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Design of a New Ultra Wideband (Uwb) Microstrip Antenna

Vala Tashvigh* and M. Tayfun Günel

Department of Communication Systems, Satellite Communication and Remote Sensing Programme, Istanbul Technical University, Istanbul, Turkey; v.tashvigh@gmail.com, gunelmur@itu.edu.tr

Abstract

Background/Objectives: Employing an antenna with the structure of heptagon patch and proper slots to reduce the size of the antenna while keeping the UWB bandwidth. **Methods/Statistical Analysis:** All the simulations have been done using HFSS software. The geometries of the antenna were determined by implementing parametric studies using this software. In the designed antenna, uniform ground plane prevents back lobs in radiation pattern and makes it suitable for some applications such as medical usages. **Findings:** Through this design, an antenna that is applied for UWB application can be achieved with a low cost and can be fabricated on a simple substrate. Not only does it cover a favorable bandwidth, but also has a new shape for its patch. The antenna's small size, desired bandwidth with acceptable gain in comparison to previously designed or fabricated antennas can make it a good candidate for future analyses. Another benefit of this designed antenna is employing probe feeding technique to improve bandwidth as well as other related parameters of UWB antennas. **Application/Improvements:** All the simulations have been done using HFSS (high frequency structural simulator) software.

Keywords: Bandwidth, Microstrip Antenna, Ultra Wideband

1. Introduction

Talking about wireless technologies is meaningless without considering antennas. Good and reliable wireless connection requires enough transmitting power, enough bandwidth, and etc. In order to provide these requirements, every part of a system should work well and antenna as the beginning or ending part of a system plays an important role. Since, the first steps of electromagnetic waves recognition, antennas known as a metallic element and different types of them introduced to the world. In recent past, by introducing microstrip technologies, microstrip antennas became as a part of interest in industry and academia. Among these revolutions in technology, there was an increasing demand for miniaturizing components, providing more bandwidth to transmit more information, higher data rates and etc. These demands on the other hand caused frequency bands saturation. So, technology needed another revolution to overcome these problems.

Ultra Wideband is one of these revolutionary technologies that introduced to overcome the aforementioned problems. It tries to solve problems by reusing the occupied bands, 3.1 to 10.6 GHz, but at very low power transmission. This technique, using low transmitting power, makes it invisible for other narrow band radio systems and allows to share the used spectrum. It needs to notice that implementing UWB technologies is very complex, since the devices need to work fast enough with the ability of working in very low power. So, the antennas in these systems need to operate in ultra broadband spectrum with the ability to receive and transmit in a low power.

The concept of multilayer substrate antennas in order to achieve greater bandwidth was reported[1]. These antennas which provide bandwidth of 16 times more than a standard patch antenna, constructed on alumina substrates with increased overall height. Another method was introduced to locate capacitive excited short circuit parasitic elements at their radiating edges. This method, doubles the bandwidth of microstrip patch antennas[2].

In[3], a broadband microstrip antenna was made by using thicker substrates of low dielectric constant. This

*Author for correspondence

is used as antenna element in an array for broadband operation. Assuming circular patch antennas as a basic broadband antenna, in[4] introduced a conical microstrip antenna with much larger bandwidth. The design of this antenna is based on the modification of the circular patch antenna by slightly depressing the patch configuration conically into the substrate.

In[5] reported a stacked two layer microstrip antenna as a base element of a 64 element Ku band array with 15% bandwidth increase. In[6] introduced a stacked configuration of triangular microstrip patch antennas to increase the bandwidth. In[7] developed a dual port microstrip antenna geometry to obtain dual frequency operation. The antenna provided wide bandwidth and excellent isolation between ports.

In[8] designed a stacked circular disc antenna using proximity fed technique with bandwidth of 26% and gain of 8 dBi. They used four linear slots in the bottom patch of the stacked arrangement. In[9] also investigated a broadband rectangular microstrip patch antenna with an L-shaped probe fed. In the proposed antenna a layer of foam is used as supporting substrate. This layer had a thickness of around 10% of the wave length. The antenna has an impedance bandwidth of 35% and an average gain of 7.5 dBi.

2. Analysis and Design

The geometries of the antennas in this paper are determined by implementing parametric studies using Ansoft HFSS. The software is an electromagnetic structure's solver, based on Finite Element Method (FEM)[10]. HFSS is known as one of the popular commercial tools using for antenna design, and complex RF electronic circuit elements such as transmission lines and filters. One of the outstanding features of this software (HFSS) is automated solution process. This means that, it is only needed to specify the geometry, material properties and the desired outputs. The software will automatically generate the appropriate mesh for solving the problem. Presenting work is based on previous works in this field. Detailed parametric study of the antenna will be discussed as follows.

2.1 A New UWB Microstrip Antenna using Coaxial Probe Feeding

Following sections present details of the new design to increase bandwidth in order to achieve the UWB frequency range and parametric study of the new antenna characters.

2.1.1 Antenna Design

The proposed Heptagon UWB antenna geometry and its dimensions are presented in Figure 1. This antenna is printed on a 30mm×30mm FR4 substrate with the thickness of 4mm and relatively permittivity of 4.4. The antenna ground is uniform, without any defected part. The antenna is fed by using probe fed technique. Tables 1 and 2 provides parameters of antenna and final achieved values of each parameter.

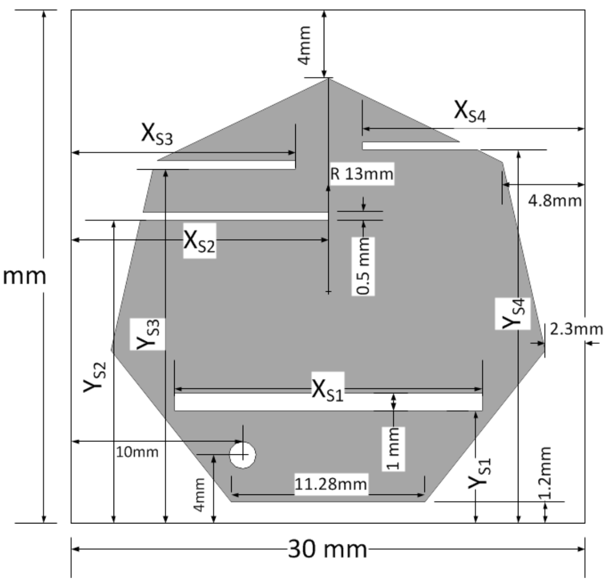

Figure 1 Geometry of the proposed antenna.

Table 1. Physical parameters of the antenna and final dimensions

Parameters	Dimensions (mm)
Total size	30mm × 30mm
Radius	13 mm
X_{s1}	18 mm
X_{s2}	15.5 mm
X_{s3}	9.1 mm
X_{s4}	14 mm
Y_{s1}	6.6 mm
Y_{s2}	16.7 mm
Y_{s3}	20.7 mm
Y_{s4}	22.3 mm

Table 2. A comparison the proposed antenna with the results of[11-13]

		proposed antenna in the thesis	proposed antenna in (11)	proposed antenna in (12)	proposed antenna in (13)
parameters	Size	30mm × 30mm	67mm × 74mm	50mm × 74mm	21.4mm × 4.5mm
	Bandwidth	2.2-11.5GHZ	5.17-5.81GHZ	3.87-13.46GHZ	10.3-17.9GHZ
	Substrate	FR4(∈ r-4.4		∈ r-2.2	∈ r=2.1and ∈ r=1
	Thickness	4mm	3.175mm	7mm	4mm
	Max.Gai	4.39dB (Φ =220, θ =20)	8.11 dBi	6dBi	7.53 dB

2.1.1.1 Study of the Effects of Shape and Feed Location

The introduced geometry has been selected by performing parametric analysis. Main parameters in this design are shape of the patch and location of the coax feeding. Figure 2 presents different positions of feeding that had been tested. It also represents current passes for each position.

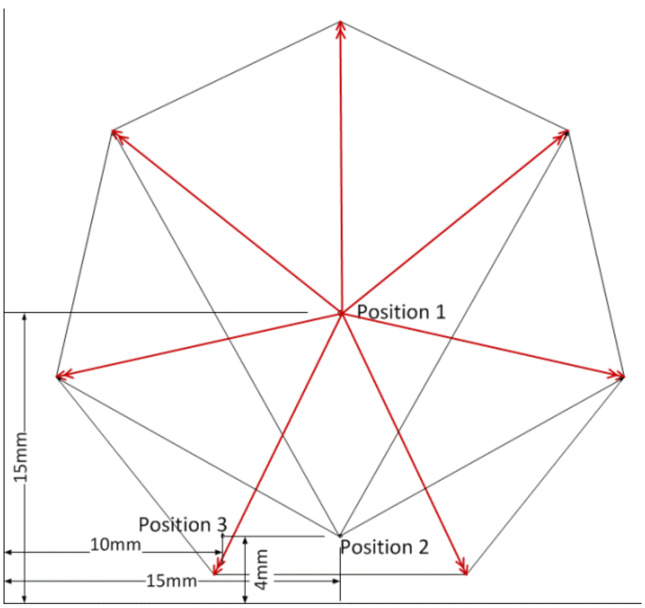

Figure 2. Different positions of feeding and current routs.

Location of the feed can be selected according to this fact that electrical length of antenna will determine the resonant frequency. Placing the feed in the center of the patch brings us almost equal lengths of surface current, see Figures 3–5 show the study of different shapes for patch with every three assumed position of feed. As it's shown in Figure. 3, we will achieve less than one gigahrtz bandwidth around the resonant frequency of 7.2 GHz. In next step, feed moved to the side of patch which causes different length for the current. As it's illustrated in Figure 4, there are still routes with the same length and so, it didn't result in a broad bandwidth. Thus, feed moved to a corner to imply different passes of current flow in the patch. Using this location for feed and shape of heptagon for patch, gave three resonant frequencies in 5.75GHz, 8.25GHz and 9.6GHz. Simulation result of |S11| for this location of feed is shown in Figure 5. As it is clear, shape of heptagon and feed in a corner, provides better |S11| in comparison with the others.

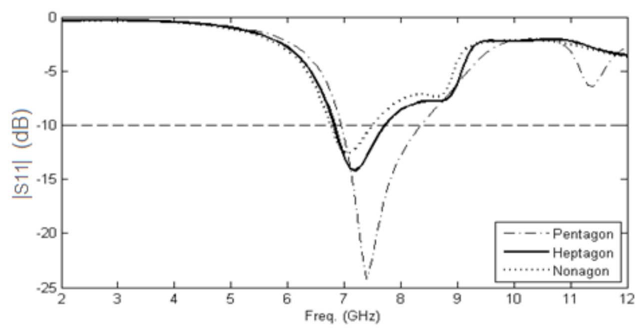

Figure 3. |S11| for different shapes of patch with the feed located in position 1.

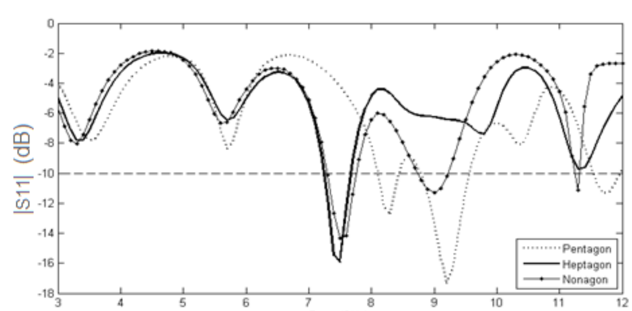

Figure 4. |S11|for different shapes of patch with the feed located in position 2.

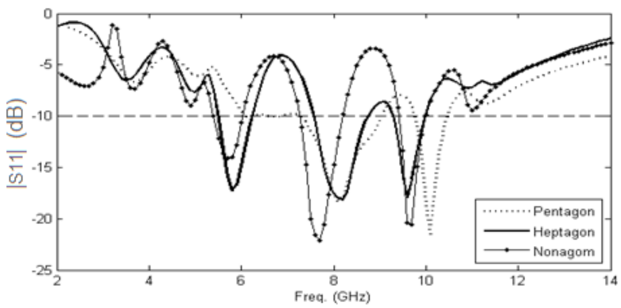

Figure 5. |S11| for different shapes of patch while locating the feed in position 3.

2.1.1.2 Effects of S1

By reconsidering the aforementioned idea as a basic theory, it's been decided to use slots, in order to control current passes in a desired rout with more accuracy. Slot, named S1, placed near the feed location which results two different passes for surface current with various lengths. Implementing this slot increases bandwidth around the resonant frequencies, also there is a slight shift in resonant frequencies. Figure 6 shows |S11| result using this slot. Surface currents for both structures, with and without slot of S1, presented in Figure 7, which simply clarifies the result of |S11|.

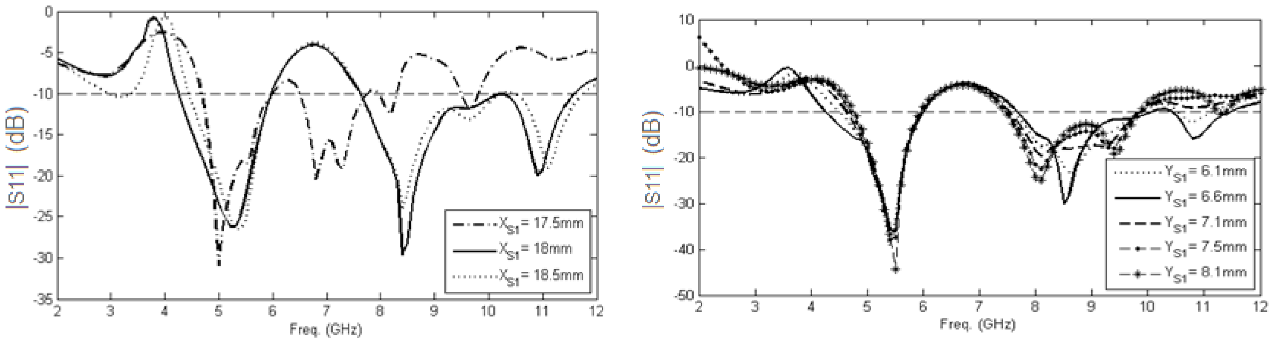

Figure 6. The effect of S1 while feed is in position 3. (a) Length of S1(YS16.6mm), (b) Position of S1 (XS1=18mm).

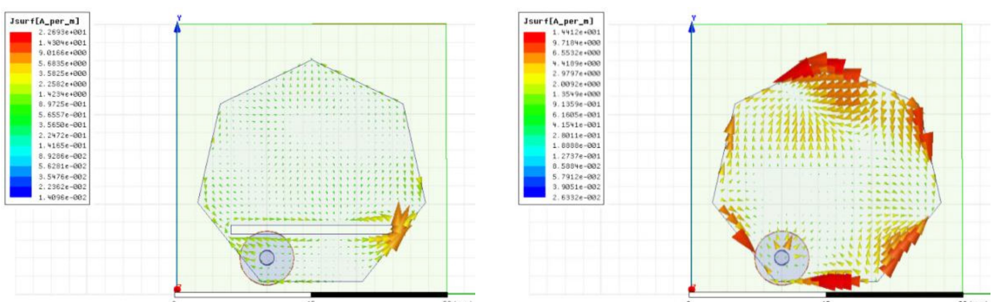

Figure 7. Surface currents and the effect of S1.

2.1.1.3 Effects of S2

By monitoring the surface current on the patch in different frequencies, it's determined that there is a need for another slot to control the path of the current. This slot which is shown as S2 in Figure 1, helps us in eliminating the notch between 6-8 GHz. Figure 8 shows parametric analysis for different positions of S2 to indicate the optimum location. Furthermore, the parametric study of the length of this slot is shown in Figure 9 and the optimum length of 15.5mm is selected. Surface current of the proposed patch with the slots S1 and S2 in various frequencies is shown in Figure 10 to clarify the passes of the current and achieved reason.

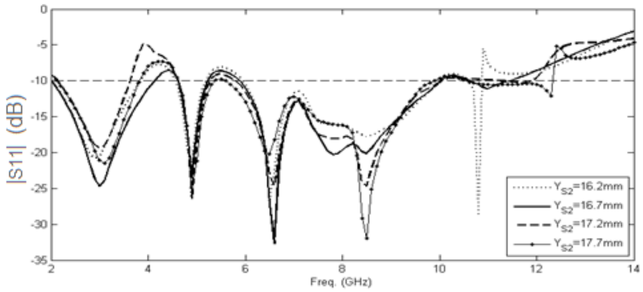

Figure 8. |S11|for different positions of S2 (X=15.5mm).

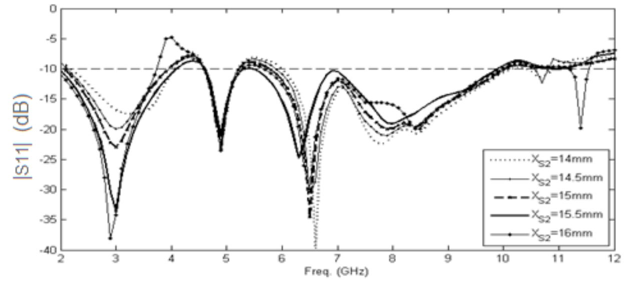

Figure 9. |S11| for different lengths of S2 (YS2=16.7mm).

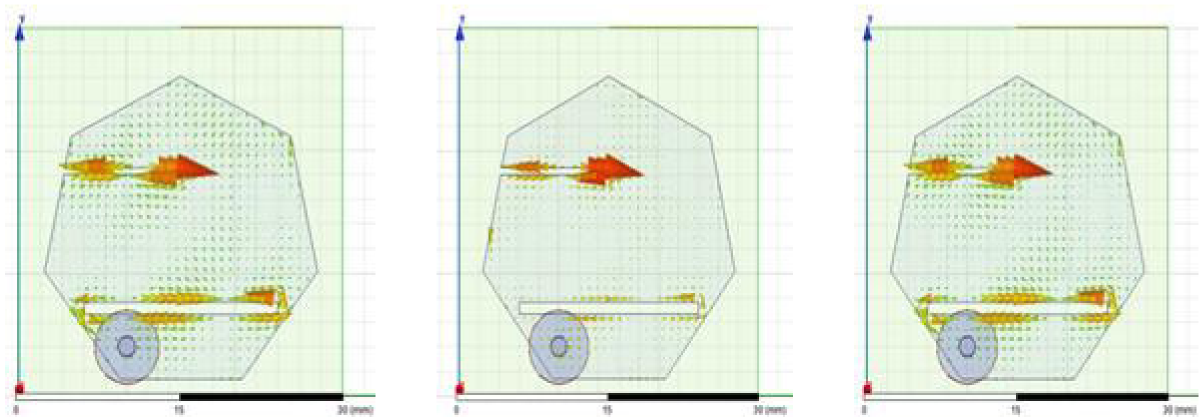

Figure 10. Surface currents of three resonant frequencies with S1 and S2.

2.1.1.4 Effects of S3

In the next step, a slot named S3 added to improve the results of the |S11| for proposed antenna. Figures 11, 12 shows parametric analysis of the length and position of this slot. As it's illustrated in Figure 11, adding this slot will help to control the band notch around 4GHz and able us to reach the bandwidth of 2GHz to 9.6GHz.

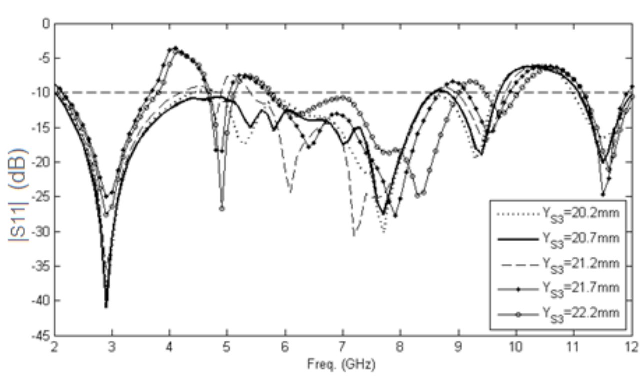

Figure 11. |S11|for different values of S3's position (XS3=9.1mm). with S1 and S2.

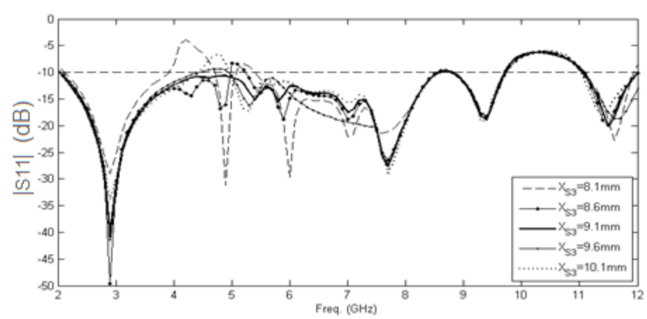

Figure 12. |S11| for various lengths of S3 (YS3=21.2mm). with S1 and S2.

2.1.1.5 Effects of S4

A good bandwidth using step by step moving forward achieved so far. But, according to the definition of UWB, 3.1GHz to 10.6GHz need to be covered. In order to reach this frequency range, another slot had been implemented, shown as S4. As it's illustrated in Figures 13, 14, by preforming parametric analysis on the position of this slot, optimum point reached.

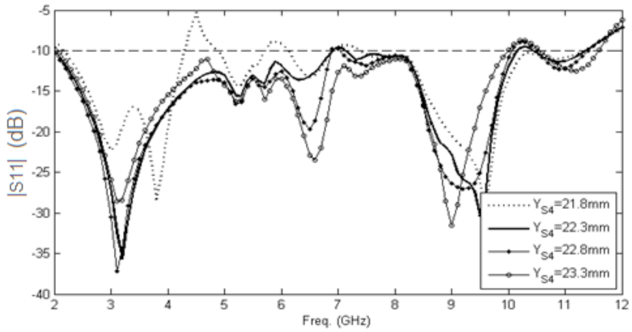

Figure 13. |S11|for different positions of S4 (XS4=14mm).

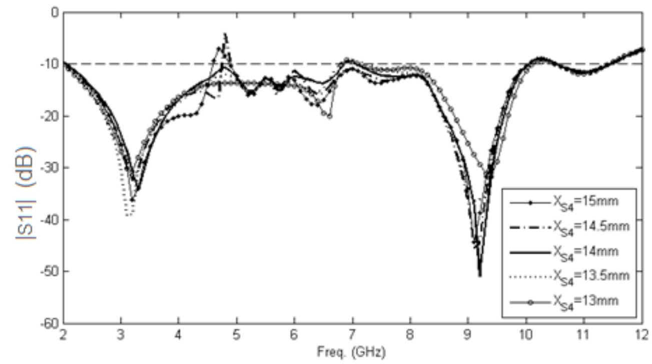

Figure 14. |S11| for different lengths of S4 (YS4=22.3mm).

2.1.1.6 Fabrication and Test

To validate the results of simulation, the proposed antenna has been fabricated and tested.

2.1.1.6.1 Radiation Pattern

As it's discussed, due to UWB applications, there is demand for omnidirectional radiation pattern. Figure 15 shows the radiation pattern of proposed antenna. It's clear that because of the uniform ground plane, radiation pattern has no back lob, but keeps its omnidirectional shape. Figure 16 shows 3D gain pattern in mentioned frequencies.

Figure 17 provides the gain of proposed antenna vs. frequency. In the proposed structure, the height of substrate reduces the antenna gain. But still it's acceptable for all known applications of UWB.

It also should be mentioned that, the according to the co and cross patterns of the proposed antenna, the polarization is linear (vertical). Figure 18 presents the efficiency of the proposed antenna which indicates acceptable efficiency in UWB band range.

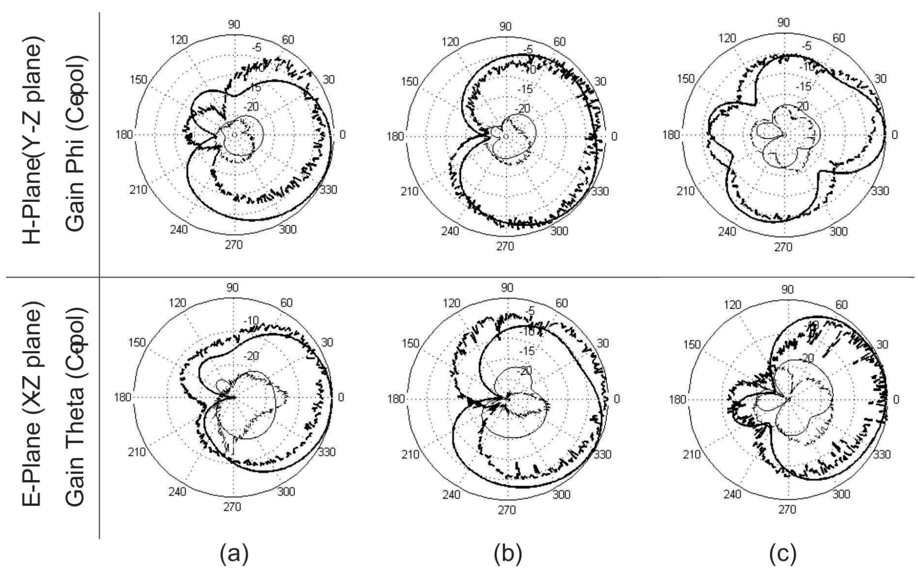

Figure 15. Normalized radiation gain patterns of the proposed antenna. (-) Simulated.(…) Measured. (a) 4GHz, (b) 6GHz, (c) 8GHz.

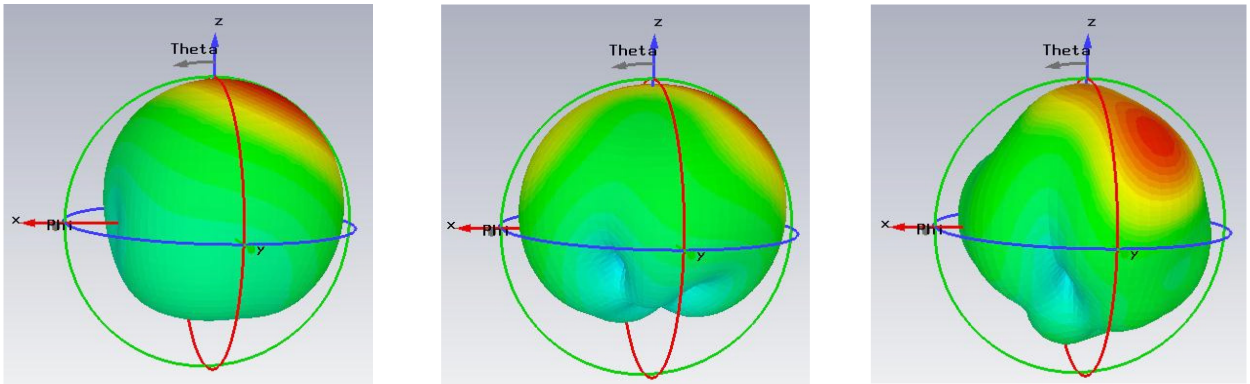

Figure 16. 3D gain pattern in (a) 4GHz, (b) 6GHz, (c) 8GHz.

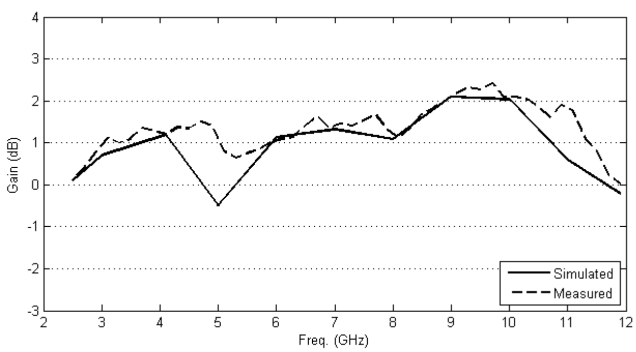

Figure 17. Gain of the antenna at θ=0, φ=0.

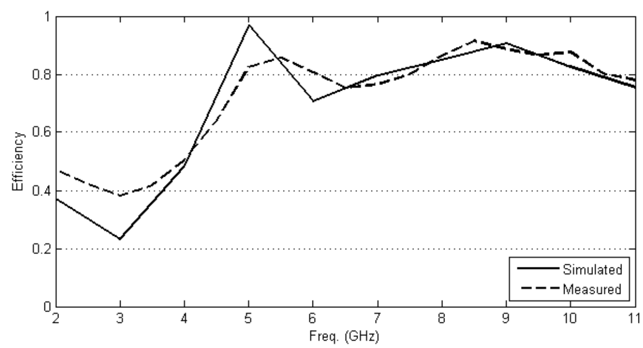

Figure 18. Efficiency of the proposed antenna.

2.1.1.6.2 Group Delay

Figure 19 shows the group delay diagram for all the available UWB frequencies. It's clear that, delay of this antenna is less than 2 ns which will provide a good communication state for different applications.

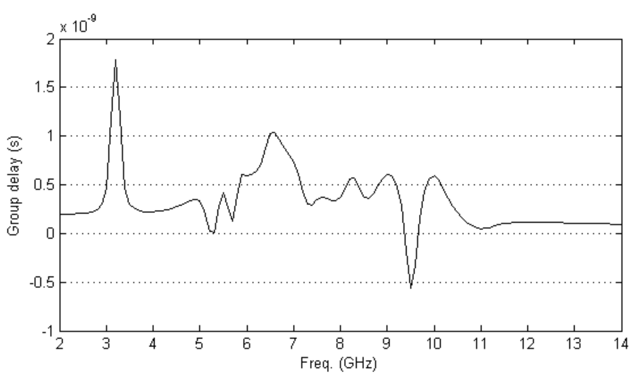

Figure 19. Measured group delay of proposed antenna.

Figure 20 shows the fabricated antenna. Figure 21 provides measurement results in comparison with the simulated |S11| of the antenna. The tests had been done using Agilent Technologies E8363C PNA network analyzer. Results show that fabricated antenna works well and provides the desired UWB bandwidth. However, there are mismatches because of fabrication process.

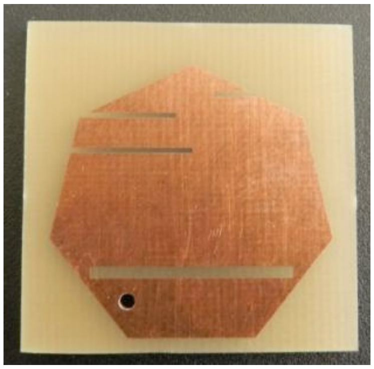

Figure 20. Fabricated antenna.

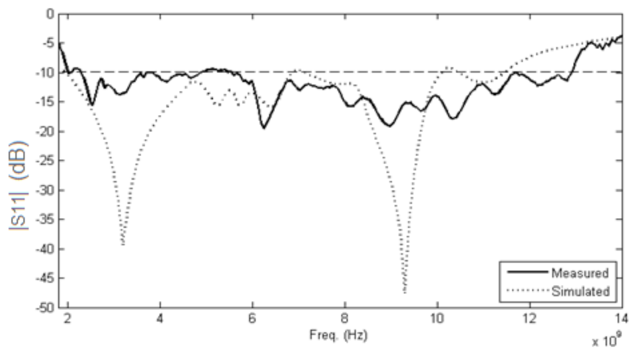

Figure 21. Simulated and measured |S11|of proposed antenna.

3. Conclusion

The major purpose of this paper was to achieve the two hypotheses mentioned in the first section. In this section, an overview of the work has been presented. A review study of previous works done and different techniques in widening bandwidth studied.

In the second chapter, it's tried to completely clarify UWB technologies, emphasizing the most important concepts in antenna design. Section three gives list of the characteristics that are using to characterize UWB antennas. In section four, a new microstrip patch antenna for UWB systems has been presented. The antenna has dimensions of 30mm×30mm which gives various usages due to its small size. The design and fabrication of the antenna has been done on a substrate of FR4 with εr=4.4. This feature results in low cost fabrication which seems vital in industry. Probe feeding technique has been employed in this design. In order to overcome the probe feeding limited bandwidth, different shapes had been studied to improve the bandwidth. Finally, a heptagon shape patch chose as a proper shape. Slots have been employed to enhance the bandwidth. Bringing together all these techniques, an UWB frequency range has been achieved. All the simulations have been done using HFSS software.

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