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A new patch antenna for ultra wide band communication applications

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ABSTRACT

A printed monopole patch Ultra Wide Band (UWB) antenna for use in UWB application is proposed in this paper. The proposed antenna consists of a patch with appropriate dimensions on one side of a dielectric substrate, and a partial ground plane on the other side of the substrate. The techniques that used to enhance the bandwidth are the partial ground plane, feed point position and adjusted feed gap. The substrate that is used in the proposed antenna is Fr4 epoxy, the optimum dimensions of the antenna are 40mm×28mm×1.5mm this antenna designed by HFSS program. The band achieved by the proposed antenna is from 3.6GHz to 15GHz. This antenna is fabricated in the ministry of science and technology Baghdad-Iraq and a good agreement between simulation and measured S11 is achieved.

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1. INTRODUCTION

In communication systems, there are constantly demand to increase the rate of data transfer [1, 2]. The increase the rate of transfer information can be achieved by either increase SNR or bandwidth according to Shanon-Nyquist (1) [3].

$$C=B\log_2(1+SNR) \tag{1}$$

Ultra-wideband is a technology used to increase the bandwidth, this technology is recognized by the Federal Communication Committee (FCC), it has a bandwidth of up to 7.5GHz, from 3.1GHz to 10.6GHz [4-9]. This technology sends the data in form of a train of pulses instead of using carrier signal to transmit the data, the width of these pulses is very narrow estimated few nanoseconds, so it has a wide band spectrum [10, 11]. The UWB system has advantages such as the power consumption is low because it does not use carrier signal, high data rate due to large bandwidth and low interference [12, 13]. UWB antenna is an important element and plays an important role in the ultra-wideband system, it has features such as the size of it is small, its weight is light and low profile. These properties make it suitable to use in a portable device and it can be integrated with a circuit of radio frequency and it has simple structure so it is easy to fabrication, and its cost is low as well as it has high precision ranging [1, 14-16]. Due to physical features of monopole antenna such as small size, the cost of it is cheap, and simple combination making it good choice use as a UWB antenna [2, 11, 15, 17-23]. A patch antenna is the type of UWB antenna and it is a planar antenna consist of three layers the medium layer is a substrate it is a dielectric material the lower layer is printed on the lower side of the substrate is a conductive sheet called ground plane and an upper layer called patch.

The patch can be in different shapes such as rectangular, circular and any other shape printed on the upper side of the substrate is a conductive material in different shapes called patch with the feed line [24].

In this paper, the design and optimization of the printed patch ultra-wideband antenna is presented. A strip feed line technique used to feed the radiator element, the proposed antenna designed by using High Frequency Structure Simulator (HFSS) software program and fabricated in the ministry of science and technology by using Fr4 epoxy substrate. This paper show simulation and the measured result of return loss and compare between them and show a simulation result of the radiation pattern, gain, and current distribution.

2. ANTENNA GEOMETRY

This patch antenna consists of the dielectric substrate and finite ground plane printed on the lower surface of the substrate and patch with feeder printed on the upper surface of the substrate. The form of the patch is a merge of a square with three triangles shown in Figure 1. The dielectric used is Fr4 epoxy has a dielectric constant 4.4, loss tangent 0.02 and thickness 1.5mm. The feed technique used is microstrip feed line of 50Ω has a width 2.89mm connected between the port and patch for exciting the radiator. There is a relation between the lower edge frequency of bandwidth of ultra-wideband and dimension of the patch so the dimension of patch calculated according to this (2) [25]:

$$\text{fl (GHz)} = \frac{7.2}{(D+0.2785D)\sqrt{\varepsilon_{reff}}} \quad (2)$$

Where:
ε_{reff} is effective permittivity.
D is dimension of patch.
f_l is lower edge frequency.

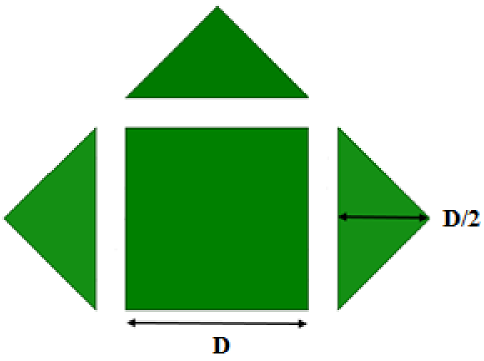


Figure 1. Patch shape

3. PARAMETRIC STUDY

Optimization is done to find the optimum dimensions of the proposed antenna by using the sweep parameters method.

3.1. Effect of Ground Plane Width

The first technique which is used to get wideband to achieve UWB requirement is a partial ground plane that means cut the ground plane. All parameters of design are fixed and chosen arbitrarily. To choose the optimum width of the ground plane different values are tested. Figure 2 shows the simulation of the effect of the ground width on the bandwidth.

It is clear that the bandwidth increase when the width of ground plane decrease until the width reach to 10mm when the best matching impedance occurred so the best bandwidth achieved but when width ground plane decreases more than this value the bandwidth is decreasing so the best width of the ground plane is 10mm.

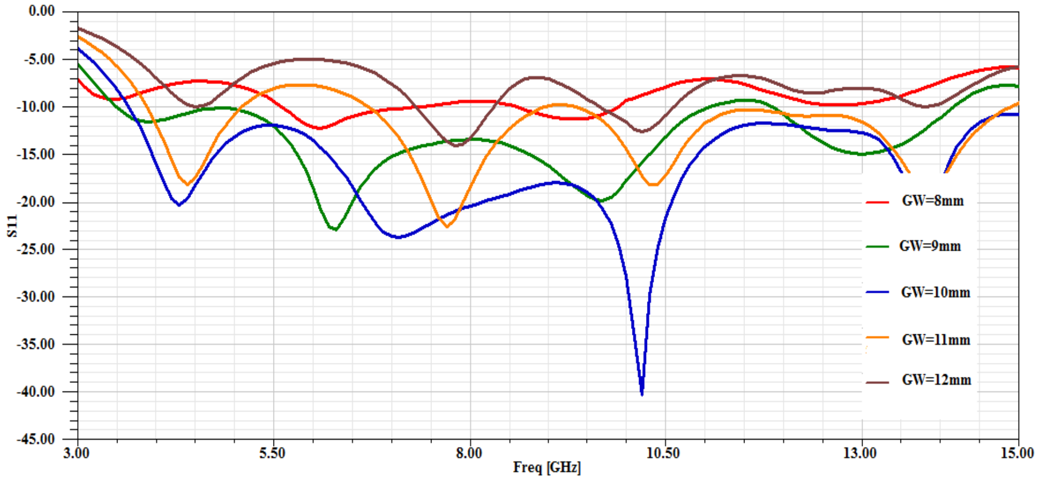


Figure 2. The effect of ground width on the bandwidth

3.2. The Effect of Ground Plane Length

The second parameter tested is the length of the ground plane when other parameters are fixed. Figure 3 shows different values of ground length, it is noticed that the change of ground length effect on the upper edge of bandwidth, the best value that achieved best matching impedance is 40mm, if the length of the ground plane is less or greater then this length the bandwidth is smaller and that means the matching impedance is worse.

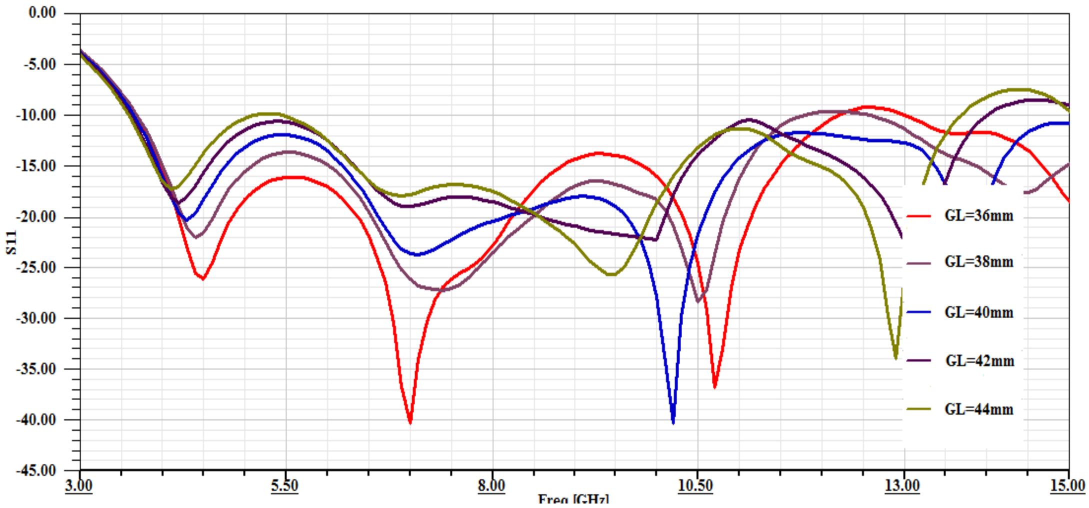


Figure 3. The effect of ground length and substrate length on bandwidth

3.3. The Effect of Substrate Width

The third parameter tested is the width of the substrate, this parameter has no large effect on the bandwidth so the less width that achieved a bandwidth of ultra-wideband is 28mm. Figure 4 shows the parameter test to find the best value of this parameter.

3.4. The Effect of Feed Point Postion

The fourth parameter tested is the feed point position at this test the required is to find the best connection point between the patch and the feed line to find the best matching impedance position. All points from the begging edge of the patch to the other edge of the patch are tested and the best feed point is that achieved to determine the best matching impedance, the best value is -3.163, the Figure 5 showing the effect of feed point position on bandwidth.

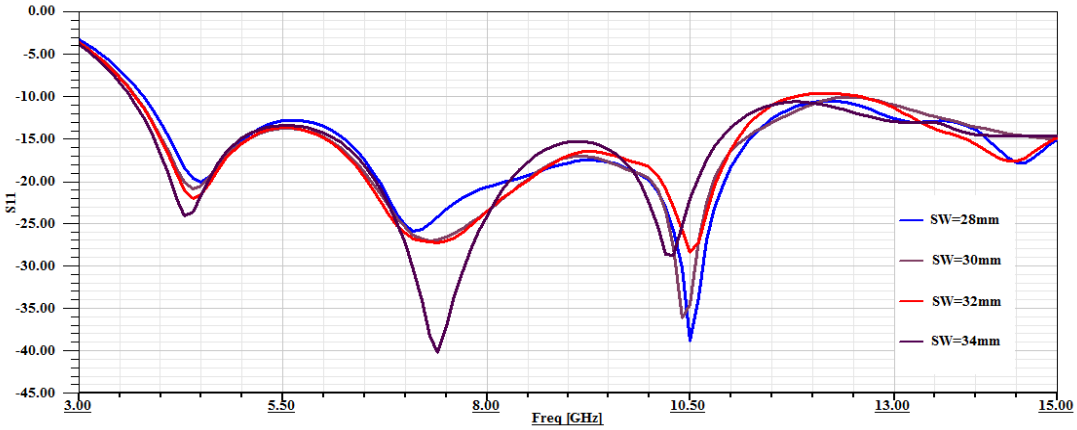


Figure 4. The effect of substrate width on bandwidth

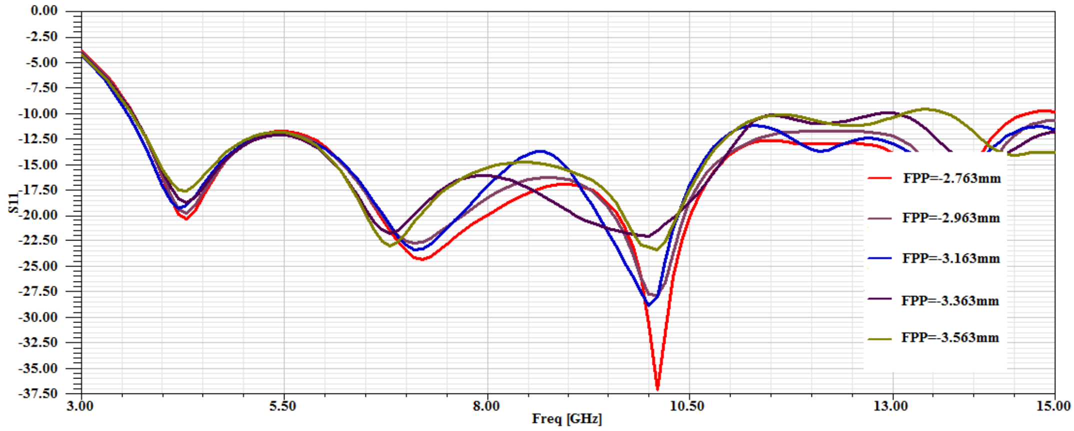


Figure 5. The effect of feed point position on band width

3.5. The Effect of Feed Gap Dsitance

The last parameter tested is feed gap distance, the feed gap is the distance between the top edge of the ground and the bottom edge of the patch this parameter has an important effect on the bandwidth. Figure 6 shows the different values of the feed gap tested to choose the best value of the feed gap that achieved maximum bandwidth. From this figure it is noticed that when the feed gap distance is equal to zero the bandwidth is small when this gap increases the bandwidth increase too until this distance equal to 0.4mm the bandwidth reaches to its max value therefor; this value can be taken as the best value of this distance.

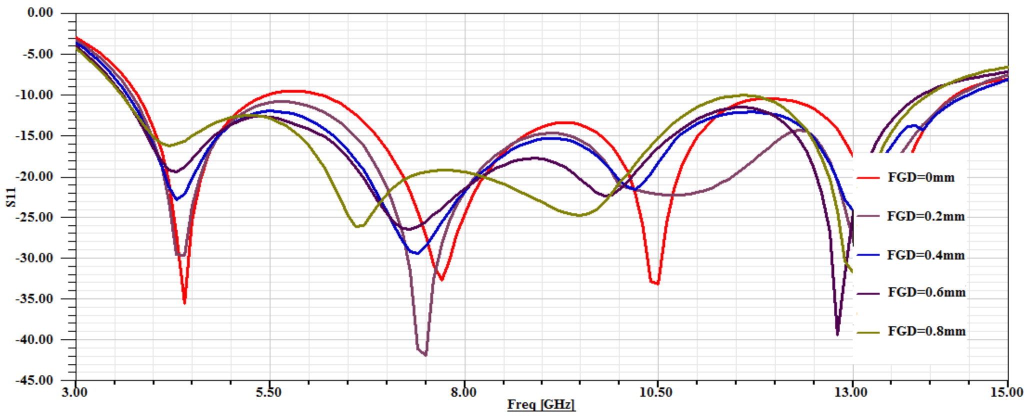


Figure 6. The effect of feed gap on band width

The proposed patch antenna is shown in Figure 7. The optimum values of all parameters that affect the performance of the proposed antenna are presented in Table 1 and the reflection coefficient of the proposed antenna shown in Figure 8. The proposed antenna with its optimum dimension is fabricated in the ministry of science and technology Baghdad-Iraq as shown in Figure 9.

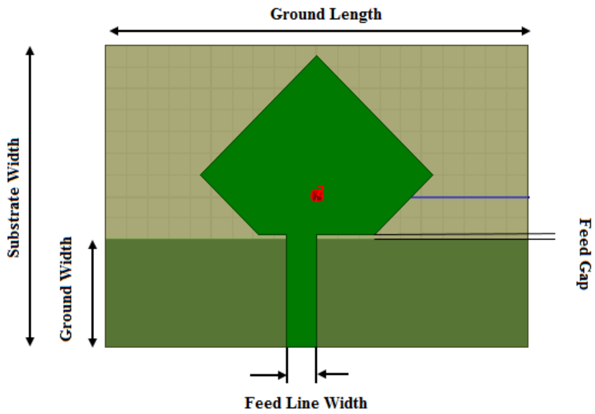


Figure 7. Proposed patch antenna

Table 1. Optimal Design Parameters of Proposed Patch Antenna

Parameter	Value (mm)
Ground Width (GW)	10
Ground Length (GL)	40
Substrate Length (SL)	40
Substrate Width (SW)	28
Feed Point Position (FPP)	-3.163
Feed Gap (FG)	0.4
Feed Line Width	2.89

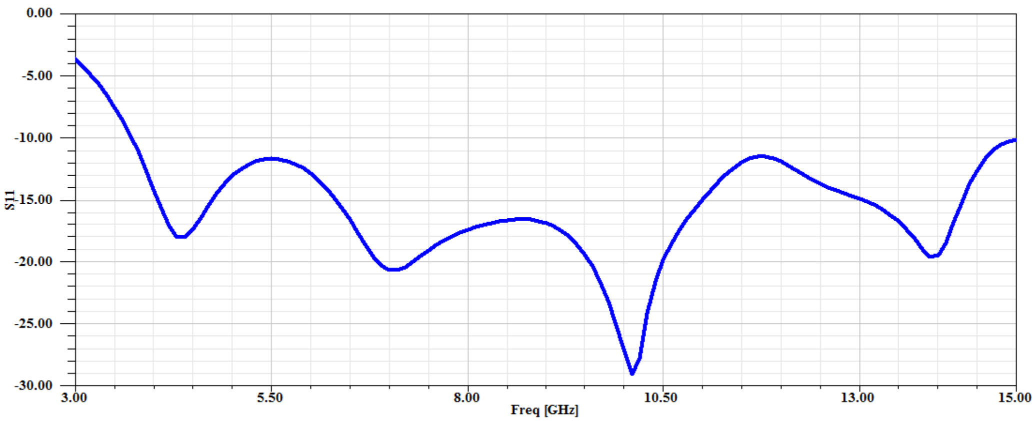
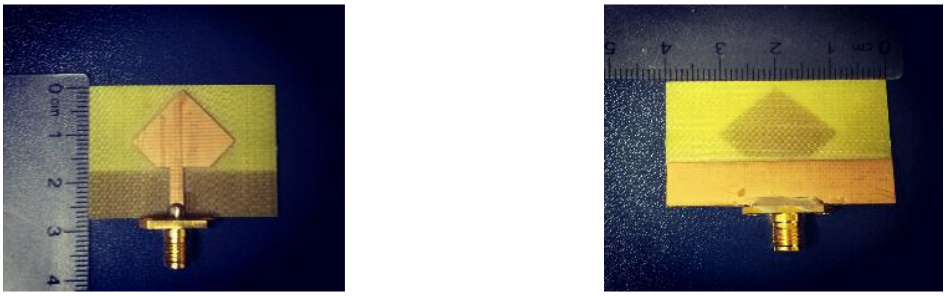


Figure 8. Simulated input reflection coefficient of proposed antenna



Top view Back view

Figure 9. Photo of the prototype patch antenna with optimum dimensions

4. RESULT AND DISCUSSION

The simulated results of the printed monopole patch antenna are obtained using the Ansoft simulation software High Frequency Structure Simulator (HFSS). Figure 10 shows input reflection coefficient S11in both cases simulated and measured for the designed antenna is lower than-10 dB from 3.6 GHz to 15 GHz this band covered the required bandwidth for ultra-wideband technology. A good agreement between the simulated and measured result of S11with a simple shift to the right due to the effect of SMA connector, the tolerance of manufacture and impurities of the constructed materials.

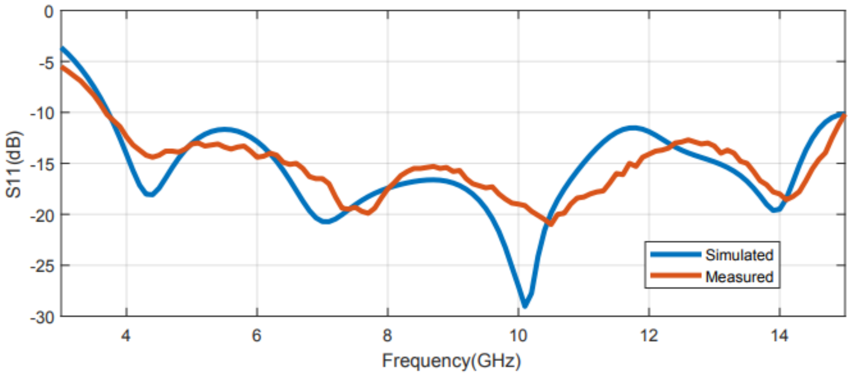
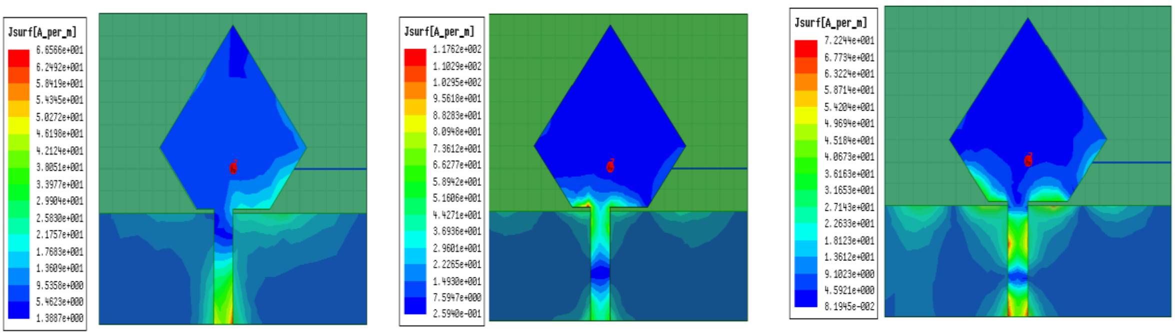


Figure 10. S11 comparison between simulation and measurement results

5. CURRENT DISTRIBUTION

The proposed antenna with optimum dimensions is simulated at different frequencies 4GHz, 8GHz, and 12 GHz, and Figure 11 below show the simulation of current distribution at these frequencies. For the three different frequencies, the current distribution is mainly concentrated along the lower edge of the patch and along the transmission line at selected frequency but the distribution of current on the ground plane increase with frequency increased.

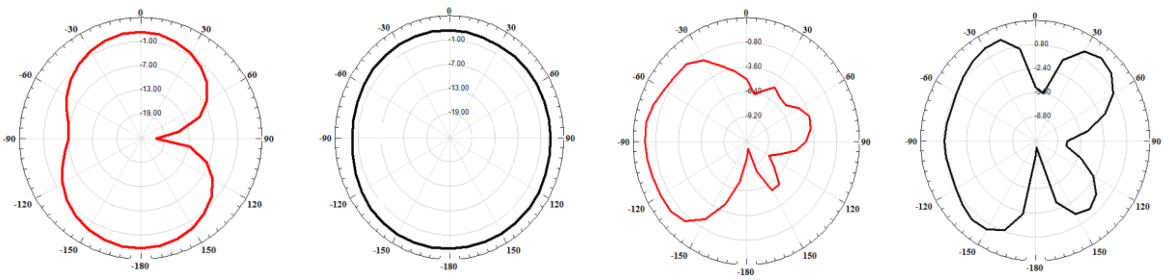


(a) 4GHz (b) 8GHz (c) 12 GHz

Figure 11. Current distribution of surface on the antenna structure: (a) at 4GHz (b) at 8GHz (c) at 12GHz

6. RADIATION PATTEN

The simulated E-plane and H-plane radiation patterns of the optimal antenna structure are shown in Figure 12 below at frequencies 4 GHz, 10 GHz, and 12 GHz respectively. It is clear that these patterns have an omnidirectional pattern at a lower frequency and nearly omnidirectional at medium and high frequency, which are needed for UWB applications. Figure 12 shows the simulated radiation pattern at a different frequency over the range of UWB, both E-plane and H-plane are shown.



E-plane at 4 GHz H-plane at 4GHz E-plane at 8 GHz H-plane at 8GHz

E-plane at 12GHz H-plane at 12GHz

Figure 12. Radiation pattern: (a) 4 GHz (b) 8 GHz (c) 12 GHz

7. GAIN

Figure 13 shown the antenna gain versus frequency. The proposed antenna has relatively low gain at low frequencies and the gain gradually increasing, at medium frequencies little degradation occurred in gain the maximum gain is (6.1) dB.

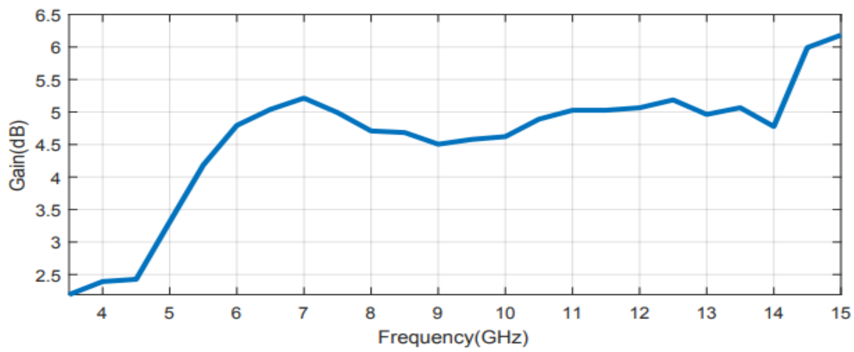


Figure 13. The gain versus frequency

8. CONCLUSION

A printed monopole patch UWB antenna is designed by HFSS program with optimum dimension 40mm*28mm*1.5mm and it was fabricated. From the study of the parameters of the proposed antenna, we concluded that the change of feed gap effect on upper edge of bandwidth larger than the effect on the lower edge of bandwidth, when the feed gap equal to zero the bandwidth is small and the bandwidth increase when the feed gap increase until certain value and the change of ground length effect on upper edge of bandwidth, the results show the bandwidth of proposed antenna from 3.6 GHz to 15 GHz and maximum gain is 6.1 dB, this antenna can be used in UWB applications.

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