A Modified U-Shaped Patch Antenna for 4G MIMO Communication Systems

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Abstract

A modified U-shaped patch antenna for triband applications with improved bandwidth and isolation characteristics is presented in this paper. The proposed antenna resonates at triband of 8 GHz, 9.73 GHz and 11.1 GHz frequencies for VSWR ≤ 1.4, with an improved impedance bandwidth of 42.3%. A 2×2 MIMO is developed by using the proposed antenna with a reduced mutual coupling of -40 dB. The simulation results of return loss, mutual coupling, VSWR and gain are presented. The proposed antenna is a good choice for MIMO systems operating for several Wideband applications.

Keywords: *U-shaped patch antenna, triband, MIMO system, Impedance bandwidth, Mutual coupling, VSWR*

1. Introduction

In the present advanced wireless communication systems, MIMO (Multiple Input Multiple Output) technology plays an important role for achieving improved data rates. The present 3G and 4G technologies requires larger data rates with high speed, quality of transmission, and accuracy. MIMO systems are very much suitable for the present and emerging communication systems like Wi-Fi, 3G and 4G, *etc.* Patch antennas are very much compatible with MIMO systems because they are easier to fabricate and are inexpensive, low in weight, planar or conformal layout, and are able to be integrated with electronic or signal processing circuitry. Patch antennas can be designed in any desired shape like ring, circular, triangular etc. Flexibility in patch antenna design makes it preferable for many modern wireless communication applications.

In recent years the demand for the design of tri-band [1] or multiband antennas is increased, as these antennas can integrate more than one communication standards in a single compact system. In this paper, we propose a modified U-shaped microstrip patch antenna giving triband operation with improved bandwidth and reduced mutual coupling with a simpler structure.

The multiple antennas placed at smaller spacing in the MIMO system suffer from a major problem called mutual coupling. The physical causes of the mutual coupling between two identical patch antennas are studied in [2]. Usually, in multiple input and multiple output systems the basic aim is to minimize the correlation between the multiple signals. The parameter that describes the correlation between the received signals is mutual coupling, which deteriorates the performance of the communication system [3]. The main source of mutual coupling is surface current flowing through the ground surface. To reduce these surface currents flowing on the ground surface, there are several techniques like

Electromagnetic band gap structure [4], defected ground structure [5], decoupling techniques, *etc*... However, all these methods make the design of the antenna more complicated.

In the present work, a modified U-shaped patch antenna MIMO system is proposed yielding better results in terms of return loss, mutual coupling and impedance bandwidth. The designed antenna resonates at a triband of 8 GHz, 9.73 GHz and 11.1 GHz frequencies for VSWR ≤ 1.4, with an improved impedance bandwidth of 42.3% and reduced mutual coupling between the antenna elements is small and is less than -40 dB. The antenna design is simulated using the EM simulator. In section 2, the proposed antenna geometry is presented and in Section 3 the two element MIMO array system is presented.

2. Antenna design

Even though the microstrip patch antennas have some advantages like low cost, light weight, simple implementation process and conformability it suffers from its narrow bandwidth. Hence, the present work mainly focuses on the improvement of impedance bandwidth. The impedance bandwidth of the patch antennas can be improved by using various techniques like introducing parasitic elements, increasing the thickness of substrate and modifying the shape of the antenna and by introducing slots on the patch.

To support the high data rates of present wireless systems, the antennas are to be designed with wideband characteristics. Most of the engineers on MIMO system design focused either on improving impedance bandwidth or reducing the mutual coupling, but in this paper we handled both the problems simultaneously. Hence, in the present literature, a modified U-shaped microstrip patch antenna that can give both improved bandwidth and reduced mutual coupling values is developed. The developed antenna gives the mutual coupling values less than -40 dB over the operating frequency ranges 7.6 GHz to 11.7 GHz. This lower value of mutual coupling is achieved without using any complex techniques like Electromagnetic band gap structure, defected ground structure, decoupling techniques, *etc*... An improved bandwidth of 42.3% is achieved using the proposed antenna.

The structure of the proposed antenna is shown in Figure 1. The dimensions of the geometry are given in the Table 1. For better performance, a thick dielectric substrate having a low dielectric constant is desirable as it provides better efficiency, larger bandwidth and better radiation. Here, the substrate selected for the design of the proposed antenna is RT/duroid®5880 of thickness 3.2 mm and with low permittivity (εr=2.2). The dimensions of the substrate are taken as 100 × 90 × 3.2 mm3.

Microstrip patch antennas can be fed by a variety of methods. These methods are classified into two categories which are contacting (direct) and non-contacting. The four most popular feeding techniques used are microstrip feed, co-axial probe feed, aperture coupled and proximity coupled feeding. Here the whole system is fed by a co-axial probe at the position (X0, Y0) = (2 mm, 1 mm) as it is simpler to implement.

The area of the proposed antenna is 26 × 26 mm2. The left and right arms have same dimensions. L1 is the length of the arm and H1 is the width of the arm. L is the length of the patch and H is the width of the patch. Two rectangular slits were placed on each side of patch, which are responsible for the improved bandwidth. The length of the slit is L2 and the width of the slit is H2. The distance between left arm and right arm is L5. The return loss of the proposed antenna is shown in Figure 2, giving an impedance bandwidth of 42.3 % between the frequencies 7.6 GHz to 12.7 GHz, and resonates at a triband of 8 GHz, 9.73 GHz and 11.1 GHz frequencies for VSWR≤ *1.4*.

Table 1. Dimensions of the proposed antenna

Parameter	L	L_1	L_2	L_3	L_4	L5
Units (mm)	26	6	4	12	10	14
Parameter	H	H_1	H_2	-	-	
Units (mm)	26	16	3			

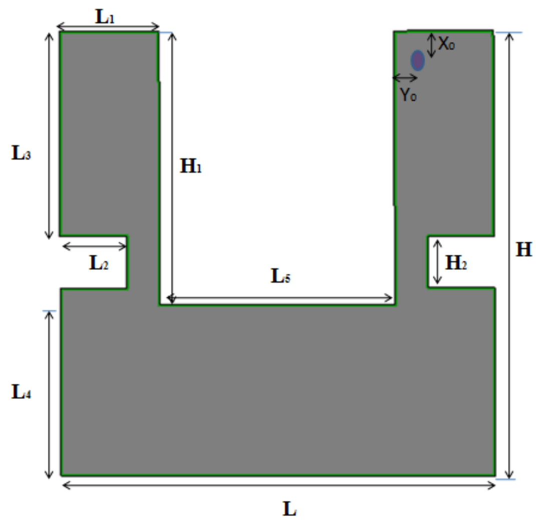


Figure 1. Proposed modified U-shaped microstrip patch antenna

The proposed patch antenna gives an improved bandwidth of 42.3% which higher compared to the bandwidth normal U-shaped antenna with same dimensions. The Figure 3 shows the return loss of the normal U-shaped antenna and the bandwidth is obtained as less than10%. The Figure 4 presents the comparison of both normal U-shaped and proposed modified U-shaped microstrip patch antenna.

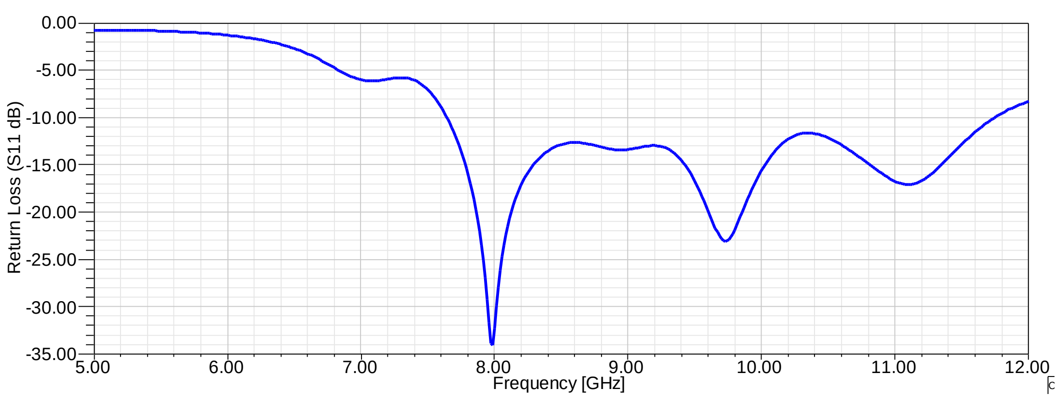


Figure 2. Return loss of the proposed antenna

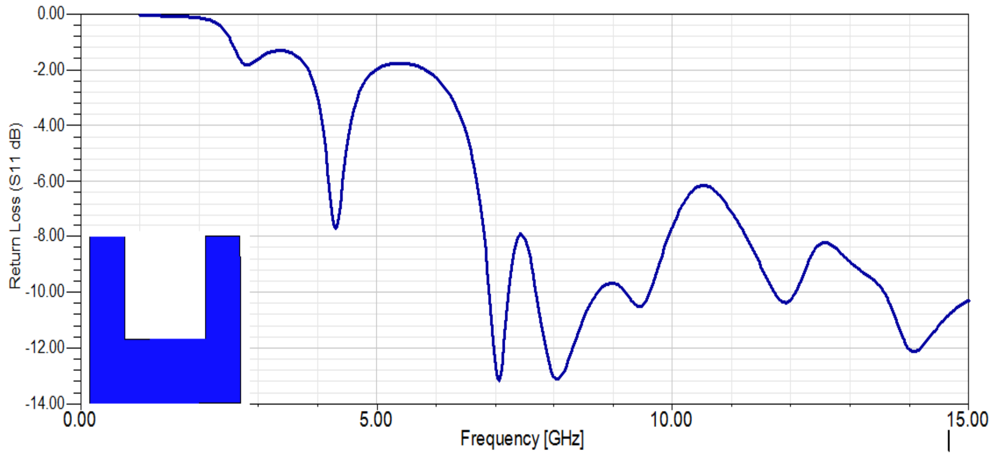


Figure 3. Return loss of the normal U-shaped microstrip patch antenna

The Figure 3 shows the return loss of the normal u-shaped antenna which has similar dimensions of the proposed U-shaped antenna. By making two rectangular slits on both sides of the U-shaped antenna we achieved the bandwidth of greater than 42% and a 2×2 MIMO system is developed using the proposed antenna giving an excellent isolation of 40 dB between the two antenna elements.

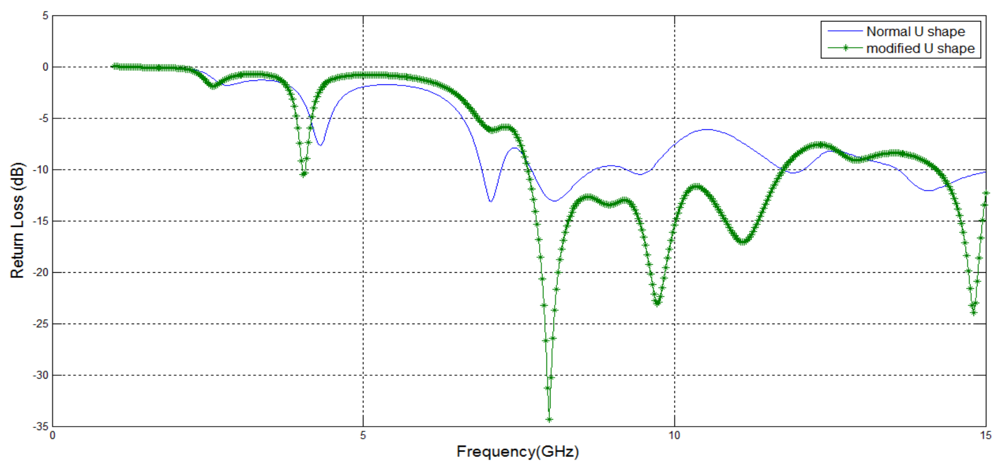
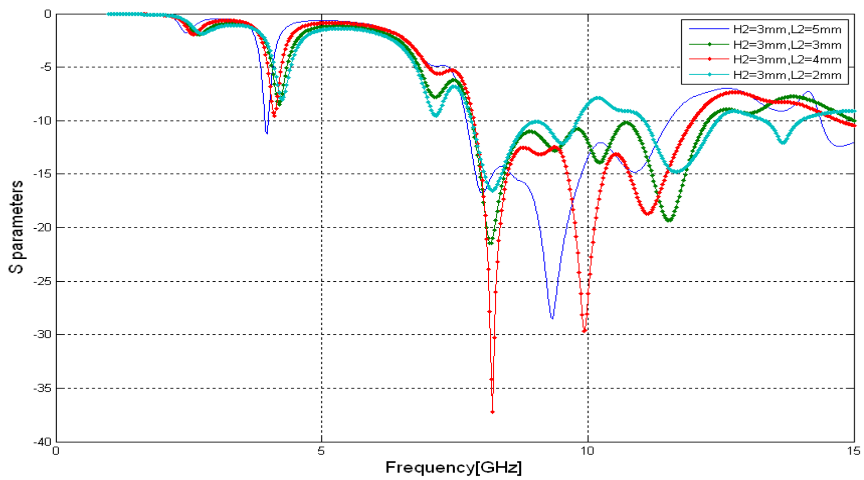
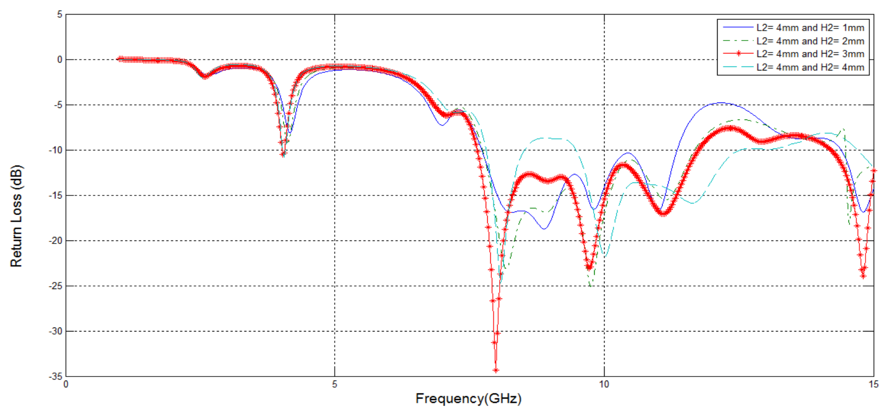


Figure 4. Comparison of return loss between normal U-shape and Modified U-shaped antenna

There are two rectangular slits on each side of the patch as shown in Figure 1. The parametric analysis of slit dimensions is given below. The Figure 5(a) presents the simulated results of the proposed antenna with slot lengths L2= 2, 3, 4 and 5 mm at H2=3 mm. The return loss is observed to be better at L2= 4 mm. Figure 3(b) shows the simulated results of the proposed antenna with slot widths H2= 1, 2, 3 and 4 mm at L2=4 mm. At H2=3 mm, the return loss is found to be better compared to other values. Hence, these particular values of L2 and H2 are chosen for the design of the antenna.



(a) Effect of L_2 on Return loss at H_2=3 mm.



(b) Effect of H_2 on Return loss at L_2=4 mm.

Figure 5. Effect of rectangular slits on Return loss

3. Two Element MIMO Array Using the Proposed Antenna

As mentioned earlier, the major problem faced by the designers in MIMO systems is mutual coupling, which arises mainly due to the electromagnetic interactions between the antennas in the array. This problem mainly occurs due to the small spacing between the antennas in the array. However, when multiple antennas are involved at closer spacing the design issues are more complicated compared to a SISO (Single Input Single Output) system. The mutual coupling depends on the distance between the elements in a MIMO system. If the distance between the antennas is more, the mutual coupling becomes less and vice versa. However, the distance between the antennas cannot be maintained too large as MIMO systems have their major applications in mobile terminals, laptops, and WLAN access points wireless communications [6], where size of the device can't be maintained too large. The reduction in mutual coupling can be achieved by properly choosing the shape of the antenna and without increasing the distance between the elements. The mutual coupling can be minimized by using diversity techniques, which is mentioned in [7] and [8].

In the present paper, a 2×2 MIMO system is developed by using the proposed modified U-shaped patch antenna as shown in Figure 6. For the proposed MIMO system, the separation between the elements is taken as 10 mm. For the proposed MIMO array, the dimensions are same as that of the single modified U- shaped patch antenna shown in Figure 1.

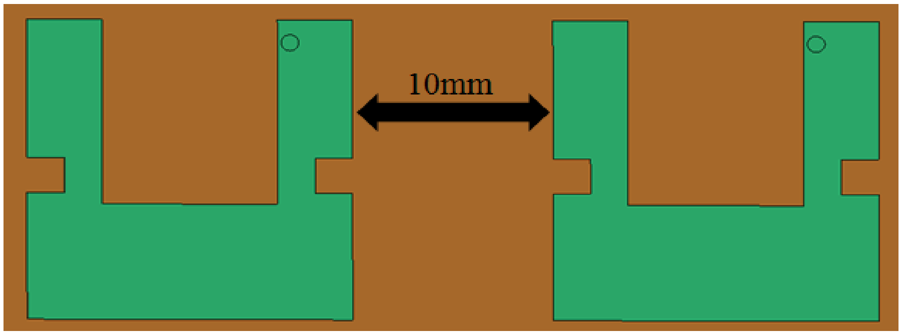


Figure 6. A two element MIMO array using proposed U-shaped antenna

The Figure 7 shows the simulated results of return loss and mutual coupling of two element MIMO array using proposed antenna in dB. The proposed antenna resonates at triband of 8 GHz, 9.73 GHz and 11.1 GHz frequencies for VSWR ≤ 1.4, with an improved impedance bandwidth of 42.3% (7.6 GHz to 11.7 GHz), covering a part of Ultra Wideband (UWB) frequencies. The two element MIMO array gives an excellent isolation of 40 dB, which is a very small for a separation of 10 mm between the two antennas. This isolation is achieved without using any additional decoupling elements and the developed antenna system meets well the requirements of wireless MIMO systems, where the antennas are to be separated at lower spacing.

Table 2. Results obtained with the proposed antenna

S.NO	*Resonant frequency (GHz)*	*Return Loss (dB)*	*VSWR*	*Isolation (dB)*
1)	8	-34	1.06	40
2)	9.73	-24	1.14	23
3)	11.1	-16	1.35	22

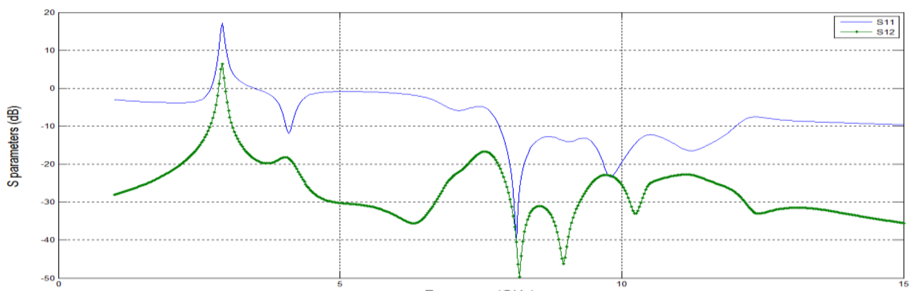


Figure 7. S parameters of the proposed MIMO array

The return loss of single antenna and their corresponding resonant frequencies, VSWR and isolation of 2 ×2 MIMO system are given in Table 2. The Figure 8 shows the VSWR plot of the proposed antenna. The plot gives the desired values of VSWR at the resonant frequencies, which are less than 1.4. The VSWR value is observed as 1.06, 1.14 and 1.35 at the resonant 8 GHz, 9.73 GHz and 11.1 GHz respectively, indicating excellent matching conditions. The Figure 9 shows the obtained radiation Patterns of the proposed antenna at various resonant frequencies. From Figure 10, we can observe that the gain at the resonant frequencies is more than 7 dB, which is sufficient for many wireless applications.

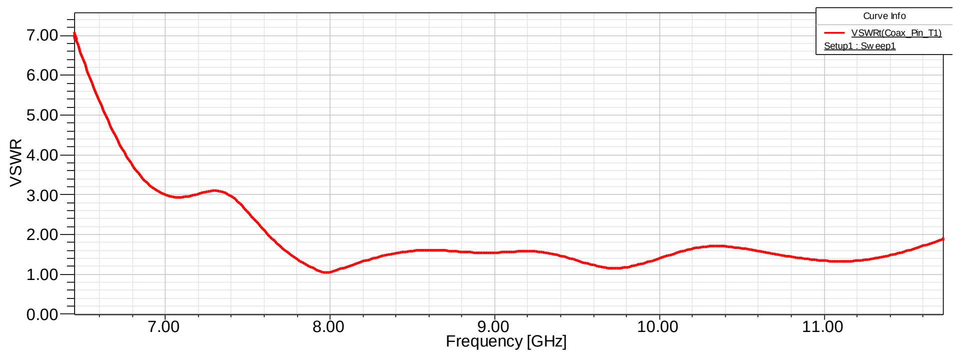
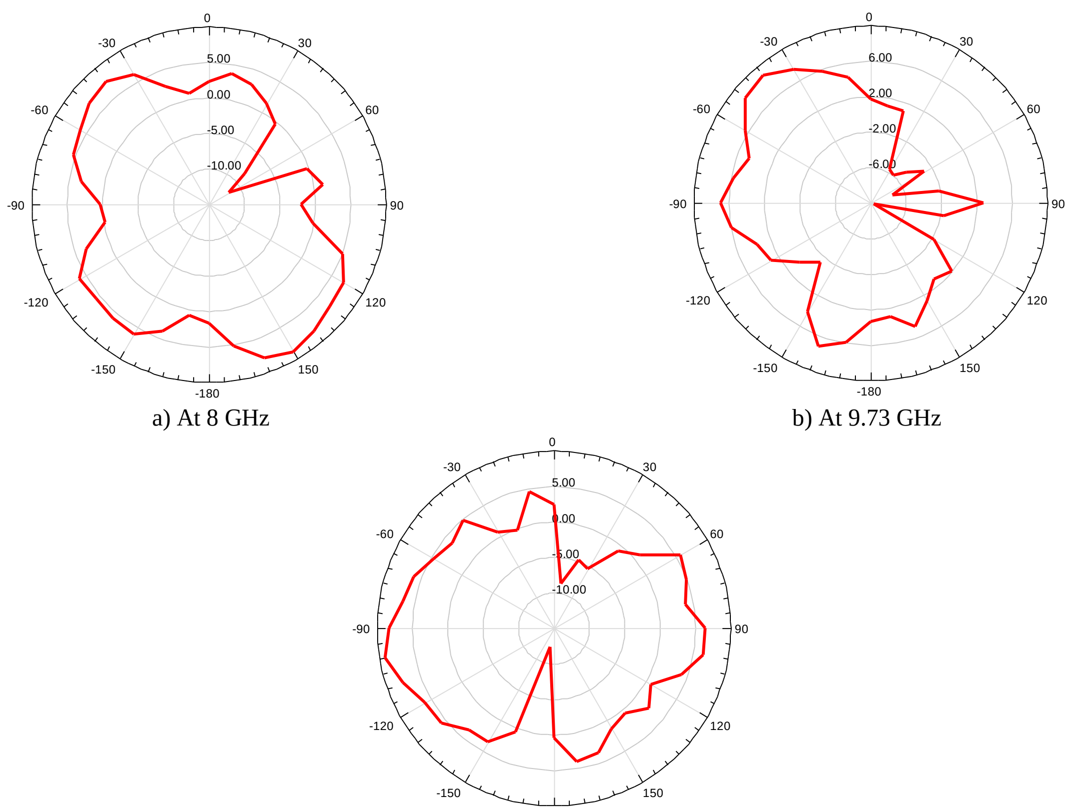


Figure 8. VSWR plot of the proposed Antenna



a) At 8 GHz

b) At 9.73 GHz

c) At 11.1 GHz

Figure 9. Radiation patterns of the proposed antenna

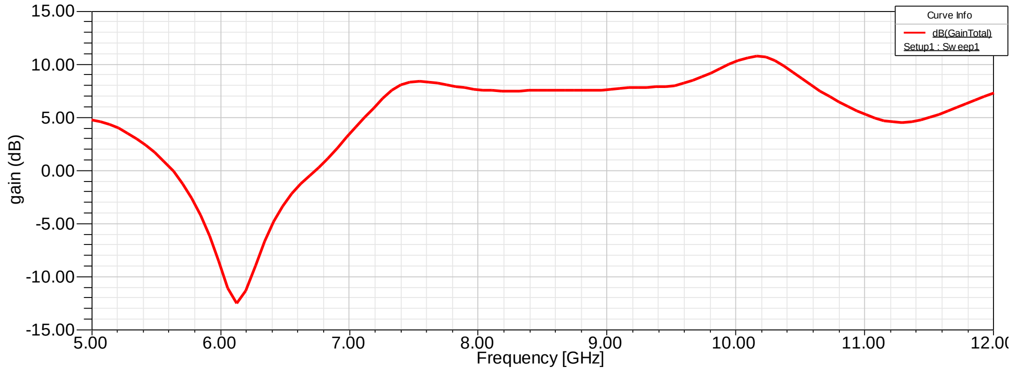


Figure 10. Gain plot of the proposed antenna

4. Conclusion

In this paper, a modified U-shaped patch antenna is proposed and a two element MIMO array is developed using the proposed antenna. The proposed antenna resonates at a triband of frequencies 8 GHz, 9.73 GHz and 11.1 GHz with an improved impedance bandwidth of 42.3% and a reduced mutual coupling of –40 dB. The obtained results are well suited for all 4G MIMO applications. The proposed study can be extended by employing more number of antennas in MIMO system for improving the channel capacity of the MIMO systems.

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