Design and Measurement of a Compact UWB MIMO Antenna With Asymmetric Coplanar Strip Feed

Ahmed A.Ibrahim[1], Jan Machac[2] , Raed M. Shubair[3,4], and Milan Svanda[2]
[1]Electronics and Communications Department, Minia University, Egypt
[2]Electromagnetic Field Dept., Czech Technical University in Prague, Czech Republic
[3]Electrical and Computer Engineering Department, Khalifa University, UAE
[4]Research Laboratory of Electronics, Massachetts Institute of Technology, USA

Abstract—**This paper presents the design and measurement of a two-element MIMO antenna for UWB applications. Feeding for the MIMO antenna is employed using Asymmetric Coplanar Strip (ACS). The two elements are printed side-by-side on FR4 substrate, without having to use a decoupling structure between the two antennas. The edge-to-edge separation distance is 0.23λ_0 at 3 GHz. The proposed antenna operates in the UWB band from 3 GHz to 11.5 GHz, with a reflection coefficient below -10dB and insertion loss less than -15dB. The envelope correlation coefficient is under the allowed limits of MIMO systems. The proposed two-element MIMO antenna has been fabricated and measured. Measurement results agree with the simulation results, which verifies the use of the proposed antenna for UWB applications.**

I. INTRODUCTION

UWB has been assigned to operate in the frequency band from 3.1 GHz to 10.6 GHz by the Federal Communication Commission (FCC) [1]. There are several advantages for UWB technology such as high data rate, low cost and low power level. Researchers have designed several antenna configurations that meet UWB application demands [2-3].The reliability as well as high capacity in wireless systems are accomplished using MIMO technology. To increase the capacity of the system without the need of additional power or spectrum, multiple antennas are used [4]. There is an essential need for designing MIMO antennas with high isolation between antenna elements. The distance between the antenna elements in MIMO system should be half-wavelength at the lowest operating frequency of the UWB band. However, this distance is considered very large and not suitable for portable device applications. Researchers have designed several techniques to decrease the coupling between antenna elements which leads to decreasing the distance between the two antenna elements below half-wavelength [5-6].

This paper introduces the design of a two-element UWB MIMO antenna with asymmetric feeding. The designed antenna operates in the frequency band from 3 to 11.5 GHz, with an insertion loss of -15 dB or deeper, and without using any decoupling structures between the elements. The proposed antenna design has been simulated using CST microwave studio. Experimental measurements of the fabricated antenna agree very well with the results from CST simulation, which verify the proposed antenna is suitable for UWB applications.

II. PROPOSED UWB MIMO ANTENNA DESIGN

Fig.1 (a) illustrates the layout of proposed UWB MIMO antenna. The feeding is considered as ACS feed with strip width of 3 mm and a 0.3 mm gap. The radiator of the two antenna elements is composed of semi–elliptical shape. The two antenna elements are located side-by-side on FR4 substrate. The ground plane has a curvature to obtain the desired bandwidth. The proposed antenna has is compact in size small size with area equal 48 × 28 mm^2. The edge to edge distance between the two antenna elements is 25 mm, which is equal to 0.23 λ_0 at 3 GHz. The low cost substrate FR4 with permittivity of 4.4 and thickness of 1.6mm is used in fabrication process. Fig.1 (b) shows the fabrication photo of the proposed UWB MIMO antenna. Fig.2 demonstrates the simulation and measured results of the S-parameters at port 1. The antenna was measured by R&S vector network analyzer (VNA). Simulation results are obtained using CST and are presented in Fig.2, where it is shown that the proposed antenna operates in the frequency band from 3 GHz to 11.5 GHz, with a reflection coefficient lower than -10 dB and an insertion loss below -20 dB in the frequency band from 5.5 GHz to 11.5 GHz. It is noted that the simulated insertion loss is around -15 dB from 3 GHz to 5.5 GHz. Moreover, Fig.2 shows that measured results agree with the simulation results. However there is small shift between the results, which is due to the mismatch of the connecting setup and the accuracy of fabrication process.

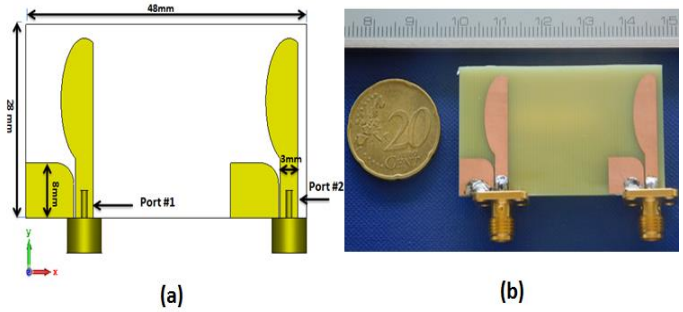

Fig. 1. Proposed UWB two-element MIMO antenna (a) Top 2D layout, and (b) Photograph of fabricated antenna.

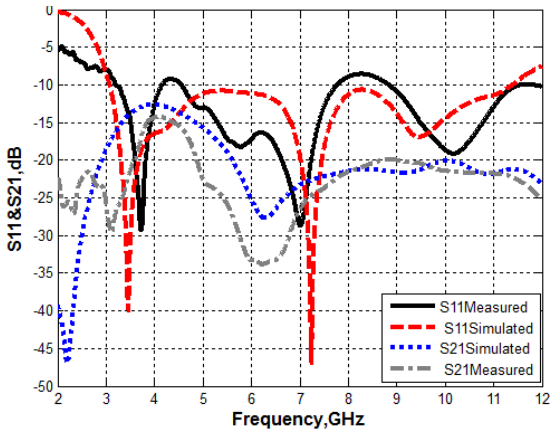

Fig. 2. Simulated and measured results of the proposed UWB two-element MIMO antenna.

Fig.3 shows simulated and measured directive gain the proposed UWB MIMO antenna at port 1, while port 2 is matched with 50-Ω load, and vice versa. The proposed antenna was measured in an anechoic chamber. The antenna radiates in the *x*-*z*-plane omni-directionally; whereas the radiation in the *x*-*y*-plane is bidirectional. An agreement between simulated and measured results is obtained. Envelope Correlation Coefficient (*ECC*) is an important parameter that evaluates the behavior of the MIMO system. It is desirable to minimize ECC between antenna elements in order to achieve higher diversity [7]. ECC can be expressed in terms of S- parameters as [15]

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

Fig.4 illustrates the simulated and measured *ECC* of the proposed UWB MIMO antenna. It is evident that *ECC* of the MIMO antenna is below 0.003dB within the entire operating frequency band.

III. Conclusion

This paper presented the design of a two-element MIMO antenna for UWB applications. The two antenna elements have been arranged in a side-by-side configuration. The proposed design has been shown to operate in the frequency band from 3 GHz to 11.5 GHz, with a reflection coefficient below -10 dB, and an insertion loss -15 dB or deeper. An agreement between the simulation and measurement has been achieved.

Acknowledgment

The experimental work has been supported by the Grant Agency of Czech Republic under project number No 13-09086S.

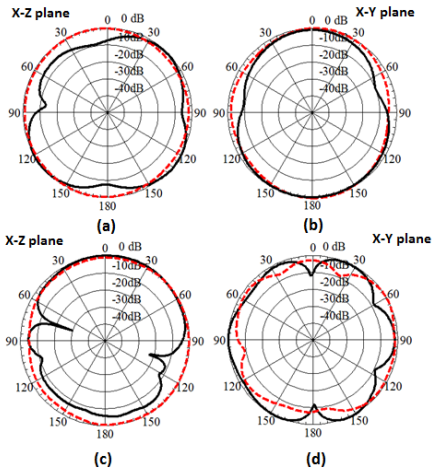

Fig. 3. Measured black(slolid) and simulated red (dashed) results of the directive gain at port 1 when port 2 is matched load at, (a) 4 GHz, (b) 4 GHz, (c) 10 GHz, (d) 10 GHz.

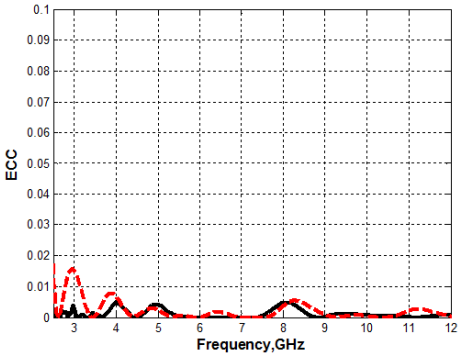

Fig. 4. Measured black(slolid) and simulated red (dashed) envelope correlation coefficent (*ECC*) of UWB two-element MIMO antenna.

References

[1] Federal Communications Commission, "Federal communications commission revision of Part 15 of the commission's rules regarding ultra-wideband transmission system from 3.1 to 10.6 GHz," FCC, Washington, DC, ET-Docket, 98-153, 2002.

[2] Mahmoud A. Abdalla, Ahmed A.Ibrahim, and Ahmed Boutejdar" Resonator Switching for UWB Antenna in Wireless Applications", IET Microwaves, Antennas & Propagation, Volume 9, Issue 13, p. 1468 – 1477, 2015.

[3] A. Boutejdar, and W. Abd ellatif, "A Novel Compact UWB Monopole Antenna with Enhanced Bandwidth Using Triangular Defected Microstrip Structure and Stepped Cut Technique," Microwave and Optical Technology Letters, 2016.

[4] . Ren, W. Hu, Y. Yin and R. Fan, "Compact Printed MIMO Antenna for UWB Applications," in IEEE Antennas and Wireless Propagation Letters, vol. 13, no. , pp. 1517-1520, 2014.

[5] Ahmed A. Ibrahim, Mahmoud A. Abdalla, Adel B. Abdel-Rahman, Hesham F. A. Hamed "Compact MIMO Antenna with Optimized Mutual Coupling Reduction Using DGS", International Journal of Microwave and Wireless Technologies, vol. 6, no. 2 ,2014

[6] L. Zhang, J. A. Castaneda, and N. G. Alexopoulos, "Scan blindness free phased array design using PBG materials," IEEE Trans. Antennas Propag., Vol. 52, No. 8, 2004, pp. 2000-2007.

[7] S. Blanch, J. Romeu, and I. Corbella, "Exact representation of antenna system diversity performance from input parameter description," Electron. Lett., vol. 39, no. 9, May 2003.