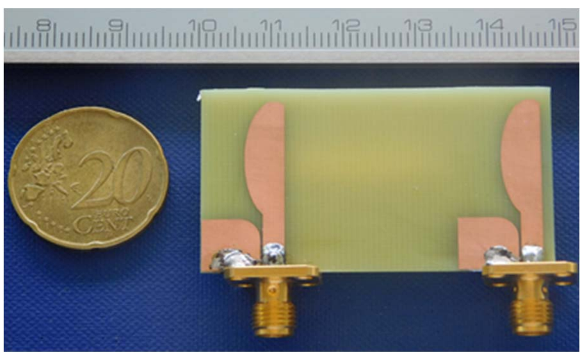

Fig. 2. Photograph of the fabricated UWB MIMO antenna.

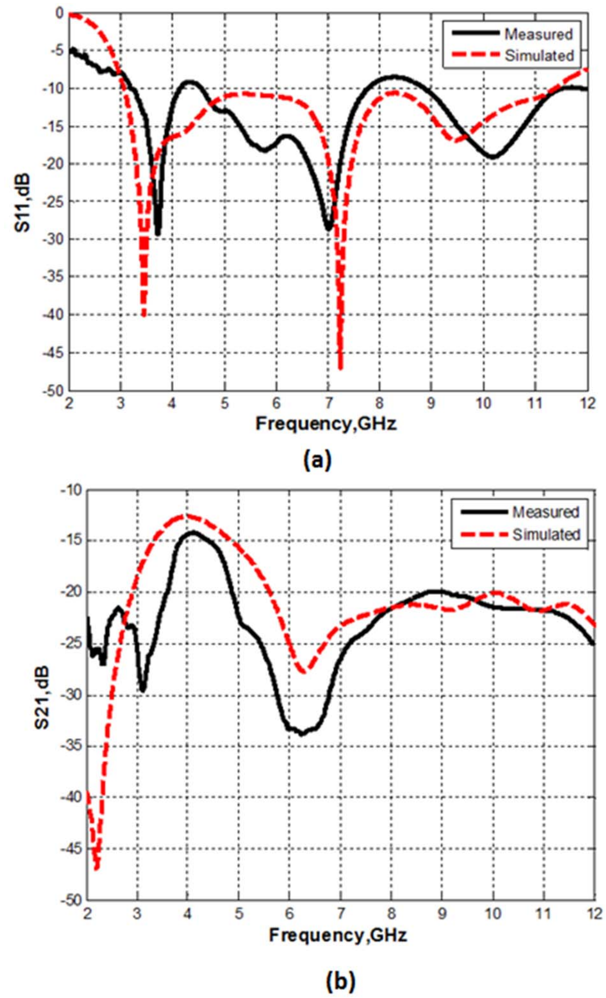

Fig. 3. Measured and simulated S-parameters of the UWB MIMO antenna, (a) return loss, (b) insertion loss.

3 to 11.5 GHz where the return loss is lower than -10 dB and the mutual coupling is lower than -20 dB in the frequency band from 5.5 to 11.5 GHz. The mutual coupling is increased to around -15 dB from 3 to 5.5 GHz. These simulations verify that the proposed MIMO antenna is suitable for UWB applications. The UWB MIMO antenna is designed on the substrate FR4 with dielectric constant of 4.4 and thickness 1.6 mm. A photograph of the fabricated UWB MIMO antenna is shown in Fig. 2. The antenna was measured by R&S vector network analyzer (VNA). Measurement results in terms of return loss and insertion loss of the proposed UWB MIMO at port 1 are shown in Fig. 3. Similar results are also obtained when the antenna is fed at port 2. Plots in Fig. 3 show that the antenna operates at a frequency band from 3 to 12 GHz, with return loss less than -10 dB and with coupling isolation better than -20 dB, within the frequency band from 5 to 12 GHz.

It can also be seen from Fig. 3 that measurement agrees with simulation, except for a slight shift, which is due to the mismatch of the connecting setup and the accuracy of fabrication process.

The normalized simulated and measured directive gain in both *x-z* and *x-y* planes of the proposed UWB MIMO antenna at 4 GHz and 10 GHz are plotted in Figs. 4 and 5, respectively. The proposed antenna was measured in an anechoic chamber. The measurement was obtained assuming excitation at port 1, while port 2 is matched with 50-Ω load; and vice versa. The antenna radiates in the *x-z*-plane Omni directionally; whereas the radiation in the *x-y*-plane is bidirectional. However, there are small discrepancies in the radiation patterns. This is due to the asymmetric ground plane of the presented design. Finally, we can observe that there is reasonable agreement between the simulated and measured radiation patterns in both planes.

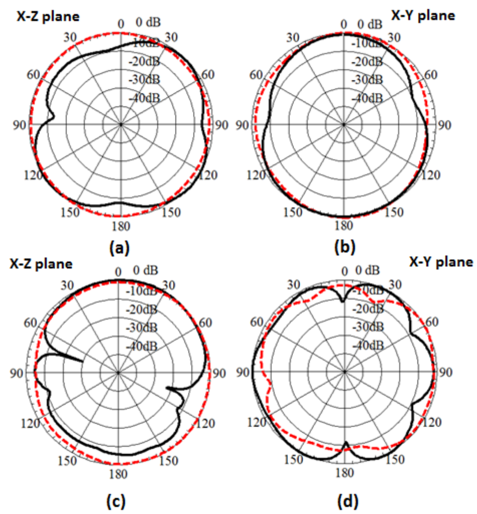

Fig. 4. Measured black(slolid) and simulated red (dashed) results of the directive gain at port 1 when port 2 is matched load, (a) at 4 GHz, (b) 4 GHz, (c) at 10 GHz, (d) at 10 GHz.

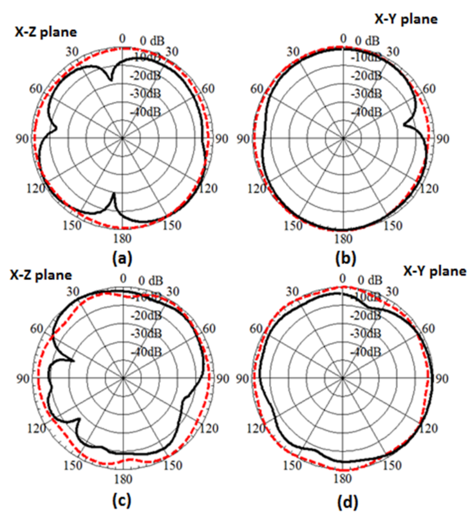

Fig. 5. Measured black(slolid) and simulated red (dashed) results of the directive gain at port 2 when port 1 is matched load, (a) at 4 GHz, (b) 4 GHz, (c) at 10 GHz, (d) at 10 GHz.

III. MIMO Performance

There are several parameters that are used to define the performance of the MIMO antennas such as envelope correlation coefficient (ECC), diversity gain (DG), and channel capacity loss (CCL).

A. Envelope Correlation Coefficient

The correlation between antenna elements is usually determined by calculating the Envelope Correlation Coefficient (*ECC*). The correlation coefficient between antenna elements should to be minimized for achieving a

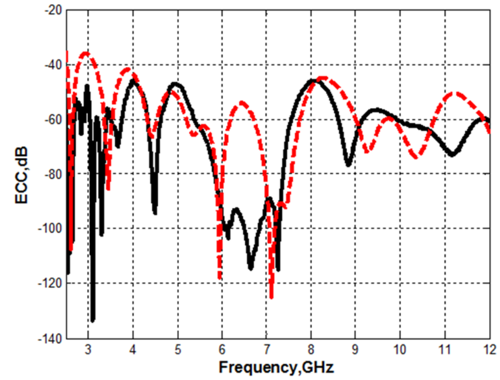

Fig. 6. Measured black(slolid) and simulated red (dashed) envelope correlation coefficent (*ECC*) of UWB MIMO antenna.

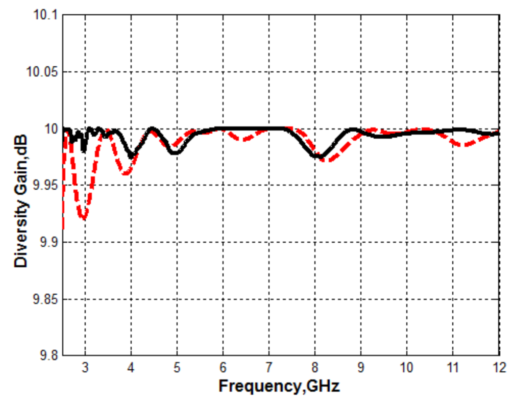

Fig. 7. Measured black (slolid) and simulated red (dashed) results of diversity gain of UWB MIMO antenna.

higher diversity between the MIMO antenna elements [15]. The envelope correlation coefficient has been calculated under the assumption of uniform multipath environment in line with [15].

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

The simulated and measured *ECC* of the UWB MIMO antenna are plotted in Fig. 6. It is clear that *ECC* of the MIMO antenna is lower than -40 dB within the whole operating frequency band. These results indicate that the correlation

between elements is very low and that the diversity performance of the MIMO system is strong.

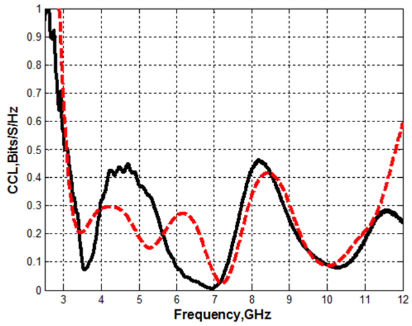

Fig. 7. Measured black(slolid) and simulated red (dashed) channel capacity loss of the UWB MIMO antenna.

B. Diversity Gain

The diversity gain (*DG*) is another parameter that is used to define the performance of MIMO systems. The diversity gain is related to *ECC* through the following equation [16]

$$DG = 10 * \sqrt{1 - |ECC|} \quad . \qquad (2)$$

The simulated and measured diversity gain of the proposed UWB MIMO antenna is plotted in Fig. 7. Both measurement and simulation indicate that the diversity gain is around 10 dB within the operating frequency band from 3 to 12 GHz.

C. Channel Capacity Loss

The last parameter that is used to assess the performance of the MIMO antenna is the channel capacity loss (*CCL*). In any conventional system, *CCL* increases linearly with the number of used antenna elements, without increasing the bandwidth or transmitted power [16-17]. The correlation between elements in the MIMO systems causes capacity loss. The simulated and measured *CCL* are plotted in Fig. 8. *CCL* is lower than 0.45 bits/s/Hz from 3 to 12 GHz. Fig. 6, Fig. 7, and Fig. 8 show that the proposed MIMO antenna is a good candidate for UWB applications.

IV. Conclusion

A two-element MIMO antenna with asymmetric CPW strip feed for UWB application is presented. The two elements of the MIMO antenna are aligned in a side-by-side configuration. The two-element antenna operates in the frequency band from 3 to 11.5 GHz, with return loss below -10 dB and isolation better than -15 dB. The isolation between elements was improved without using any decoupling structures. Good agreement was achieved between simulation and measurement. This verifies the validity of using the proposed MIMO antenna design for UWB applications. Moreover, the performance of the MIMO antenna has been verified by computing the envelope correlation coefficient (ECC), diversity gain (DG), and channel capacity loss (CCL).

Acknowledgment

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