A60 GHz UWB-MIMO Antenna with Defected Ground for WPAN Applications

Syrine Lahmadi[1(✉)] and Jamel Bel Hadj Tahar[2]

[1] El Manar University, ENIT, Tunis, Tunisia
syrine.lahmadi@gmail.com
[2] Sousse University, NOCCS, Sousse, Tunisia

Abstract. The article presents a novel ultra-wideband (UWB) multi-input multi-output (MIMO) antenna with high isolation. The proposed MIMO antenna consists of four folded L-shaped strips patch which has very compact size of 2, 2 × 2, 2 mm^2. A line-slot is etched on the ground to reduce the mutual coupling on the 60 GHz band. Four other no-ended slots are etched on subtract to improve the impedance matching and to enlarge the bandwidth. Proposed antenna is resonating at 61 GHz. The mutual coupling is less than −15 dB throughout the 60 GHz band. The envelope correlation coefficient is less than 0.006 in the whole operating band. The performances of the proposed antenna indicate that it is a good candidate for UWB applications.

Keywords: Defected ground · UWB · ECC · MIMO

1 Introduction

The antenna is the most important element on the communication channel. It has the role of transmitting/receiving signal into free space. In old communication systems, a single antenna is used at the transmitter and a single one is used at the receiver. It's known as a single input/single output technology (SISO). This technology is very sensitive to multipath effects [1]. During the last years, in order to reduce this effect a new technology has been developed: multi input/multi output technology (MIMO). It consists on using multi antenna excited apart at the same frequency in the same antenna structure. This technology is an important solution to improve the capacity of wireless link [2].

However, MIMO antenna is affected by the radiation emission conductor and coupling losses caused by the radiating element which are placed on limited space. In literature, we can find many methods [3–5] to limit the mutual coupling and increase the efficiency and the gain of the system. One of the lowest cost method and less complicated to realize is to add slots [5]. The slots can be etched in different element of the patch antenna such in patch, in ground even in the subtract.

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2 Antenna Configuration

Figure 1 shows the geometry of the proposed MIMO antenna. It is printed on the silicone subtract with compact size of 2, 2 × 2, 2 mm^2, thickness of 0, 2 mm and relative dielectric constant of 11,9. The top layer consist of four radiating elements which are placed on vertical and horizontal to cover signals in both directions to enhance the preciseness of the signals [6]. This diversity technique reduces space and limits the mutual coupling between the radiators. Each element is fed by a meander line of 50 Ω impedance. The radiator is divided symmetrically by the central line. At each side, there is one L-shaped strip. On the bottom layer, there is a narrow ground plane with line slot for each radiating element. On the middle layer (subtract), there are four no-ended slots to ameliorate the performance of the MIMO antenna. Thanks to an soft HFSS and parametric studies, we obtain this optimized values (millimeters) of the proposed antenna: Lg = 1.1, wg = 0.1, w1 = 0.1, w2 = 0.1, w3 = 0.98, ws = 2.2, WL = 0.6, L = 0.1, X1 = 0.1, X2 = 0.4, X3 = 0.5.

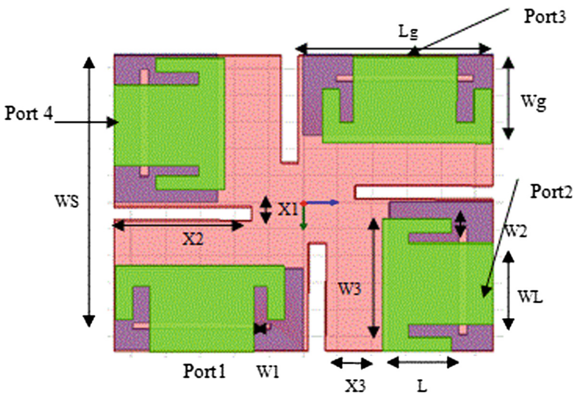


Fig. 1. Configuration of the proposed antenna

3 Antenna Design

The proposed antenna was developed step by step. The good performance in terms of high isolation, broadband impedance and bandwidth are attended by etching a stepped slot on the ground and a line slot on the subtract. These performances are also realized thanks to the inverted ground branches. It is used to limit the direct linking current between radiators [7].

3.1 Line Slot

The coupling between the two ports (port1/port2 and port2/port3) can be enhanced by increasing the distance between the radiating elements, but it will increase the physical area of the proposed MIMO antenna. So to maintain the compactness of the antenna, a line slot of dimension Ls1 × Ws1 is etched at the ground plane of each radiating element (Fig. 2b).

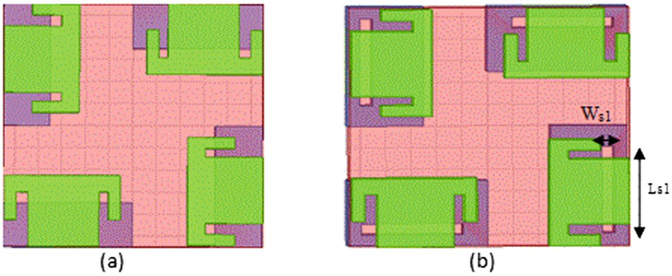


Fig. 2. The configuration of (a) antenna A (b) antenna B

Figure 3 shows a comparison of |s| parameters of antenna A and antenna B. As it shown, due to the introduction of this line slot the mutual coupling become lower than −15 db throughout the bandwidth (56.5–67.5 GHz). However, the adaption of the antenna is increased slightly. So to have a better isolation and good adaptation four no-ended sots are etched at the subtract.

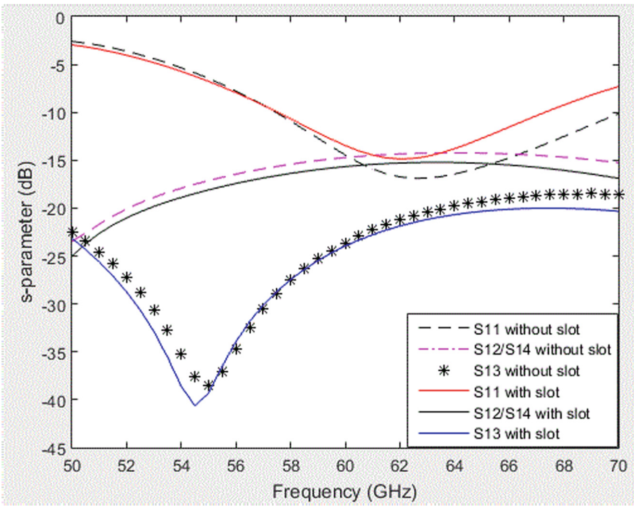


Fig. 3. The Simulated s-parameter

3.2 No-Ended Slot

To ameliorate the performance of the MIMO antenna (the impedance matching (sii) and the mutual coupling sij), a no-ended slot which is inspired from [8] is adopted as an element of the proposed antenna. The effect of different dimensions (x1, x2 and x3) of the no-ended slot was studied. For fixed length of the no-ended slots x2 = 0.1 mm and a position of x3 = 0.5 mm, the simulated reflection coefficient for different width x1 are shown in Fig. 4. As can be seen in Fig. 4, the bandwidth is more and more important when the width is narrower.

The effects of the slots lengths are also studied. Fig. 5 shows the simulated mutual coupling (s12/s14 and s13) at the length of the slots changed for width x1 = 0.1 mmn. the isolation increase with the increasing of the slots length.

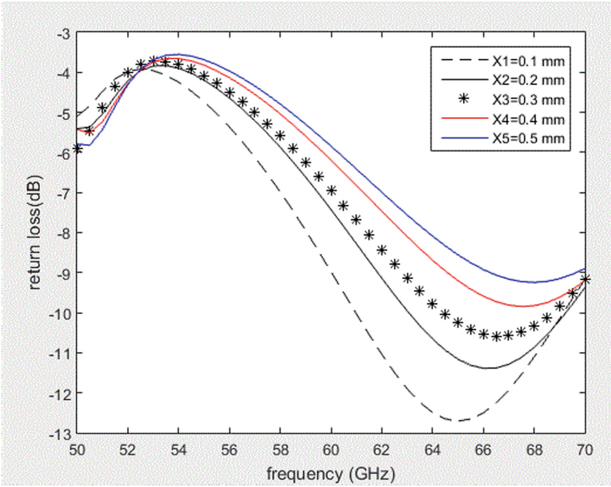


Fig. 4. The simulated S11 for different slot width

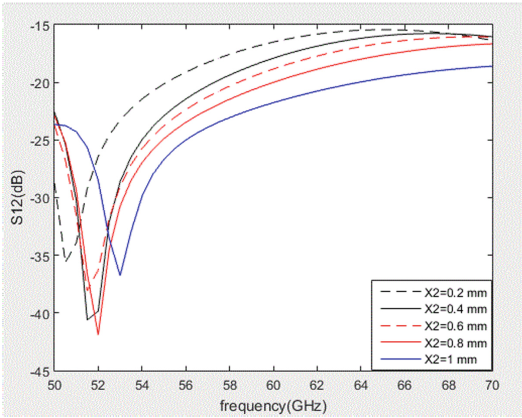
The slot position, x3 denote the spacing between the slot and the middle of the proposed MIMO antenna. By adjusting the position of the slot, the proposed MIMO antenna can achieve a good impedance matching. In Fig. 5, results for the parameter x3 is varied from 0.2 mm to 0.5 mm are shown.

As shown in Fig. 6, the simulated S11 is more interesting when the slot is nearer to the middle of the antenna. Good S11 is obtained when the position is x3 = 0.5 mm

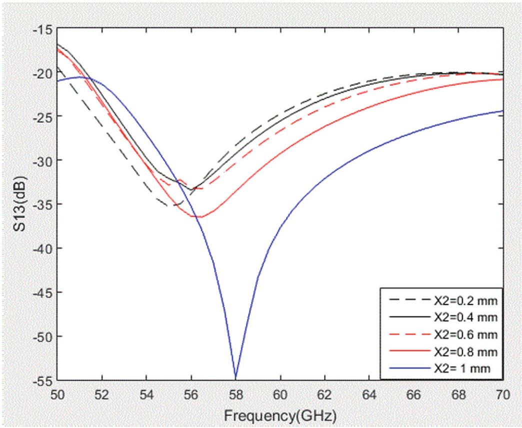
4 Results

4.1 S-Parameter

From HFSS simulated s-parameters, we find that the return-loss at different ports is s11 = s22 = s33 = s44, and the mutual coupling between adjacent ports is s12 = s21 = s14 = s41 = s32 = s23 = s34 = s43, and at diagonal ports s13 = s31 = s42 = s24. The return loss is the same for different ports because the radiating elements are the same. As shown on Fig. 3, The MIMO antenna without slots on subtract (Fig. 2b) is having −10 db impedance band of 56.5–67.5 GHz .it resonate at 61 GHz frequency where the return loss is −15 db. In this case the achieved bandwidth is 10 GHz .When



(a)



(b)

Fig. 5. The simulated (a) S12/s14 (b) S13for different slot

the proposed antenna (with slots on the subtract) having −10 db impedance band of 52–70 GHz. The bandwidth of 18 GHz is obtained here. In this case, the proposed antenna resonates at 61 GHz, where the return loss is −27 db. That means the fours slots made at the subtract improve the wideband and the impedance matching. Concerning the isolation, there is a good one along the 60 GHz band. As can see in Fig. 7, the mutual coupling is less than −15 db.

4.2 The Voltage Standing Wave Ration

The VSWR informs about the power reflected from the proposed MIMO antenna. It also indicate how efficient antenna input impedance is coordinate to the impedance of the transmitter line (in this case it is 50 Ω). Figure 8 shows the VSWR of the proposed antenna is less than 2 along the bandwidth. It attains 1.1 at 61 GHz.

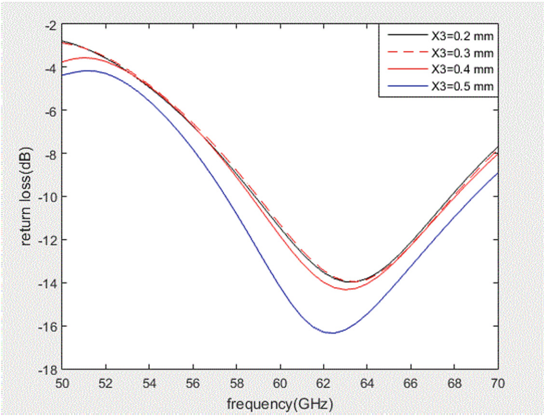


Fig. 6. The simulated S11 for different position X3

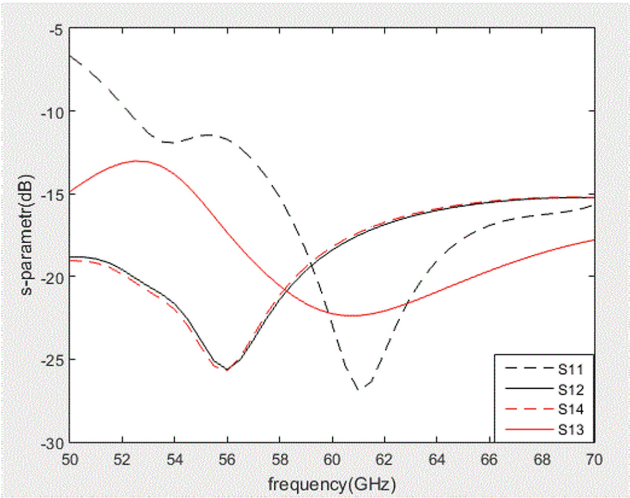


Fig. 7. The simulated S-parameter

4.3 The Radiation Efficiency

The radiation efficiency of a MIMO antenna must be important (about 0.9) to assure a good performance. The efficiency is affected by dielectric (especially when relative dielectric is very high like in this case), losses caused by conduction and losses due to the reflection. As shown in Fig. 9, the proposed MIMO antenna has a very high efficiency (high than 0.9) in the UWB frequency band.

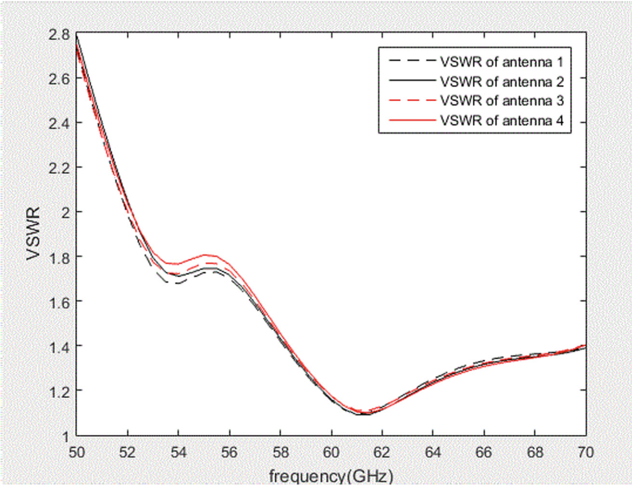


Fig. 8. The simulated VSWR of the proposed antenna

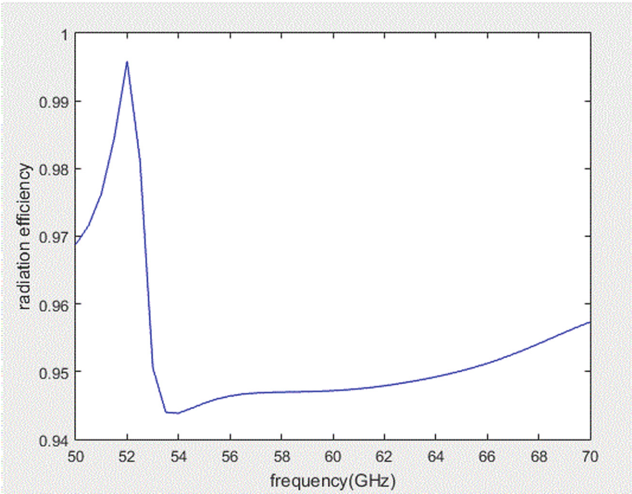


Fig. 9. The simulated radiation efficiency

4.4 The Envelope Correlation Coefficient

Orderly, to confirm the capability of the proposed antenna for MIMO application, it is obligatory to have a low envelope correlation coefficient (ECC). The envelope correlation coefficient describes how much the communication channels are isolated. To have a value of 0.5 as an envelope correlation coefficient is acceptable for diversity condition [9]. It can be calculated using the following formula [10]:

$$\mathrm{ECC(i,j,N)} = \frac{\left|\sum_{n=1}^{N} S_{in}^{*} * S_{nj}\right|^2}{\prod_{k=(i,j)}\left[1 - \sum_{n=1}^{N} S_{in}^{*} * S_{nk}\right]} \quad (1)$$

where i, j are the antenna elements and N is the number of the antenna

Figure 10 shows the simulated envelope correlation coefficient (ECC) of the proposed antenna. As can be seen, the ECC of the proposed structure is less than 0.006 between any of the two ports.

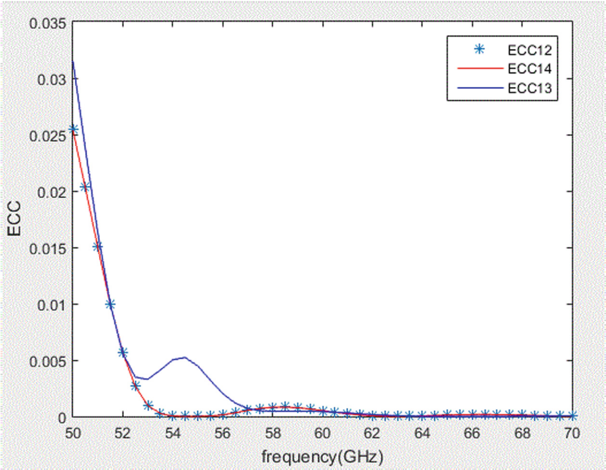


Fig. 10. The simulated ECC of the proposed antenna

5 Conclusion

A novel MIMO antenna with polarization diversity technique has been developed to limit the problem of multipath propagation. The proposed MIMO antenna offer a large bandwidth over 18 GHz which is enough to cover the 60 GHz band. With the optimized antenna geometry and the slots added to the ground, the proposed MIMO antenna provides good performances in term of good return loss, radiation efficiency and envelops correlation coefficient which is less than 0.06 in the whole operating band.

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