HEARTH SHAPE ULTRA WIDEBAND ANTENNA

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HEART SHAPE ULTRA WIDEBAND ANTENNA

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ABSTRACT

HEART SHAPE ULTRA WIDEBAND ANTENNA

In this thesis, ultra wide band antenna is designed and realized. To overcome the narrow band characteristics of patch antenna, the structure of the radiation is designed with elliptical and rectangular patch. Also triangular patches are used edge of the antenna to enhance the VSWR and gain. In addition, presented antenna ground plane is consisting of rectangular and elliptical patch which is modified with a small segment of arc at the middle.

Antenna performance is specified in terms of system gain not only at azimuth, but also at low elevation angles, and the Voltage standing wave ratio (VSWR) over a prescribed frequency band. Numerical simulation show that the antenna has a bandwidth ratio of 5:1 within the frequency range of 4-19.1 GHz with compact dimensions of 25 x 26 mm^2. It is printed on substrate having 0.5 mm thickness. However, measured values were slightly higher than the simulated ones in a small frequency range. Even with that discrepancy, ultra wide band antenna performance is observed. Since we did not have the ability to measure system gain, we relied on simulated values which were higher than 0dBi over the target frequency band.

ÖZET

KALP SEKLİNDE ULTRA GENIS BAND ANTEN

Bu projede, ultra geniş bantlı antenin tasarımı ve gerçeklemesi yapılmıştır. Yama antenin dar bant özelliğinin üstesinden gelmek için antenin canlı kısmında eliptik ve dikdörtgen yamalar kullanılmıştır. Ayrıca dizaynı yapılan antenin köşelerine üçgen yamalar eklenerek antenin duragan dalga oranının ve kazancının artırılması sağlanmıştır. Buna ek olarak, antenin toprak kısmında da dikdörtgen ve orta noktası kavisli bir yapı ile desteklenmiş eliptik yama kullanılmıştır.

Bu antenimizin performansı, belirtilen frekans aralığındaki antenin kazancı ve durağan dalga oranına bağlıdır. Nümerik simülasyonlar 25 x 26 mm^2 boyutlarındaki ve 0.5 mm kalınlığındaki ultra geniş bantlı antenin 5:1 oranında bir bant genişliği, 4-19.1 GHz aralığında da frekans aralığı olduğunu göstermektedir. Ölçülen değerler, simülasyonda elde edilen değerlerden çok kısa bir frekans aralığı için biraz farklı olmasına rağmen antende geniş bantlı çalısma performansı gözlenmiştir. Sistem kazancını ölcebilecek imkanımız olmadıgı için 0dBi'den buyuk olan hedef kazancımızın simülasyon sonucları doğrultusunda tutturulduğu varsayılmıştır.

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LIST OF SYMBOLS / ABBREVATIONS

CAD	Computer-Aided Drawing
CPW	Coplanar Waveguide
FCC	Federal Communications Commission
GPS	Global position satellites
IEEE	Institute of electrical and electronics engineers
MOM	Moment method
PCB	Printed circuit board
UWB	Ultra wide band
VSWR	Voltage standing wave ratio

1. INTRODUCTION

In last decades, the ultra-wideband (UWB) technology is developed widely and rapidly. There are so many applications employing UWB technology. For broadband and ultra wideband (UWB) applications, patch antennas are attractive candidate because of their light weight, low cost, wide bandwidth, compact size, and ease of fabrication [1-3]. In the work of [1], compact ultra wide band monopole antenna is presented with a compact size 30x35 mm^2dielectric substrate. In that work, the antenna has a rectangular radiating patch with a staircase structure and fed by microstrip transmission line. On the other hand, in [2], a low cost small UWB antenna has been presented with a frequency range 4GHz to 10 GHz. The antenna was fabricated using 1.6-mm FR4 substrate with a form factor of 30x30mm^2.

To overcome the inherently narrow bandwidth of patch antennas, different type of techniques have been investigated to cover the entire UWB bandwidth [4-7]. In the work of [4], various shapes of the slot excitation have been investigated with the help of a numerical modeling of coplanar waveguide (CPW) fed microstrip antennas. The CPW is providing an easy matching. Since antenna structure has been one of the most significant challenges in UWB systems and antenna research for narrowband system has already been mature, UWB technology has given raise a new interest in research area for providing challenges and opportunities in antenna design. UWB antenna designers aim to sustain high radiation efficiency with wide impedance bandwidth.

In order to guarantee a wide impedance match is obtained through the band that has power loss less than 10% which occurs at antenna terminals due to the reflections. Power loss due to the dielectrics and conductor losses needs to be minimized because of so low transmission power. The receive end architecture of UWB systems needs to be sensitive to receive the UWB signal so extra losses may not be acceptable in terms of the functionality of system. Therefore power loss percentage becomes an important parameter for UWB systems.

UWB technology has become very popular in high speed short range communication systems. Since antenna has a major effect on the performance of these systems, design of the compact antennas has become more important [8]. Antenna which is presented in [8], has a compact size with 30x30 mm^2 and operation frequencies are 3.6 to 15 GHz. UWB technologies occupies bandwidth greater than 25% of center frequency whereas narrowband systems usually occupy bandwidth that is almost 10% of center frequency and they require higher power for transmission.

There are several points in UWB antenna design which makes it more efficient and challenging such as antenna size, low manufacturing cost, radiation stability and impedance matching [9-11]. It can be pointed out that there are some physical constraints and challenges for the design of a UWB system antenna but these design criteria’s needs to be compatible with portable electronic devices and integrated circuits.

In this thesis, “Heart shape” slot antenna with enhanced impedance bandwidth has been introduced and fabricated. Our target is to enlarge the bandwidth of the antenna while reducing the antenna dimensions. With the help of triangular patch [12-13] and small segment of arc at the middle of the ground plane [14-15], wide input impedance matching is achieved over the entire 4–19.1 GHz band. The measured return loss and VSWR value that obtained from simulation indicate that the presented structure exhibits an ultra wide band impedance matching. Overall frequency range, antenna gain is also desired level and higher than 0 dBi. After going through a series of attempts, the final design has been concluded and simulated antenna was fabricated.

2. ANTENNA THEORY

2.1. INTRODUCTION TO PATCH ANTENNA

An antenna is a transducer used for receiving and radiating electromagnetic waves. Many different geometrical shapes or structures are seen as patch antenna. Patch antennas are type of antennas which provide several advantages over other type of traditional antennas. For wireless and mobile applications, patch antennas are very common. They are mostly used as efficient radiators in many communication systems. Generally patch antennas consists of a radiating patch on one side of a dielectric substrate, which has a ground plane on the other side. Figure 2.1 is represented the patch antenna. The patch residing over the substrate is made of a conducting material such as copper and gold and it can take any possible shape.

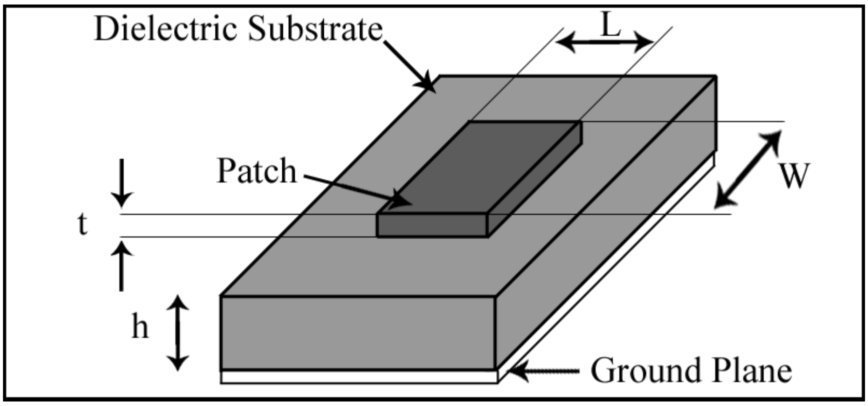


Figure 2.1. Patch antenna

In recent years, size miniaturization of patch antenna has become very popular. Especially, wireless local area networks, global position satellites (GPS), mobile cellular handsets, broadcast satellites applications are used UWB antennas. In order for today’s mobile communication applications to meet miniaturization requirements, these systems usually require smaller antenna size. Therefore size reduction has become one of the most significant design considerations for many applications with patch antennas. Due to this

fact it can be said that studies on the area of patch antennas have increased in recent years, most important research and studies on this area has been done in past several years.
A physical size of antennas is a major criterion in case of miniaturization in the design process of the mobile terminals. There are different techniques in literature for the miniaturization of patch antenna sizes and all the techniques has received much attention in research areas. Some electrical requirements can be listed for these mobile antennas as; high efficiency, impedance matching, wide bandwidth, Omni-directional radiation patterns, and gain. "Different type of patch", "high dielectric constant substrates shape", "Use of short circuits" or combination of those techniques may help to minimize the antenna size.

All the above listed methods can achieve the aim of size miniaturizing but can also cause some undesired cases. Usage of high dielectric constant substrates seems as the simplest way however it brings up high loss, narrow bandwidth and low efficiency because of surface wave excitation. Although the first method, modification of the basic patch shapes achieves substantial size reduction it will also cause the inefficient use of available areas. Lastly the method of shorting ports is known as a more efficient technique and used in different arrangements for reducing the overall size of microstrip patch antenna.

2.2. BASIC PATCH ANTENNA GEOMETRIES

The patch is usually made of some conducting material as gold or copper. Patch can take any possible shapes but generally is used as square, rectangular, circular, triangular and elliptical in order to simplify analysis and performance prediction. Different common shapes of patch can be seen in Figure 2.2.

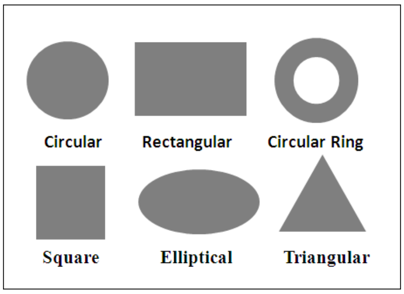


Figure 2.2. Common patch shapes

Since circular and elliptical shapes are smaller than rectangular patches it is expected them to provide smaller bandwidth and gain. Moreover analysis of this circular geometry is difficult because of its actual geometry. Although triangular patch is even smaller than both rectangular and circular ones, this will cause smaller bandwidth, lower gain and higher cross-polarization due to its unsymmetrical geometry.

2.3. PATCH ANTENNA ANALYSIS METHOD

2.3.1. Full Wave Solution- Method of Moments (MOM)

The main aim of this method, Method of Moments, is to provide full wave analysis for microstrip patch antenna. This method uses surface currents and volume polarization currents to model microstrip patch and dielectric slab. In the work of [26], an integral equation for unknown currents and these equations which can be transformed to matrix equations by using methods of moments were shown. The main form of the equation is given with equation (2.1), which aims to find g where F and H are unknown. Here F stands for known linear operator and h is the source function.

$$\mathrm{F(g) = h} \tag{2.1}$$

In order to solve the equation, the unknown function g can be expanded linearly as below;

$$\mathrm{g} = \sum_{n=1}^{N} \mathrm{a_n g_n = a_1 g_1 + a_2 g_2 + \cdots + a_N g_N} \tag{2.2}$$

Where $\mathrm{g_n}$ is a known function and called “expansion function”, $\mathrm{a_n}$ is an unknown constant. Since F is a linear operator, by using (2.1) and (2.2) it can be written;

$$\sum_{n=1}^{N} \mathrm{a_n F(g_n) = h} \tag{2.3}$$

The selection of g_n directly effects the calculation of each$F(g_n)$, therefore basis function should be selected with the consideration of this calculation. Since there are N unknowns in the above equation the constant cannot be determined. Weighted residuals method can be used to determine these constants by establishing a number of trial solutions.

Difference between these trial solutions and the real solution is measured with residuals. Then these residual are minimized by the selection of parameters that best fits the trial functions. In order to apply this method a set of N weighting functions in the domain of operator F. Then equation (2.3) is modified as below by taking the inner product of these weighting functions;

$$\sum_{n=1}^{N} a_n[w_m, F(g_n)] = [w_m, h] \qquad (2.4)$$

where *m* = 1,2,.....

Writing in Matrix form as shown in [5], we get;

$$[F_{mn}][a_n] = [h_m] \qquad (2.5)$$

where,

$$[F_{mn}] = \begin{bmatrix} [w_1, F(g_1)][w_1, F(g_1)] \dots\dots \\ [w_2, F(g_2)][w_2, F(g_2)] \dots\dots \\ . \\ . \\ . \end{bmatrix} [a_n] = \begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ \cdot \\ \cdot \\ \cdot \\ a_N \end{bmatrix} [h_m] = \begin{bmatrix} [w_1, h] \\ [w_2, h] \\ [w_3, h] \\ . \\ . \\ . \\ [w_N, h] \end{bmatrix} \qquad (2.6)$$

Different techniques such as Gaussian elimination and LU decomposition now can be used to determine constants a_n. Here most important point is the selection of linearly independent w_N which provides minimization of computations. There is one well known method as Galerkin's method [27] that selects the weighting and basis function same, which is given as; $w_n = \mathrm{g_n}$. The electric field equation can be written as;

$$E = f_e(J) \tag{2.7}$$

Here E is the known incident electric field, J is the unknown induced current and e f is the linear operator. When the moment method is applied to equation the first step will be the expanding J as;

$$J = \sum_{i=1}^{M} J_i b_i \tag{2.8}$$

where b_i is the ith basis function and J_i is an unknown coefficient. As the second step M linearly independent weighting functions are determined and inner product on both sides is calculated. Subtractions of equation (2.7) and (2.8) gives;

$$\left[\mathrm{w_j, E}\right] = \sum_{i=1}^{M} \left[\mathrm{w_J, f_e(J_i, b_i)}\right] \tag{2.9}$$

where j=1,2,3……M.

Writing in Matrix form as,

$$\left[Z_{ij}\right][J] = \left[E_j\right] \tag{2.10}$$

where $Z_{ij} = [\mathrm{w_J, f_e(b_i)}]$ and $E_j = [\mathrm{w_J, H}]$.

Known incident field quantities are involved in the vector E, whereas Z matrix is termed by functions of geometry. In addition terms of J vector are the unknown coefficients of the induced current. Now these equations can be solved by using any of algebraic methods to determine current. Then scattered electric and magnetic fields can be computed from induced current.

2.4. UWB ANTENNA

2.4.1. History of UWB Antenna

The main idea of Ultra-wideband is well known. Guglielmo Marconi has developed first pulse-based UWB spark GAP radio in the late 1800 and it has been used for several years in the transmission of Morse code. Since these radios have strong emission and interference with other narrow band systems, they were forbidden to use in 1900s [15].

UWB technology has become a hot research area in the late 1960s especially in military area due to its use in form of impulse radar. Many researchers worked on different aspects of UWB technology and reported different works on this area. In 1964, it has been a significant challenge in UWB system design. Later different antenna designers started to work on UWB systems. Logarithmic spiral antennas [16-17] were developed by Rumsey and Dyson while Ross designed wideband radiating antenna elements by using impulse measurement techniques [18]. In the following years several there has been several publications on this area.

With the approval of commercial use of UWB by FCC in 2002 it has again gained a great interest. Since UWB has variety of advantages over traditional narrowband systems such as low complexity, low cost and more efficient time domain resolution, it becomes more suitable for number of applications [10]. UWB technology has some significant specialties which makes it a good solution for through-the-wall and ground penetrating applications, such as inherent immunity against detection and interception, strong penetration ability through different materials, negligible interference to narrowband systems and low power consumption.

2.4.2. UWB Antenna Specifications

In order to characterize antennas and determine suitable applications, several antenna parameters have been presented in Section 2.5. “IEEE Standard Definitions of Terms for Antennas” is also a good reference to explain specifications [19].

One of the critical antenna parameter is Radiation pattern. Radiation patterns of ultra-wide band antenna could be Omni-directional. Omni-directional means that the signal waves radiates uniformly in all directions in one plane. The VSWR, Voltage Standing Wave Ratio, is so critical for UWB antennas. VSWR value could be less than 2. If the VSWR could be equal to 1, then the antenna would be perfectly matched.

Antenna gain in dB could be less than 5 and relatively constant over UWB frequencies. Size and cost are also crucial for UWB antennas. The antenna could be small in size and be printed on a high frequency circuit board. The size of the antenna is not exactly limited because the definition of small is interpreted differently for applications.

Another important specification is impedance. The impedance, the ratio of the appropriate components of the electric to magnetic fields at a point, of the antenna could be matched and be a value that is easy to create on a high frequency circuit board. Several factors are considered in the simulation, design and testing of an antenna, and most of these metrics are described in 2.4, Fundamental Antenna Parameters. These parameters must be fully defined and explained before a thorough understanding of antenna requirements for a particular application can be achieved.

2.4.3. Advantages of UWB

Due to the number of significant advantages of UWB, it can be clearly said that it provides a more efficient solution to wireless broadband than all other technologies [20-22]. To start with, ultra wide frequency bandwidth can be considered. According to Shannon-Hartley theorem UWB can provide great capacity even hundred Mbps or several Gbps within distances up to 10 meters, due to the ultra wide frequency bandwidth. High security and reliability in communication systems due to the low energy density of UWB signal can be given as the second important advantage. The signal of UWB is noise like which brings major security advantages such as difficulty in unintended detection [23].

2.4.4. UWB Antenna Applications

UWB technology provides some challenges and unique properties which make it suitable for number of applications. To start with, UWB is used in applications of WPAN due to the high data rates that are provided by UWB in addition to low power at very limited range. This significant property of high data rate transmission between computers and peripheral devices like cameras, MP3 players, DVD players and televisions has provided a new challenge in personal entertainment applications.

Secondly, due to another unique property of UWB which is namely positioning and tracking, it becomes an excellent solution for indoor locations. It also provides high data rate characteristic and much higher accuracy than GPS. Moreover, since UWB provides efficient tracking mechanism, the precise determination of the tracking of moving objects for indoor applications can be achieved within several centimeters [10]. UWB systems can also be used in variety of complex situations for fastening the communication between people such as earthquakes, burning buildings etc.

Thirdly, sensor networks provide a huge area for the applications of UWB solutions. Sensor networks are the networks which contain large number of sensors that are located in large geographical areas. The characteristics of the sensors can vary due to the applications, for some applications such as tracking and monitoring static sensor are used where mobile sensors are preferred for robots in military and emergency response situations [24]. UWB technology provides some key requirements of these sensor networks such as low power, low cost and multi functionality. Since UWB sensors are devoid of wires, the installation and maintenance cost decreases significantly for sensor networks. Furthermore this property makes UWB more attractive for medical applications. In case of extensive medical monitoring patients will not need to be shackled by cables or wires by the employment of UWB sensors.

Another area that UWB can also be applied is radar and imaging applications [25]. In order to locate enemy objects behind walls or around corners UWB technology can be used. Furthermore, UWB is also helpful in some rescue work; it can detect the breath of a person under rubble. Since UWB pulses can provide very accurate delay estimates it can be also used in intelligent collision avoidance and cruise control systems with high ranging accuracy. Moreover, these systems are also appropriate for some application such as airbag deployment, suspension systems, location and movement detection.

3. DESIGN AND SIMULATION RESULTS

3.1. INTRODUCTION

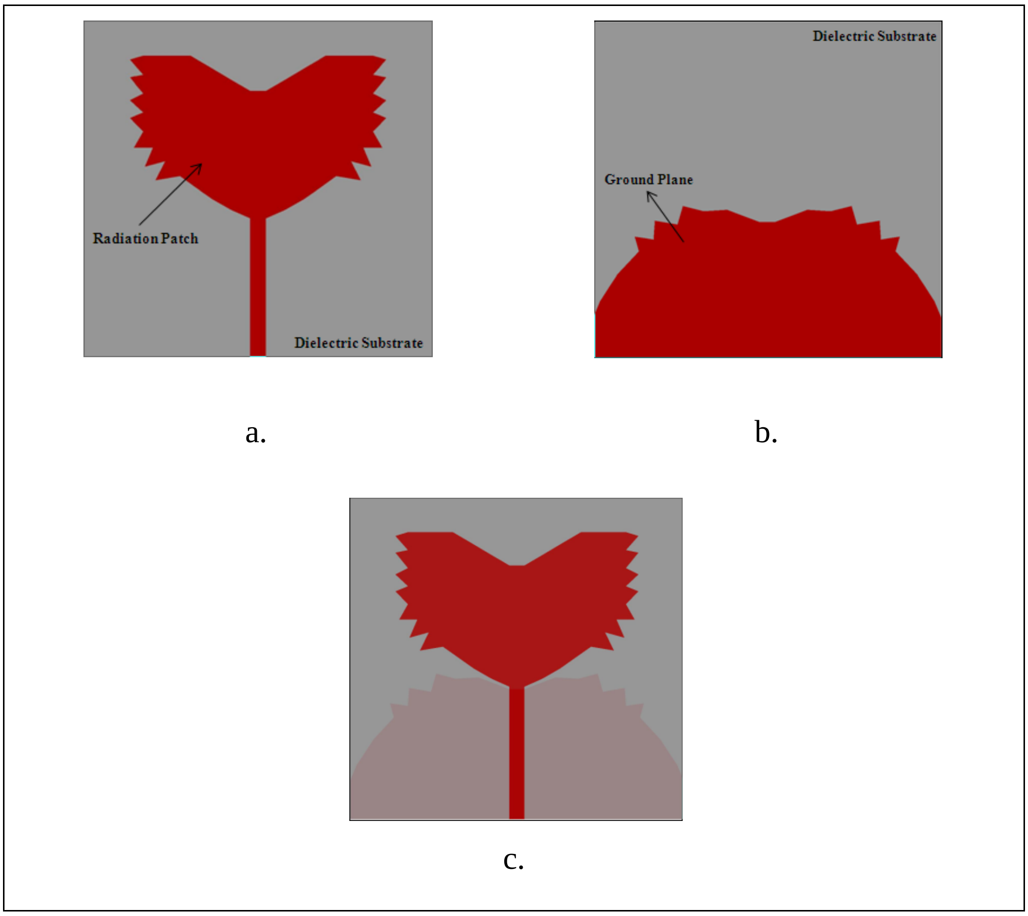
In this thesis, a novel shape UWB antenna was designed and simulated. Presented antenna is called “Heart shape Antenna” since radiation element of antenna looks like heart. All the antenna parameters are taken into consideration to have ultra wide band operation frequency with desired antenna specifications. The design of heart shape UWB antenna involves calculating the approximate triangular patch on radiating element and modified ground plane size. As mentioned in section 2.3.1, “Method of Moment” is one of the well known analysis method for numerical analysis. This method is used to analyze microstrip antennas of rectangular or nonrectangular common shapes. For the dielectric substrates, surface currents are used to model microstrip patch and volume polarization currents. Since presented antenna shape is not consisting of one common shape, it is hard to do precise numerical computations. Because of this reason, simulating and optimizing the design are performed by using FEKO, commercial antenna computer-aided drawing (CAD) software.

3.2. DESIGN AND SIMULATION OF A HEART SHAPE ANTENNA

A full wave electromagnetic solver, FEKO, was used in the design and simulation of the proposed a heart shape antenna. FEKO can help us to make assumptions on the performance of the actual antenna before its realization. A full wave solution of Maxwell’s equations and method of moment (MoM) technique is used for analysis of electromagnetic problems.

The basic structure of a heart shape antenna consists of a radiation element and modified ground plane. The radiating element of the presented antenna was designed with rectangular patch and elliptical patch. Proposed antenna’s radiation element is shown in Figure 3.1a. Rectangular shape and elliptical shape are well known antenna type as a patch antenna and they have UWB characteristics over the large frequency range. In the work of [8], UWB antenna was designed by using rectangular patch and between the frequencies ranges 3.6-15 GHz antenna has a suitable return loss and gain value. Antenna which is presented in [14] has elliptical shape radiation patch and it has advantages by means of size miniaturization and impedance matching over a large frequency range.

To enhance the advantages of rectangular shape patches, some modifications and techniques are needed. “V” slot notch is one of the techniques that help us to increase the gain and impedance of the antenna [28]. By using [28], rectangular part of the radiation patch is modified with V shape notch which enhance the gain and increase the impedance matching frequency range of antenna. With the help of [12,29], to achieve impedance matching that results in bandwidth enhancement, triangular shape patches are also used at the edge of rectangular patch. When we consider the overall frequency range of the presented antenna, % 101 BW enhancements is achieved.



a.

b.

c.

Figure 3.1. Heart shape of antenna a. Top view b. Bottom view c. Transparent view

The ground which we used here is also a combined structure, and part of the two circle patch together over the rectangular patch composes our ground. As mentioned in [14], we improved the gain and bandwidth of the antenna by adding a small segment of arc at the middle of the ground plane. Modified ground of Heart shape UWB antenna is shown Figure. In this thesis, a modified ground plane structure was employed to achieve the desired ultra-wide bandwidth operation. The dimensions and positions of ground plane and radiation element are also taken into consideration for heart antenna design. Dimensions of the heart shape UWB antenna's radiation patch and modified ground are shown in Figure 3.2 and Figure 3.3**.** Proposed antenna has compact dimensions of 25 x 26 mm^2 which is printed on substrate having 0.5 mm thickness and relative dielectric constant of 3.50. Rogers "RO3035" was used for the realization of this antenna. Since the dielectric substrate thickness is 0,5 mm, antenna is so ductile. Because of this reason, presented antenna can be suitable for wearable or flexible applications.

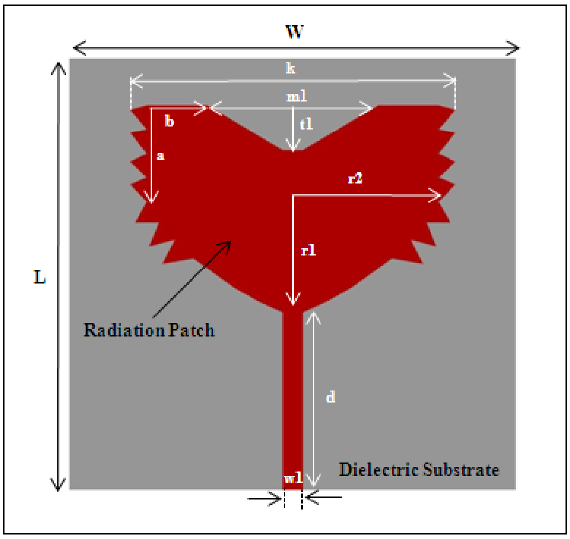


Figure 3.2. Dimensions of heart shape antenna radiation element

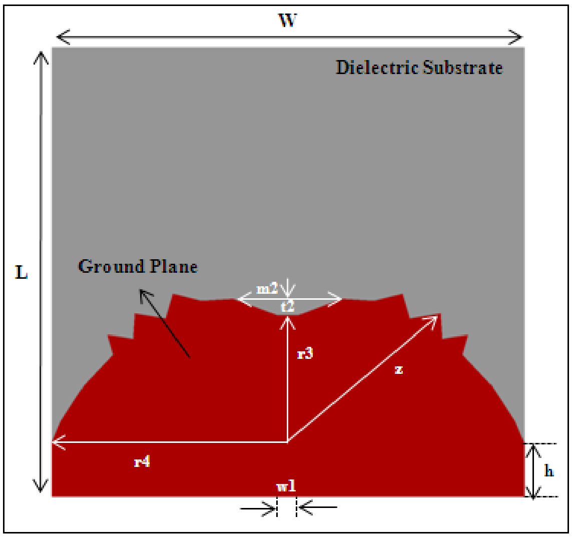


Figure 3.3. Dimensions of heart shape antenna ground plane

The effect of the triangular patch on the bandwidth, gain and radiation pattern was also studied in Section 3.3. Dimensional changes on the antenna will be tested and simulated in a software simulation package to achieve the required performance. To validate the design, a test model will be built and tested. The design specifications and optimization of the antenna are given in Table 3.1 and Table 3.

Table 3.2. Optimized value of antenna dimensions

Parameter	**Value (mm)**	**Parameter**	**Value (mm)**
w1	1.16	**a**	5.6
m1	10	**b**	3.5
m2	6	**r1**	6.4
t1	2.6	**r2**	8.5
t2	2.1	**r3**	12
z	13	**r4**	12.5
h	3	**k**	19
W	25	**d**	11.9
L	26		

Table 3.1. Design specifications

Items	Value
Bandwidth	4-19.1 GHz
VSWR	< 2
Return Loss	< -10dB
Gain	> 0dBi
Dimensions	25x26 mm2
Radiation Pattern	Omni-directional

3.3. DESIGN PROGRESS OF A HEART SHAPE UWB ANTENNA

The approach of designing involves three phases. The first phase is to perform without any triangle shape patch on radiation element and ground plane, followed by the second phase is performed without triangle on ground plane. The approach to the third stages is performed without triangle patch on radiation element. While patches are removed rest of the parameters and dimensions are retaining. This is to observe the corresponding effects on return loss, VSWR, gain and radiation pattern with respect to the changes.

3.3.1. Antenna w/out Triangle Patch on Radiation Element and Ground Plane

The first phase of design, triangular patch on radiation element and modified ground is investigated on the effect on the antenna total gain, VSWR and return loss. This is to identify the changes of the antenna’s performance when the triangular patch is removed from radiation element and ground patch. In this simulation, remaining antenna parameters keep the same and Figure 3.4 is illustrated the antenna top and bottom view. Even other parameters keep the same, radiation element and ground plane total size reduce with a value of triangular patches.

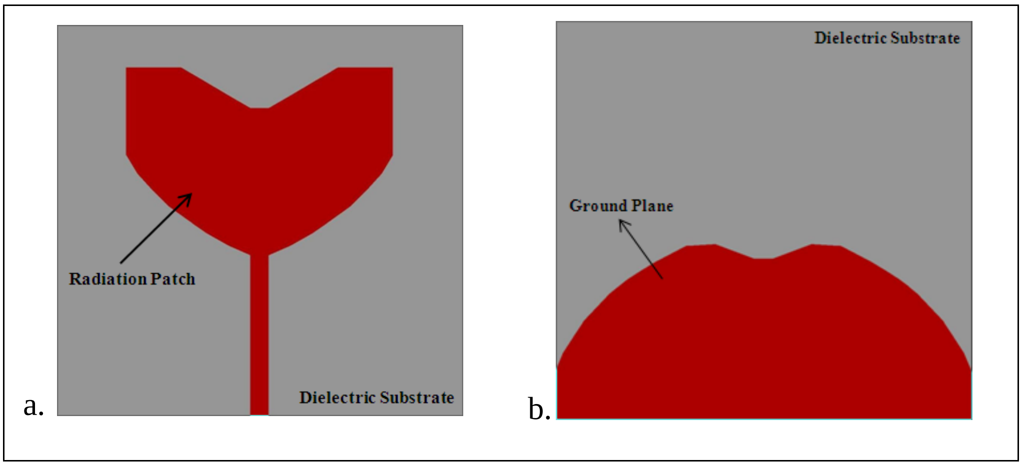


Figure 3.4. Antenna without triangles a. Top view b. Bottom view

In this phase, the presented antenna without triangular patch on the ground and radiation part of the antenna is simulated. From the graphs shown in Figure 3.5, it was observed that, when triangular patches are removed from the presented antenna, VSWR value increase to over 2 between the frequencies ranges 6.75 GHz to 11.5 GHz. With these design parameters, antenna is not so suitable for UWB applications since impedance matching is not desired level. The return loss value and comparison of antennas with and w/out triangles is illustrated in Figure 3.6. Like VSWR, return loss value is also increase between the same frequency and the value is higher than -10dB. As mentioned in [12] and [28], triangular shape patches enhance the matching bandwidth.

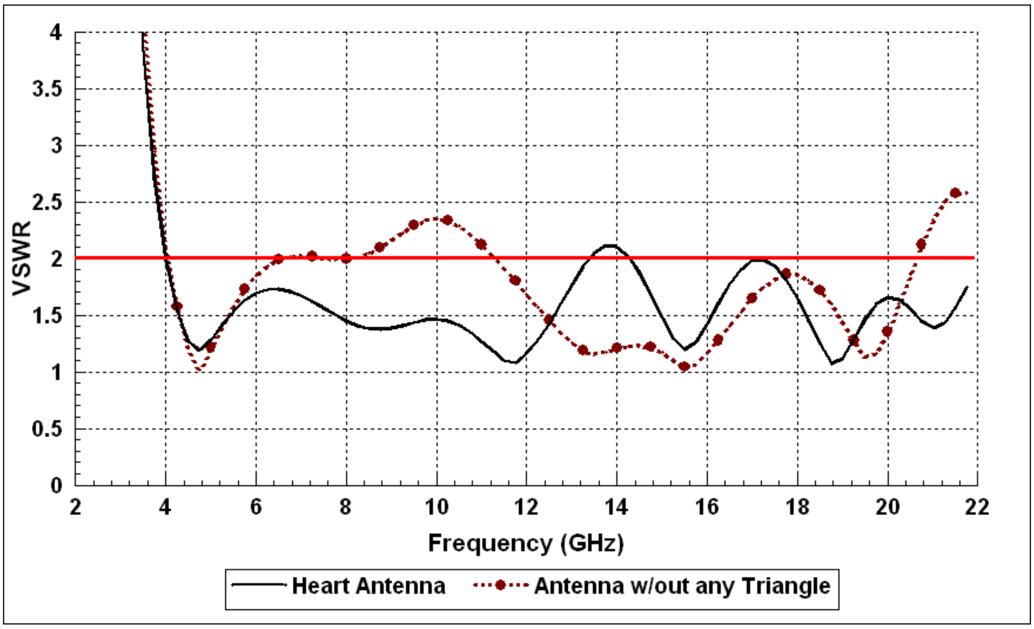


Figure 3.5. VSWR without triangular patches

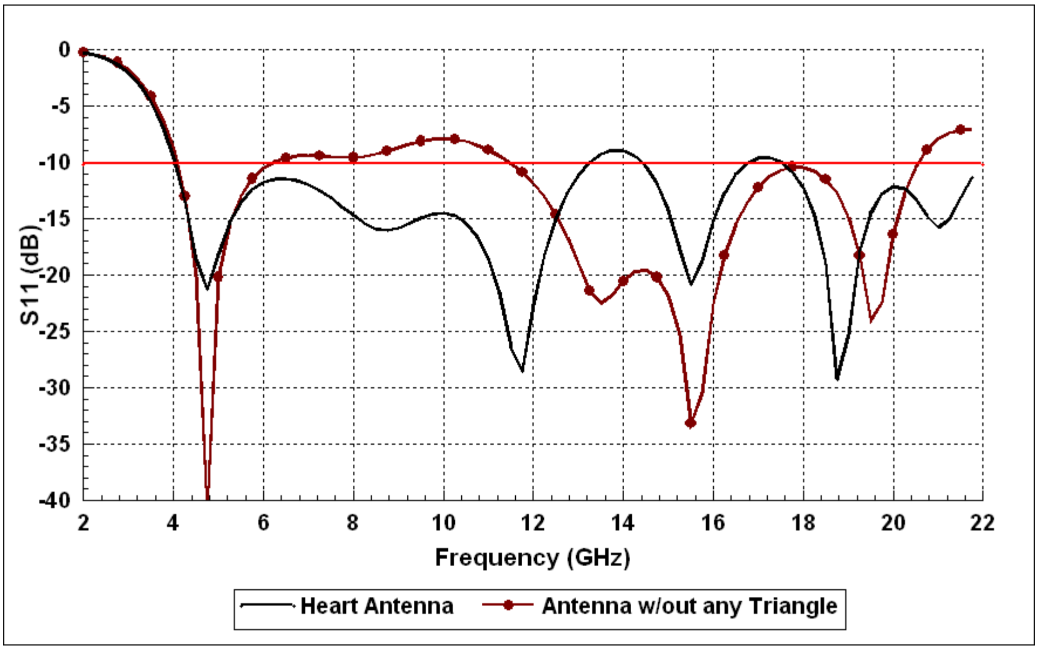


Figure 3.6. Return Loss without triangular patches

Figure 3.7 is represented the gain of the antenna which has no triangular patch on top and bottom of the antenna. When we look at the gain over all frequency range, it is observed that gain decreased after 15.5 GHz and not over the required gain level (0dB). Triangular type of patch can help to increase the gain of the antenna [13-14].

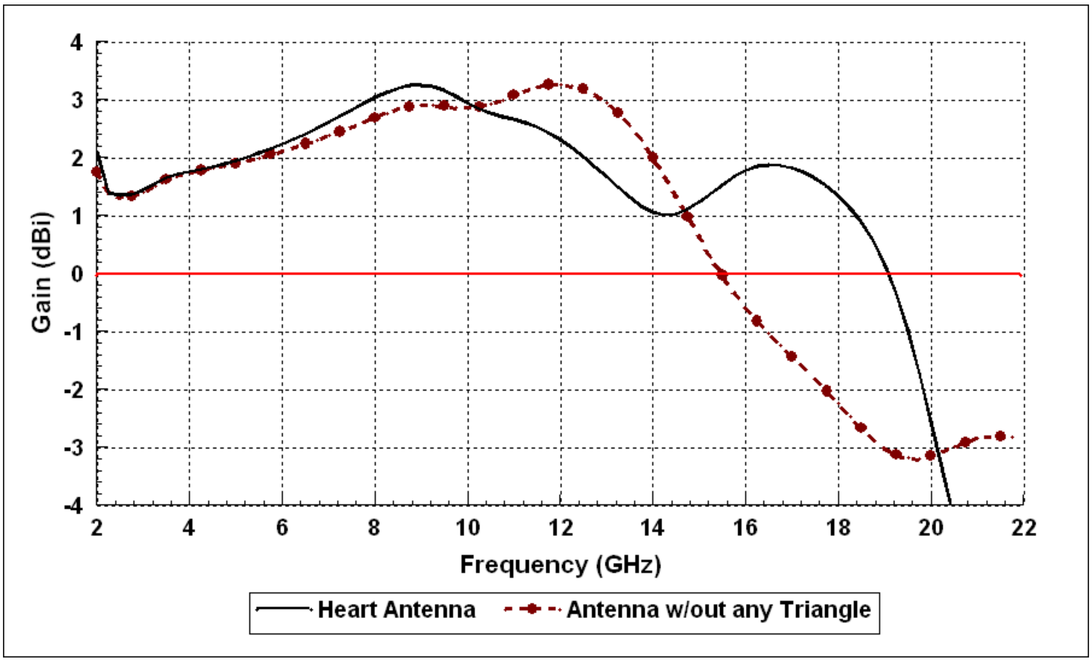


Figure 3.7. Gain without triangular patches

As an UWB antenna specifications, VSWR value need to be fewer than 2 and gain should be over 0 dBi. However, the antennas without triangular patches are not suitable for UWB applications. In Section 3.3.2, the antenna with triangular patch on radiation element is simulated and results are compared with presented antenna. Figure 3.8 and Figure 3.9 are shown the Radiation pattern and 3D graphics of the antenna and Omni-directional characteristic is observed. From the above, we conclude that without triangular patch on radiation element and ground plane, VSWR and return loss are not satisfy antenna design specifications. Even antenna gain is higher than 0 dBi, antenna is not suitable for UWB wireless applications since input impedance of the antenna is not under two.

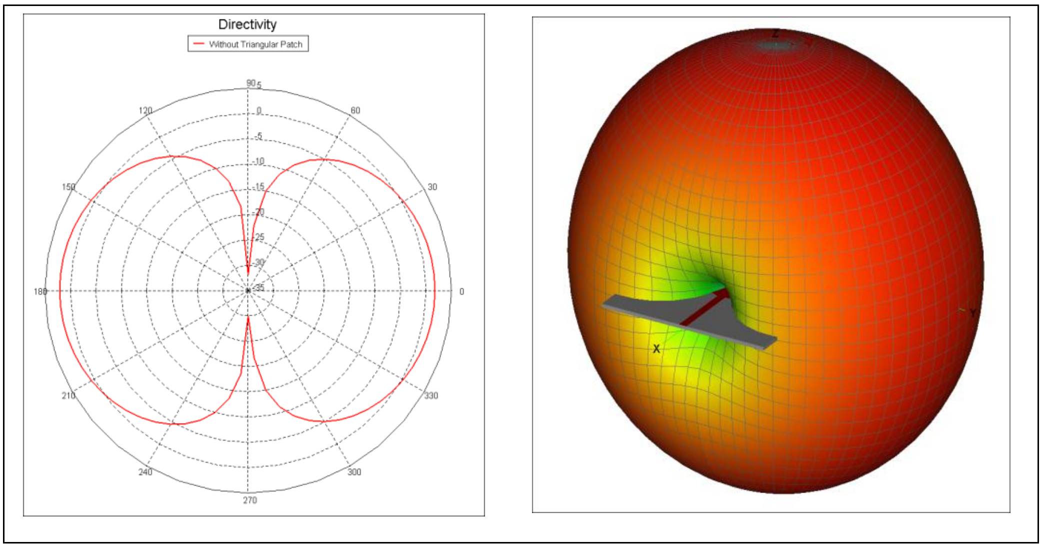


Figure 3.8. Radiation pattern and 3D graphic of antenna at 4 GHz

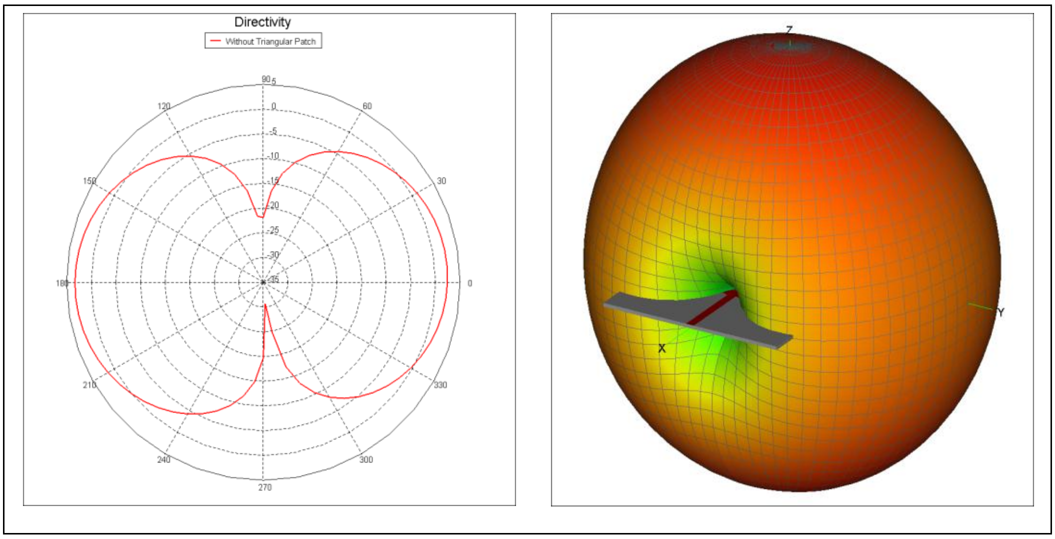


Figure 3.9. Radiation pattern and 3D graphic of antenna at 7 GHz

3.3.2. Antenna w/out Triangle Patch on Ground Plane

The second phase of design is to see the effect of the triangular patch on modified ground. While triangular patch were removed from the ground plane, rest of the parameters keep the same with presented antenna. Figure 3.10 is shown the antenna top and bottom view without patches respectively.

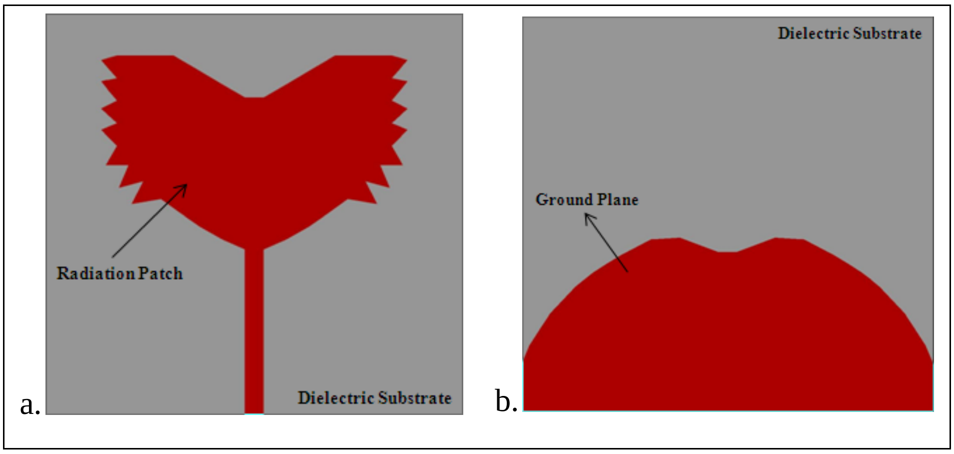


Figure 3.10. Antenna without triangles on ground a. Top view b. Bottom view

In this phase, triangular patch on the ground plane is removed and triangles on radiation element of the antenna keep the same as presented antenna. VSWR, return loss, gain and radiation pattern are investigated and results are compared with the presented antenna. VSWR and return loss are illustrated in Figure 3.11 and Figure 3.12 respectively. From the graph shown in Figure 3.11, it was observed that, when triangular patches on ground plane are removed from the presented antenna, VSWR value increase between the frequencies ranges 6 GHz to 13 GHz and 15 GHz to 18 GHz. It shows that with the help of triangles on ground plane, desired input impedance matching is achieved. It also proves that, general characteristics are not affected with those triangles. As seen in graph, VSWR value which is higher than 2 also decrease between 13 GHz to 15 GHz. VSWR is only higher than two and max value is 2.1 between the frequencies 16 GHz to 18 GHz.

Between 16 GHz to 18 GHz, the return loss value which is presented in Figure 3.12 is higher than -10 dB. Compare with previous Section simulation results, it is observed that triangular patch on radiation element has a good impact on VSWR and return loss. For UWB wireless applications, VSWR and return loss must be take into consideration and over all frequency range, antenna without triangles on ground plane, is suitable for wireless applications. However, another important parameter, gain, must be simulated and results are needed to investigate to clarify the operation BW of simulated antenna. As a next step, gain and radiation patter are simulated and compared with presented heart shape antenna.

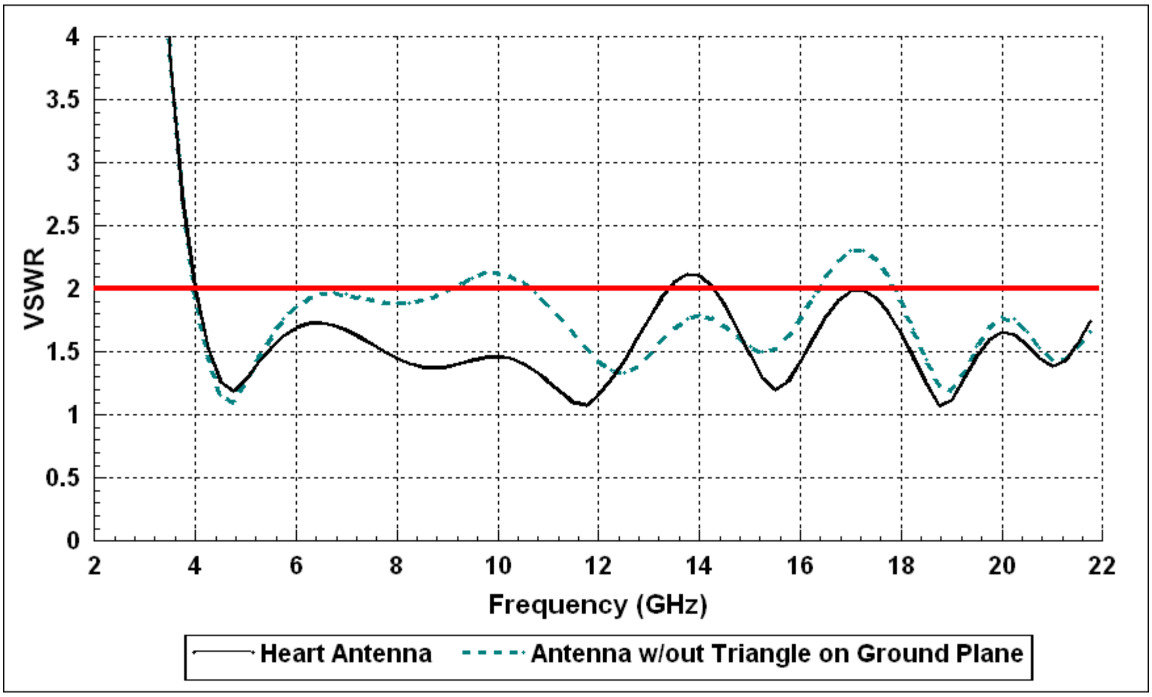


Figure 3.11. VSWR without triangles on ground plane

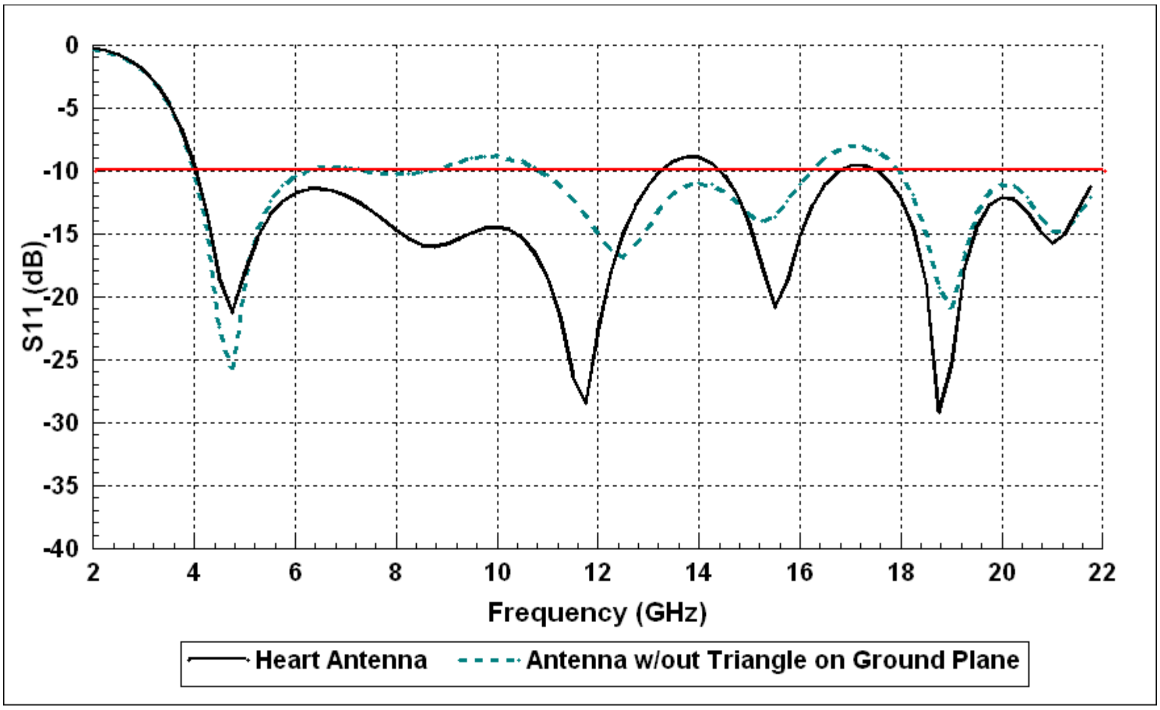


Figure 3.12. Return loss without triangles on ground plane

Figure 3.13 shows the gain of the antenna which has no triangular patch on ground. When we look at the gain over all frequency range, it is observed that gain decreased after 14.5 GHz and not over the required gain level (0dB). It proves that triangular type of patch can help to increase the gain of the antenna [14]. After we consider VSWR and gain value, antenna without triangular patch on ground is suitable only the frequency range between 4 GHz to 14 GHz. To see the antenna radiation characteristics, Radiation pattern and 3D graphic representation are illustrated in Figure 3.17 and Figure 3.18

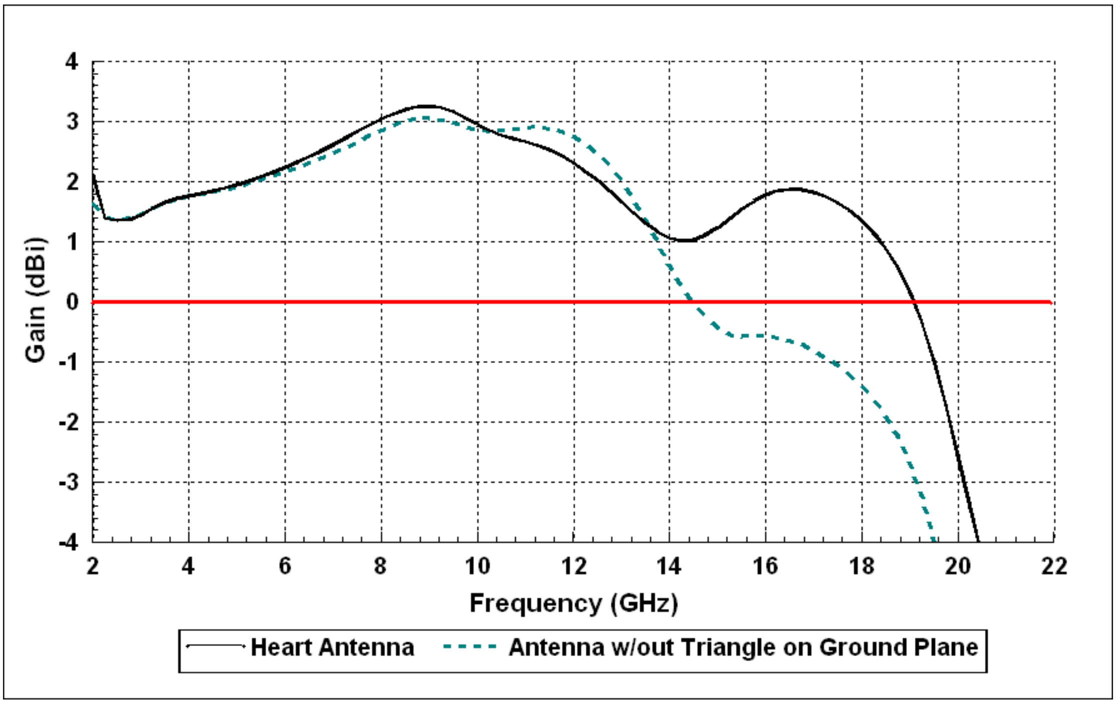


Figure 3.13. Gain without triangles on ground plane

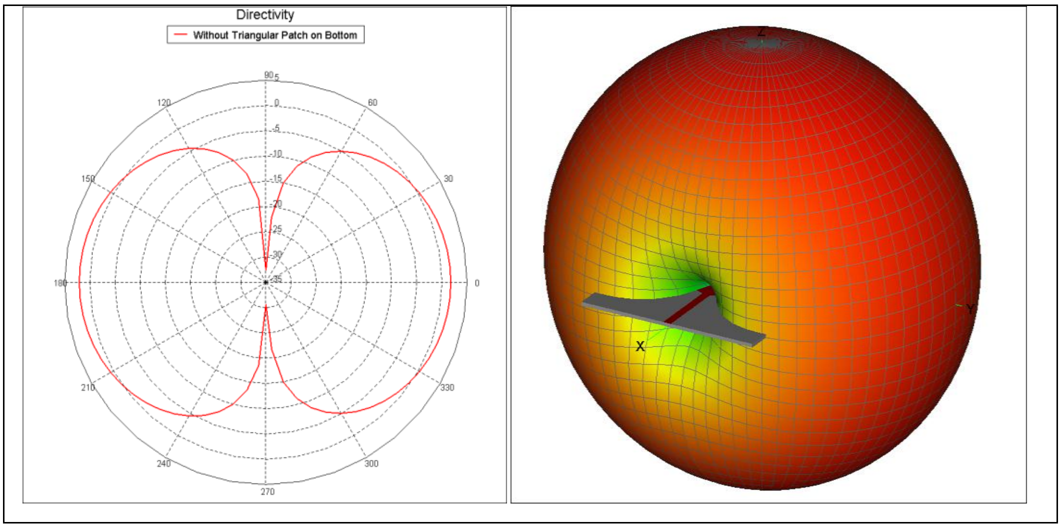


Figure 3.14. Radiation pattern and 3D graphic of antenna at 4 GHz

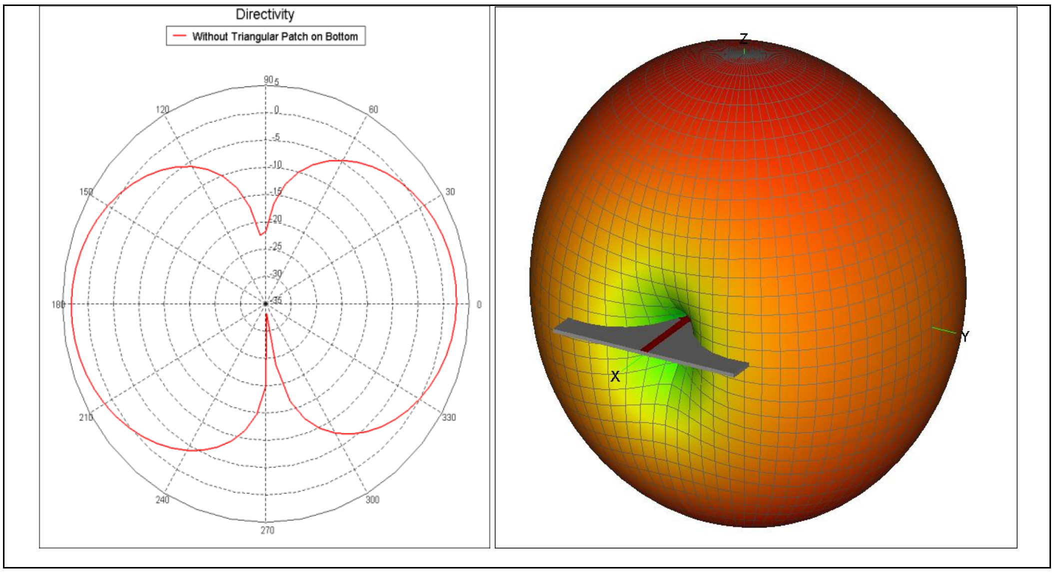


Figure 3.15. Radiation pattern and 3D graphic of antenna at 7 GHz

From the above, we conclude that the triangular patch on modified ground may help to increase the Gain and help to match in different frequencies as VSWR and return loss. In the next phase, the presented antenna will be simulated without triangular patch on radiation element of the antenna.

3.3.3. Antenna w/out Triangle Patch on Radiation Element

The last phase of design is to see the effect of the triangular patch on radiation element. The rest of the parameters are same with presented antenna. Figure 3.16 is shown the antenna top and bottom view without patches on radiation element respectively. The patch from edge of the antenna will affect the antenna parameters performance. From [13], the triangular patches are affected the lower resonant frequency and then increasing the maximum achieved impedance bandwidth. In this phase, the presented antenna without triangular patch on the radiate part of the antenna is simulated in FEKO to see how it affects the related parameters. In this part, Section 3.3.2 and simulations results of this Section are also compared to each other to understand and differentiate the impact of the triangles.

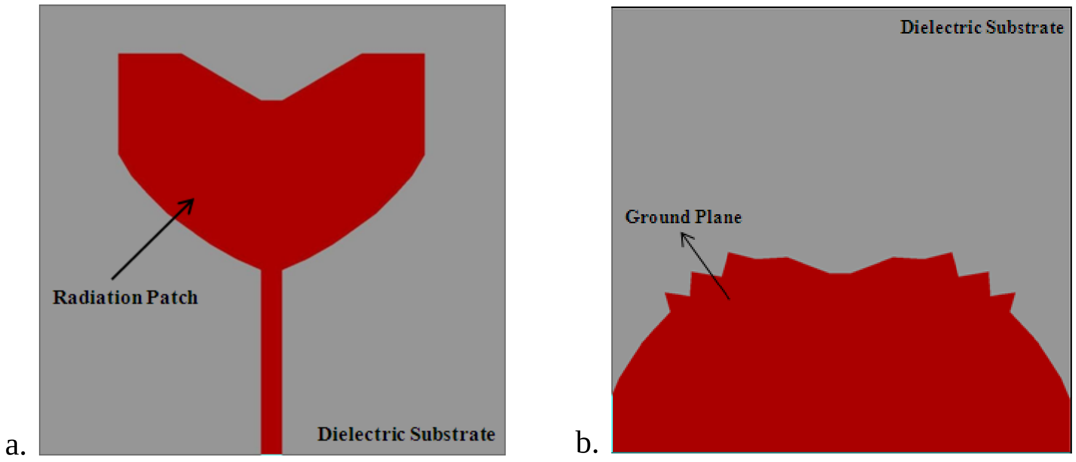


Figure 3.16. Antenna w/out triangle on radiation element a. Top view b. Bottom view

From the graphs shown in Figure 3.17, it was observed that almost same characteristics for VSWR between the frequencies 4 GHz to 20 GHz. In those graphs, w/out triangular patches antenna VSWR values are compared. When we look at the VSWR it is lower than desired level and suitable for UWB antenna applications. With the help of the triangles on the ground plane, overall frequency range, desired VSWR value is achieved.

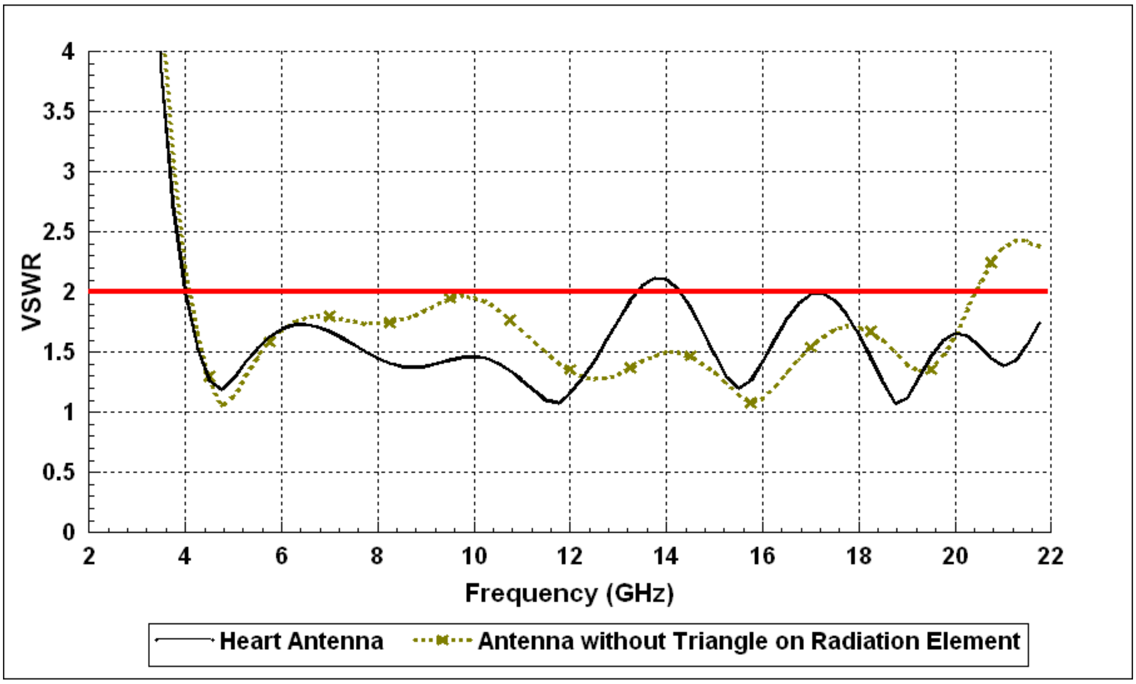


Figure 3.17. VSWR without triangles on on radiation element

Next Figure, antenna return loss value is illustrated and compared with presented heart antenna. As seen in Figure 3.18, return loss is lower than -10 dB over all frequency range like VSWR value. However, on different frequency, different return loss values are observed because of triangle shape patches. To define the antenna operation frequency, antenna gain and radiation patter also should be taking into consideration.

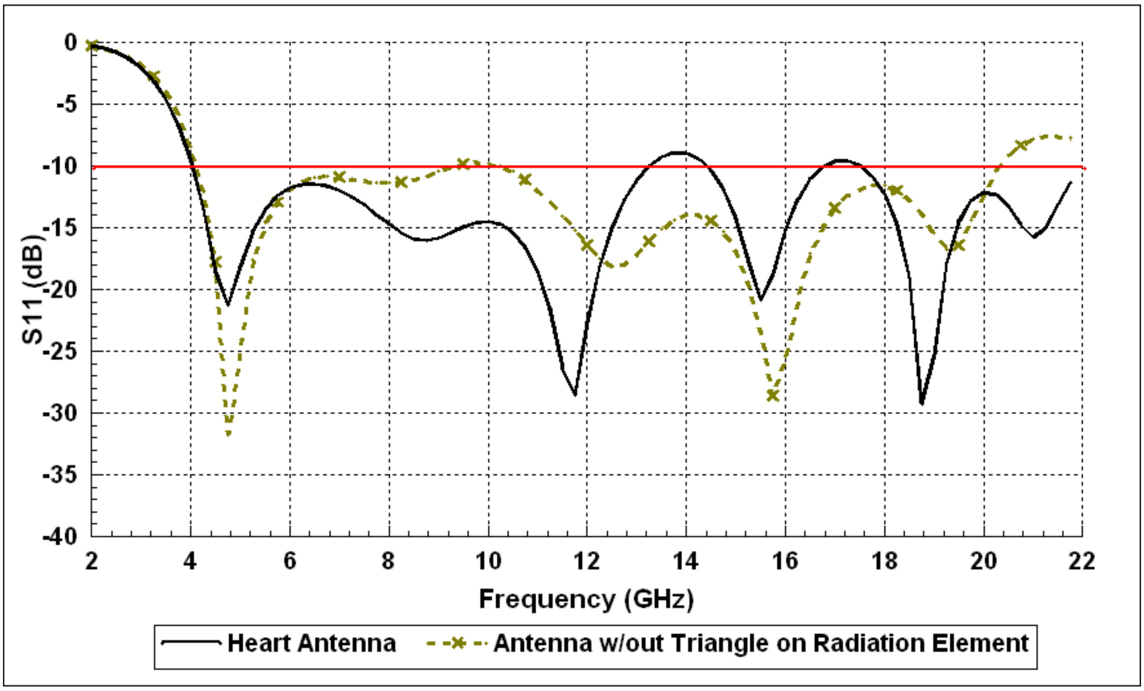


Figure 3.18. Return loss without triangles on on radiation element

When we look at the gain over all frequency range, it absorbed that gain decrease after 14 GHz and not over the required gain level (0dB). Figure 3.19 shows the gain of the presented antenna. As mentioned in [13], triangular type of patch can help to increase the gain of the antenna. Over the frequency range 2 GHz to 14 GHz, with and without triangle patch on radiation element is not affected the characteristics of antenna gain and same gain is observed. Same as previous Section, at 4 GHz and 7GHz radiation pattern and 3D graphic representations are also illustrated in Figure 3.20 and Figure 3.21.

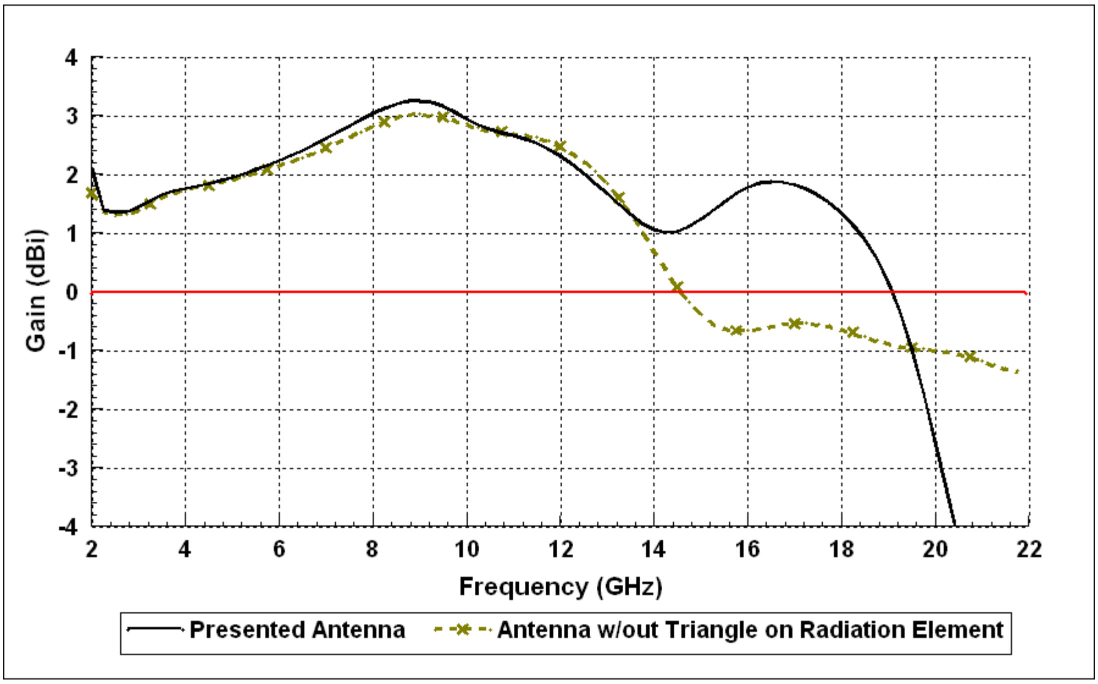


Figure 3.19. Gain without triangles on on radiation element

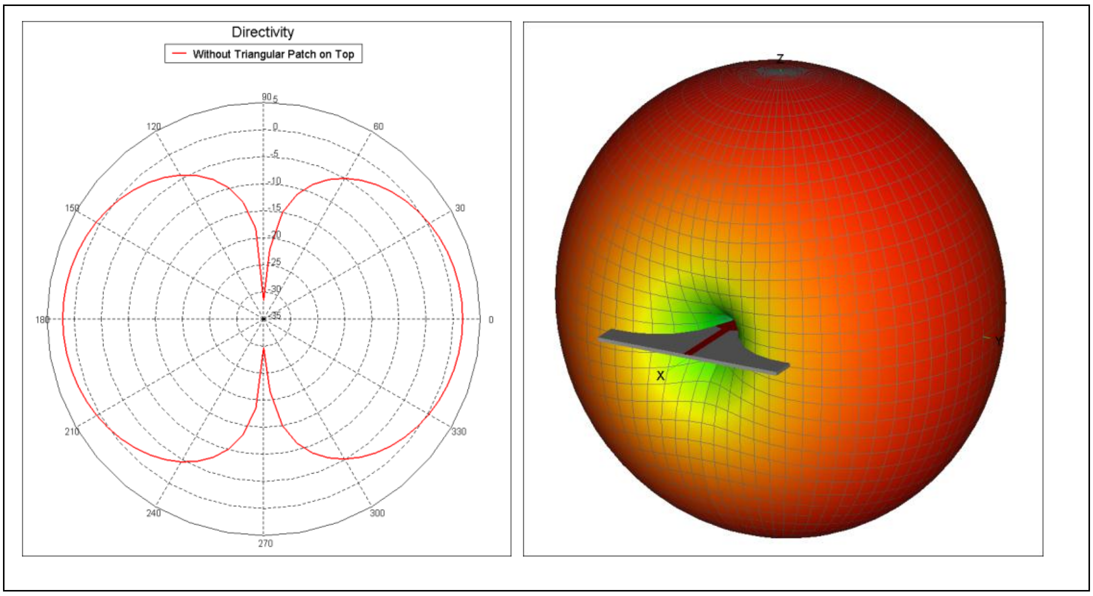


Figure 3.20 Radiation pattern and 3D graphic of antenna at 4 GHz

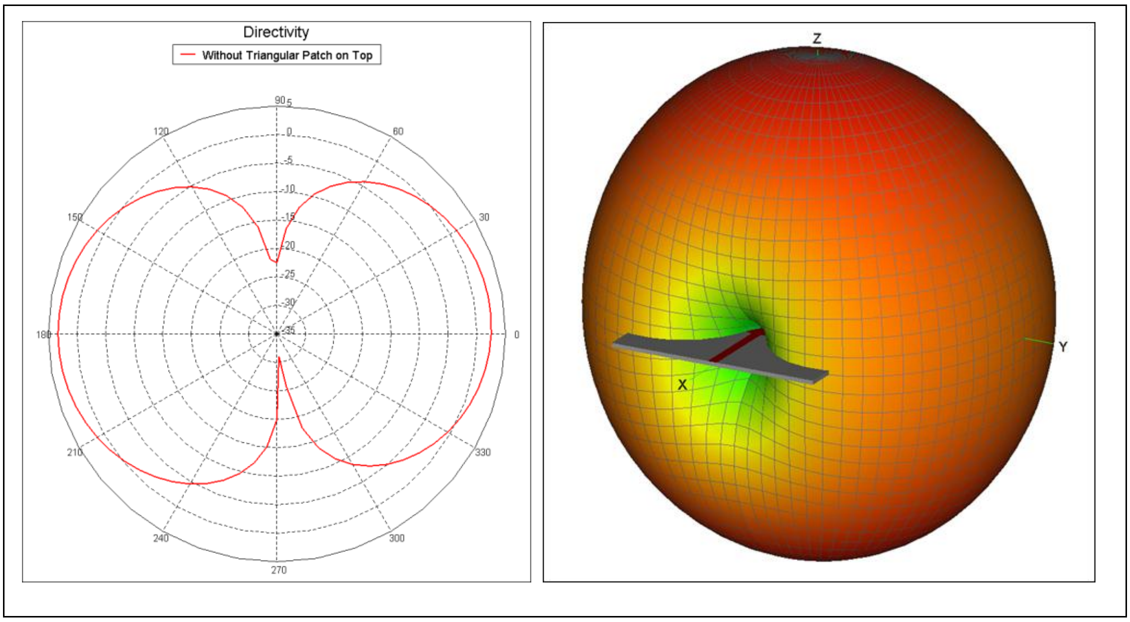


Figure 3.21. Radiation pattern and 3D graphic of antenna at 7 GHz

From the above, we conclude that the triangular patch can help to increase the Gain over the higher frequencies. For lower frequency ranges, triangles which are located on radiation element have no major impact on gain As a VSWR and return loss value are not affected with triangles and may help to decrease VSWR on different frequencies. Since UWB antennas design have more than one dependency, all simulation results which were presented previous Section should be take into consideration. Table 3.3 is illustrated the comparison of presented heart shape antenna and modified antenna specifications. To understand the impact of triangles simulated antenna which is presented Section 3.3.2, VSWR, return loss and Gain were compared in Figure 3.18, Figure 3.19 and Figure 3.20 respectively.

Table 3.3. Comparison of presented and modified antenna parameters

Items	**Presented Antenna**	**Modified Antenna**
Bandwidth	**4-19.1 GHz**	**4-14 GHz**
VSWR	**< 2**	**< 2**
Return Loss	**< -10dB**	**< -10dB**
Gain	**>0 dBi**	**>0 dBi**

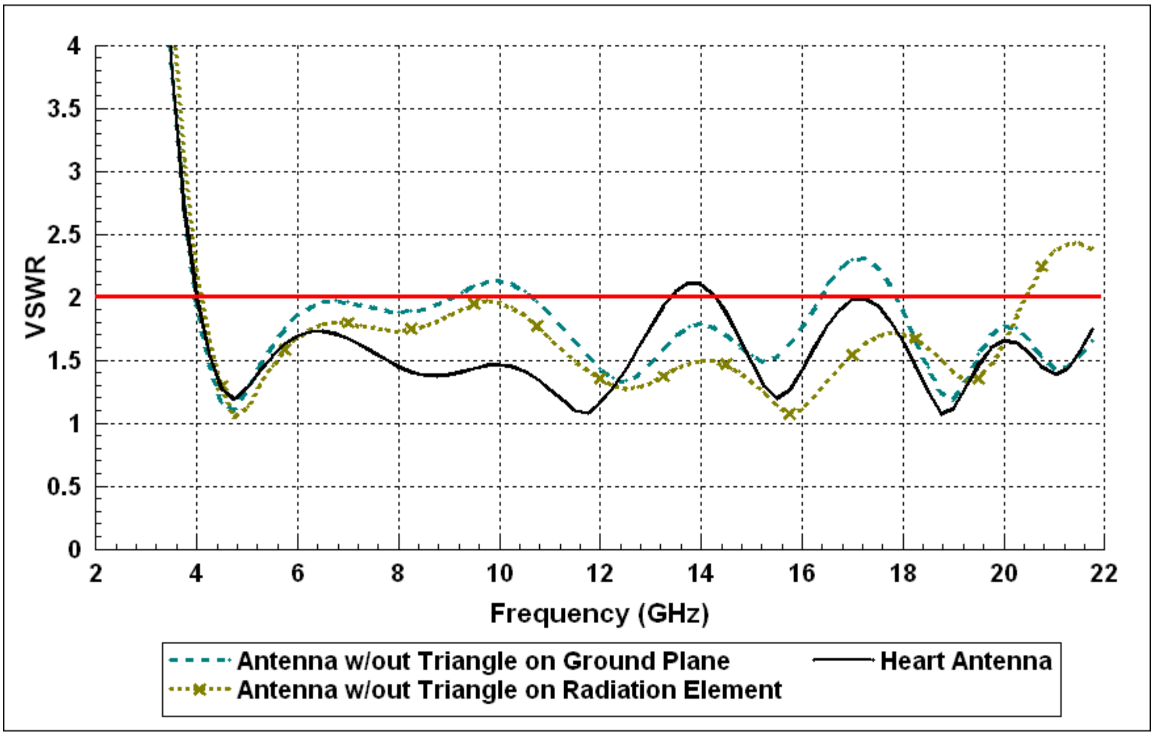


Figure 3.22. Comparison of VSWR w/wout triangles

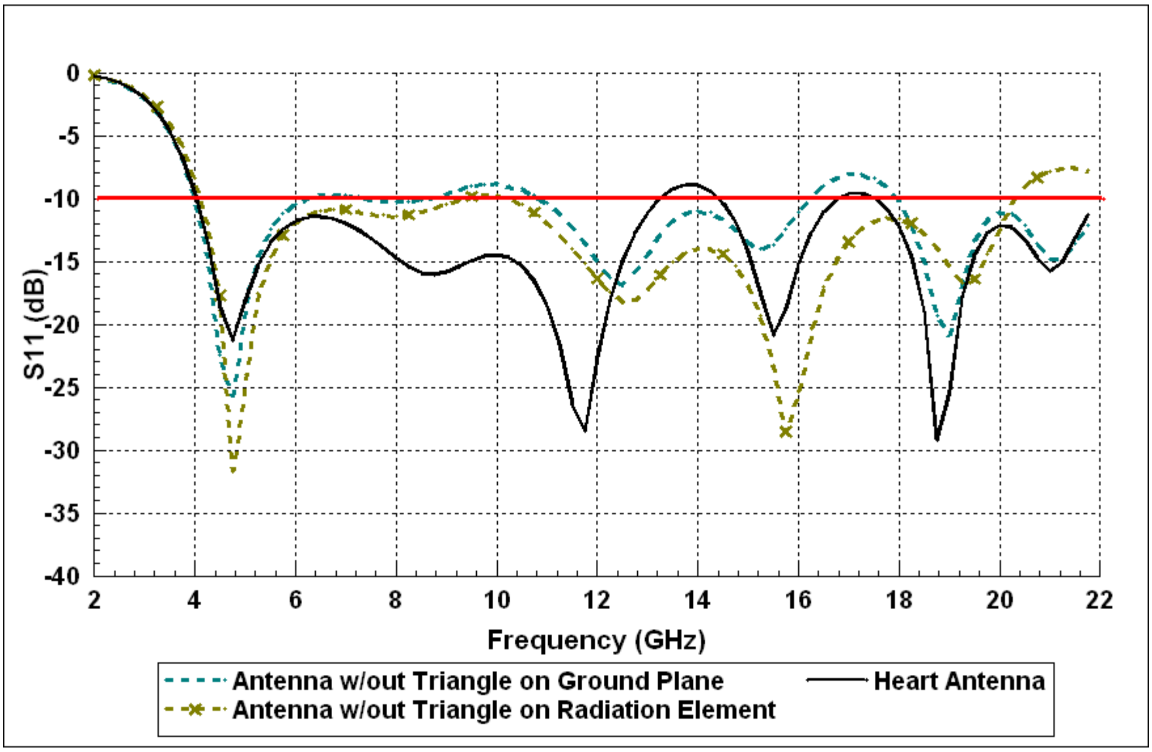


Figure 3.23. Comparison of return loss w/wout triangles

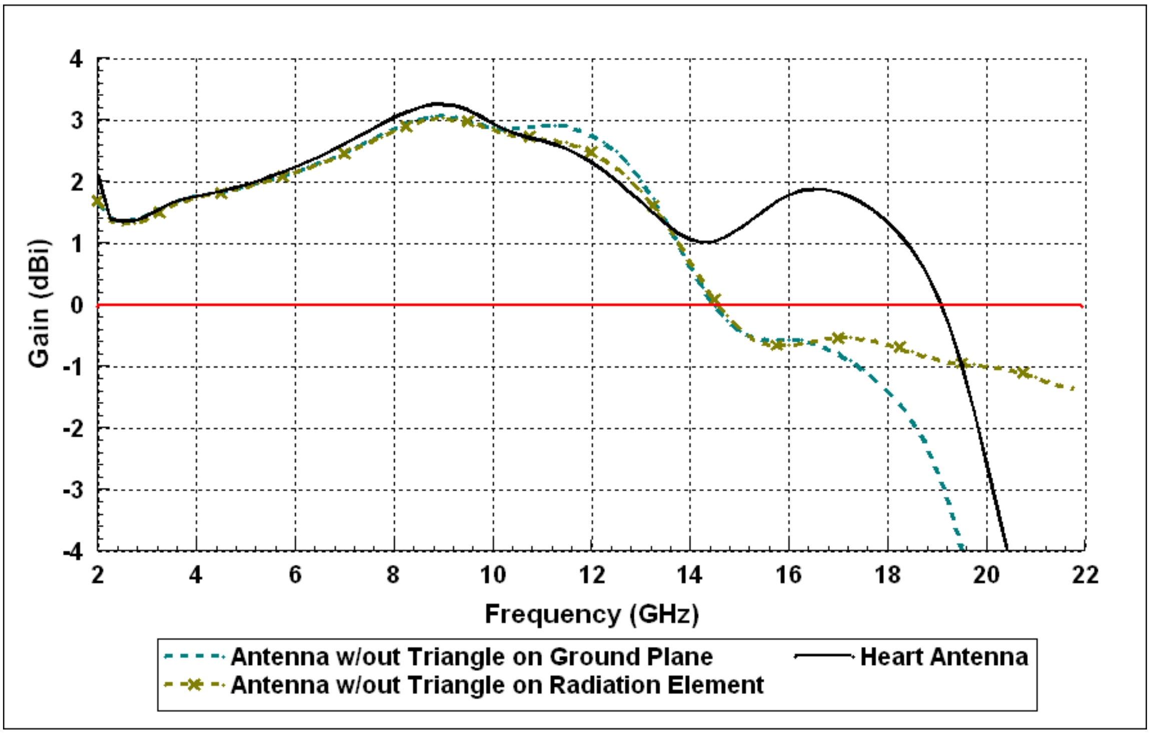


Figure 3.24. Comparison of gain w/wout triangles

3.4. DISCUSSION OF SIMULATION RESULTS

After evaluating the three phases, the results are put together for a final confirmation and comparison. The parameters are finalized and the results of VSWR, return loss, and gain, far-field radiation pattern are shown in Figure 3.25 to Figure 3.29.

As seen in Figure 3.25, presented heart antenna's VSWR is less than two over the entire frequency range. Only small frequency range, VSWR is higher than two and highest value is 2.1. It proves that heart antenna is suitable for wireless UWB antenna applications between the frequency 4 GHz to 22 GHz. In addition, comparison of return loss is given in Figure 3.26. Since return loss characteristics is same with VSWR, over all frequency range desired return loss level is achieved

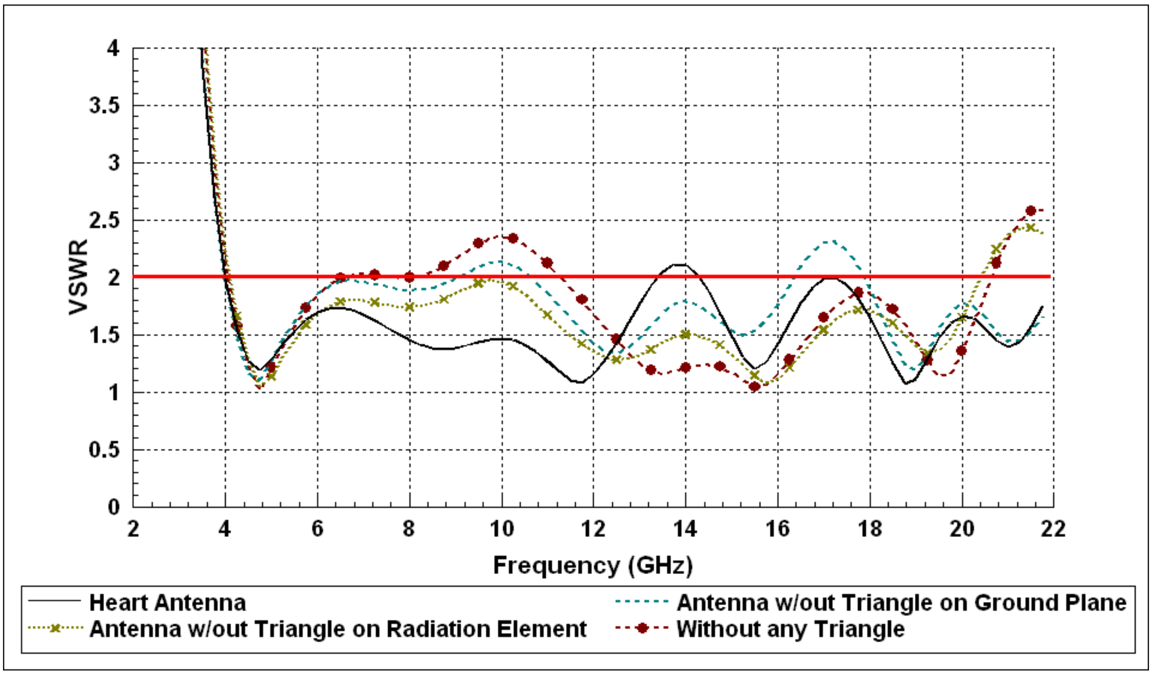


Figure 3.25. Comparison of VSWR for all simulations

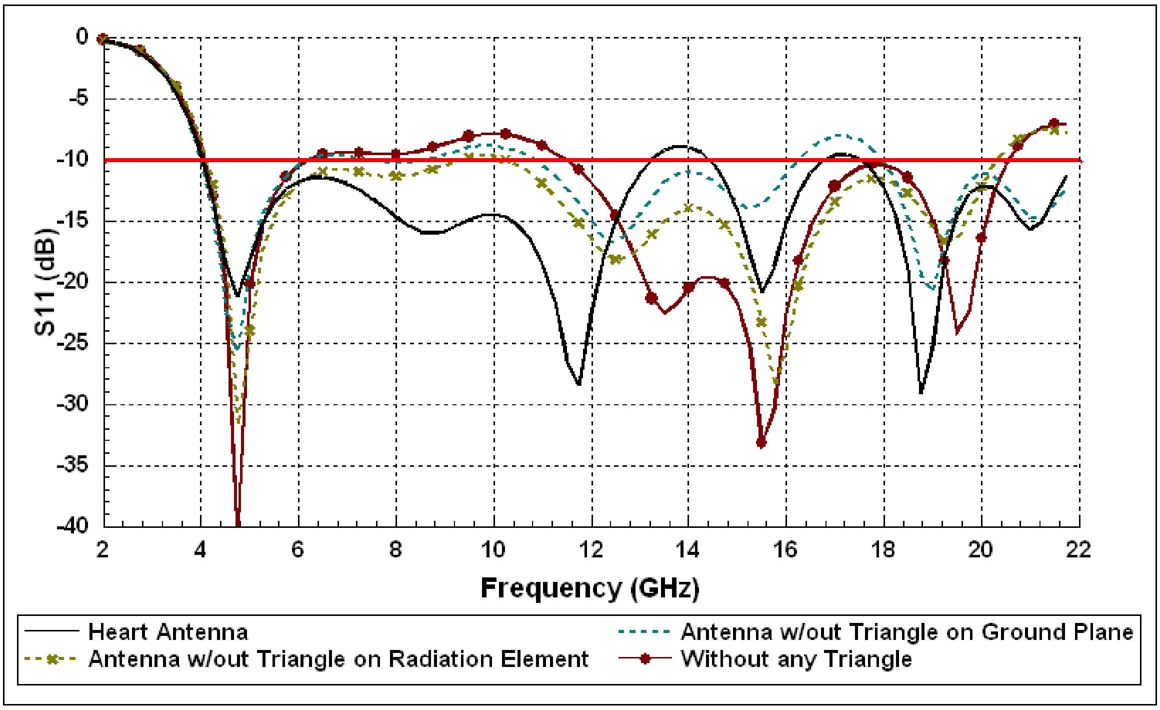


Figure 3.26. Comparison of return loss for all simulations

As a next step, gain of the presented heart antenna is compared with previous simulation steps and seems that between 2 GHz to 19.1 GHz antenna gain is higher than 0 dBi. However, since antenna matching frequency range is started at 4GHz, antenna gain is also valuable after 4 GHz. As seen in Figure 3.27, Heart antenna max gain is 3.1 dBi at 9 GHz and almost all frequency range min 1 dBi antenna gain is achieved. With the help of the simulation results of VSWR and antenna gain, presented heart antenna operation frequency start at 4GHz and ended at 19.1 GHz. Between these frequencies, antenna could be use for various UWB applications. In Section 3.5, final design specifications and parameters are presented. The parameters are used to realize the Heart shape antenna.

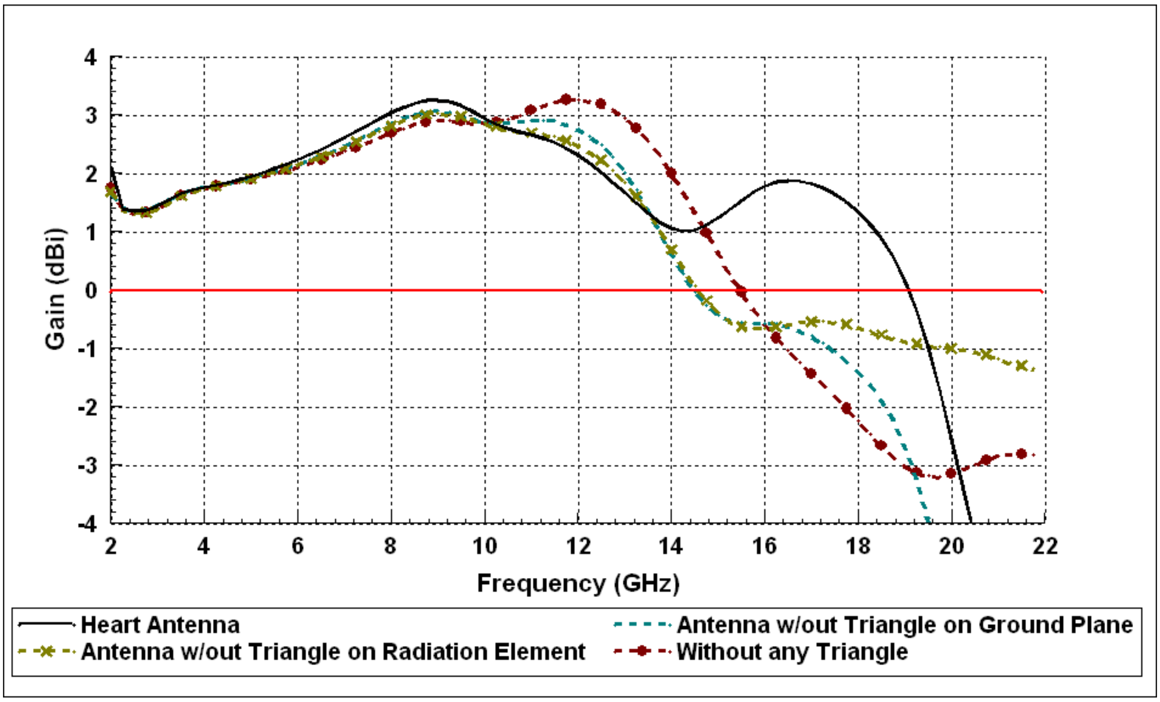


Figure 3.27. Comparison of Gain for all simulations

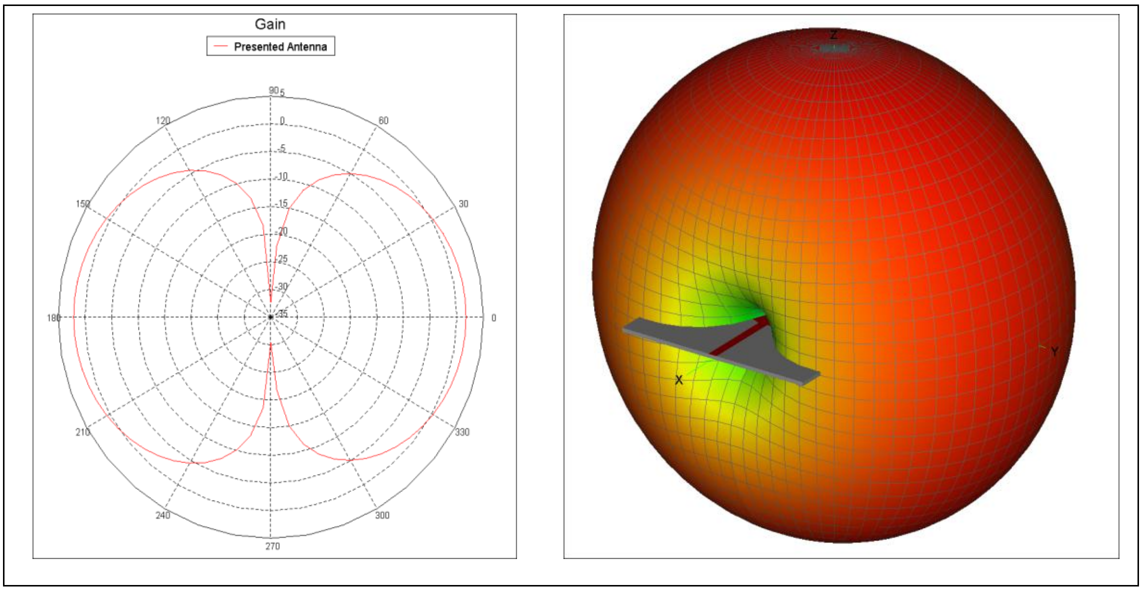


Figure 3.28. Radiation pattern and 3D graphic of the presented antenna at 4 GHz

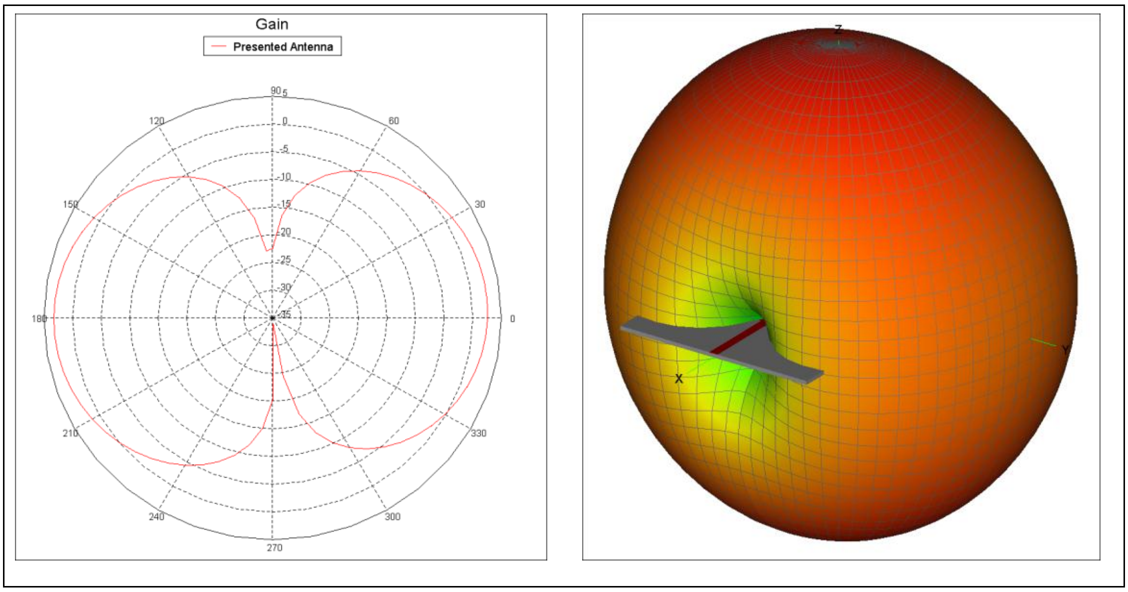


Figure 3.29. Radiation pattern and 3D graphic of the presented antenna at 7 GHz

3.5. FINAL DESIGN SPECIFICATIONS AND PARAMETERS

This antenna was designed to exhibit ultra-wide bandwidth in the case of wireless and mobile applications. With the help of the above design progress, finalize antenna parameters are performed and realization of the antenna is done with those results. Table 3.5 shows the presented antenna specifications and design parameters.

Table 3.4. Heart shape antenna specifications and design parameters

Items	Value	Items	Value
Bandwidth	4-19.1 GHz	**Substrate**	Rogers RO3035
VSWR	< 2	**Dimensions**	24x26 mm2
Return Loss	< -10dB	**Height**	0.5 mm
Gain	>0 dBi	**Dielectric Constant**	3.50

4. REALIZATION OF HEART SHAPE UWB ANTENNA

After going through a series of attempts, the final design has been concluded. To do that first we draw our antenna on EAGLE as you seen Figure 4.1. We draw the identical antenna that we built on FEKO so that we can send a copy of our antenna to industry to realize it.

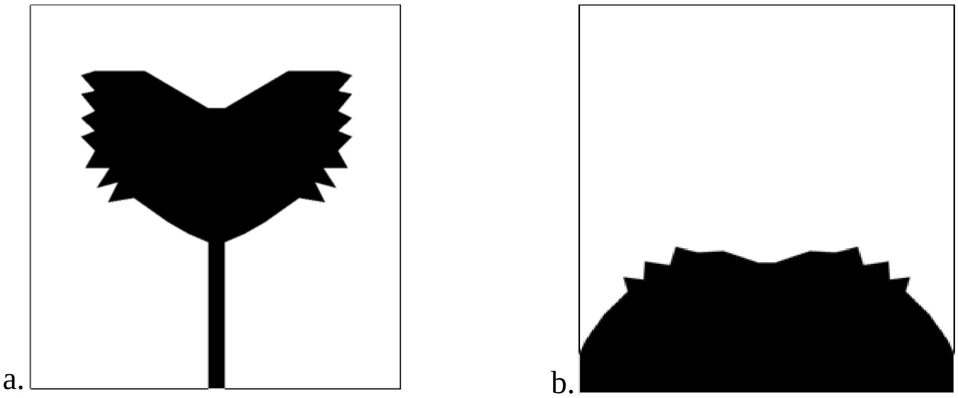


Figure 4.1. Eagle drawing of presented antenna a. Top view b. Bottom view

After drawing our antenna we sent our artwork to realize our antenna. Here in Figure 4.2, it’s seen our antenna top and bottom view respectively.

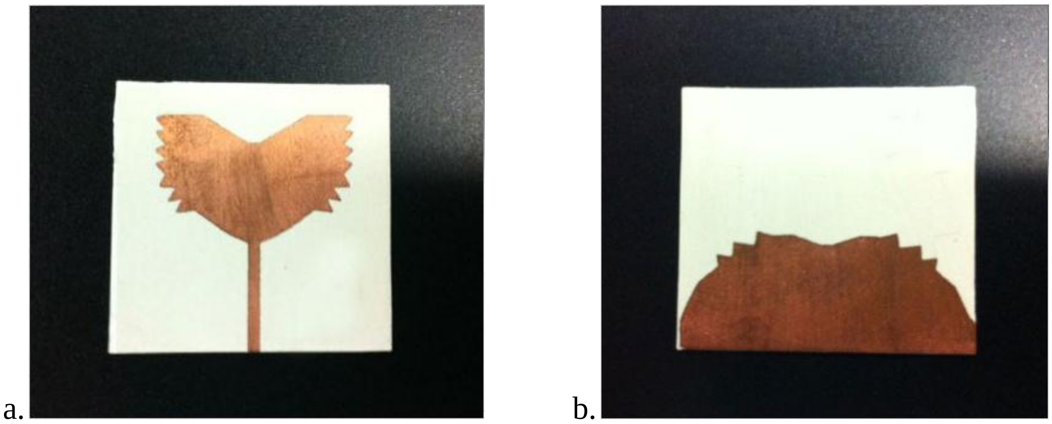


Figure 4.2. Realization of heart shape antenna a. Top view b. Bottom view

5. MEASUREMENT RESULTS AND COMPARISION

5.1. MEASUREMENT RESULTS

After all simulation and realization steps, finally Heart shape UWB antenna was completed. Figure 5.1 is shown the fabricated antenna.

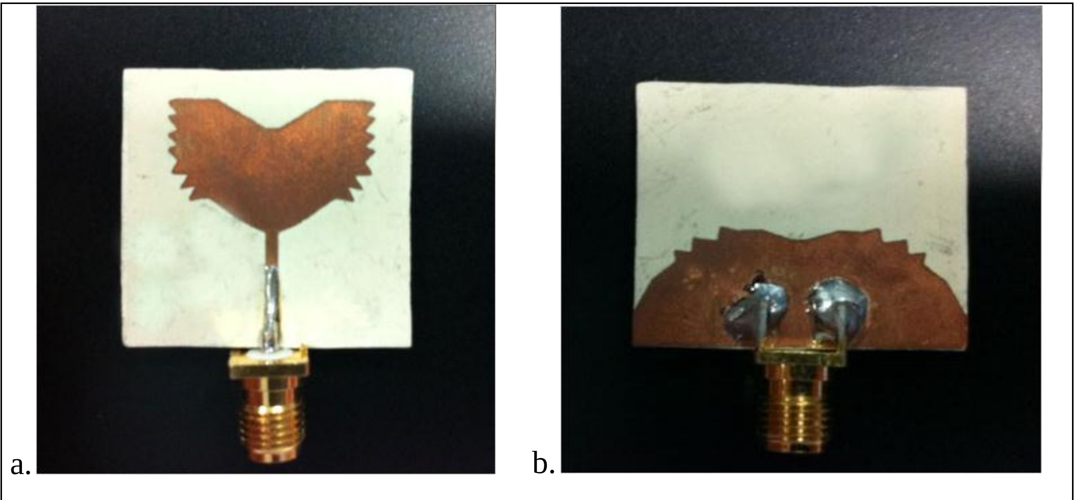


Figure 5.1. Fabrication of heart shape antenna a. Top view b. Bottom view

To measure the values of VSWR, network analyzer is used. Network analyzer is an instrument used to analyze the properties of electrical networks, especially those properties associated with the reflection and transmission of electrical signals known as scattering parameters (S-parameters). Network analyzers are used mostly at high frequencies. Before measurement was started, first of all calibration was done. Calibration is the process of establishing the relationship between a measuring device and the units of measure. Calibration was done for the ultimate accuracy and performance in tester verification. Our presented antenna was connected to Network analyzer and VSWR measurement was performed. Figure 5.2 shows the VSWR of the presented antenna.

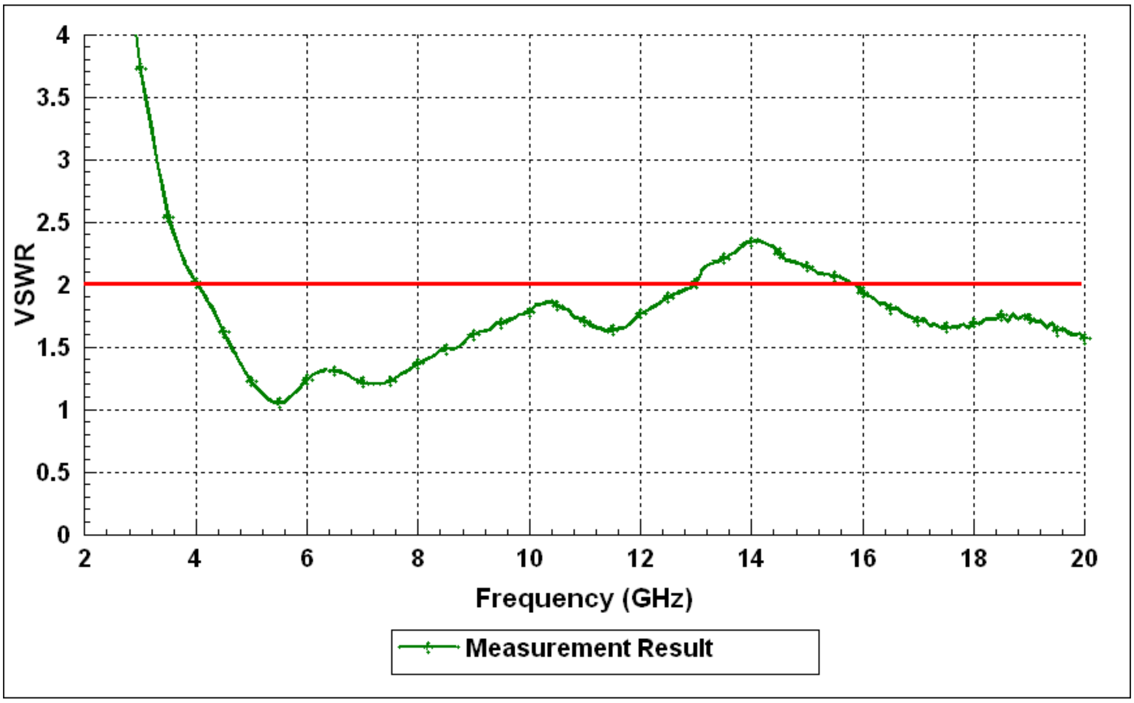


Figure 5.2. Measurement results of VSWR

As seen in Figure 5.2, over all VSWR target is achieved and suitable for wireless and mobile application. Only the small frequency range VSWR value is over two with a less value. The return loss of the represented antenna is also measured and Figure 5.3 is shown the return loss value. Next chapter, the measurement and simulation results will be compared of the presented antenna.

5.2. COMPARISION OF MEASUREMENT AND SIMULATION RESULTS

In order to understand measurement is accomplished, simulation and measurement results were plotted. Figure 5.3 shows the comparison of VSWR values.

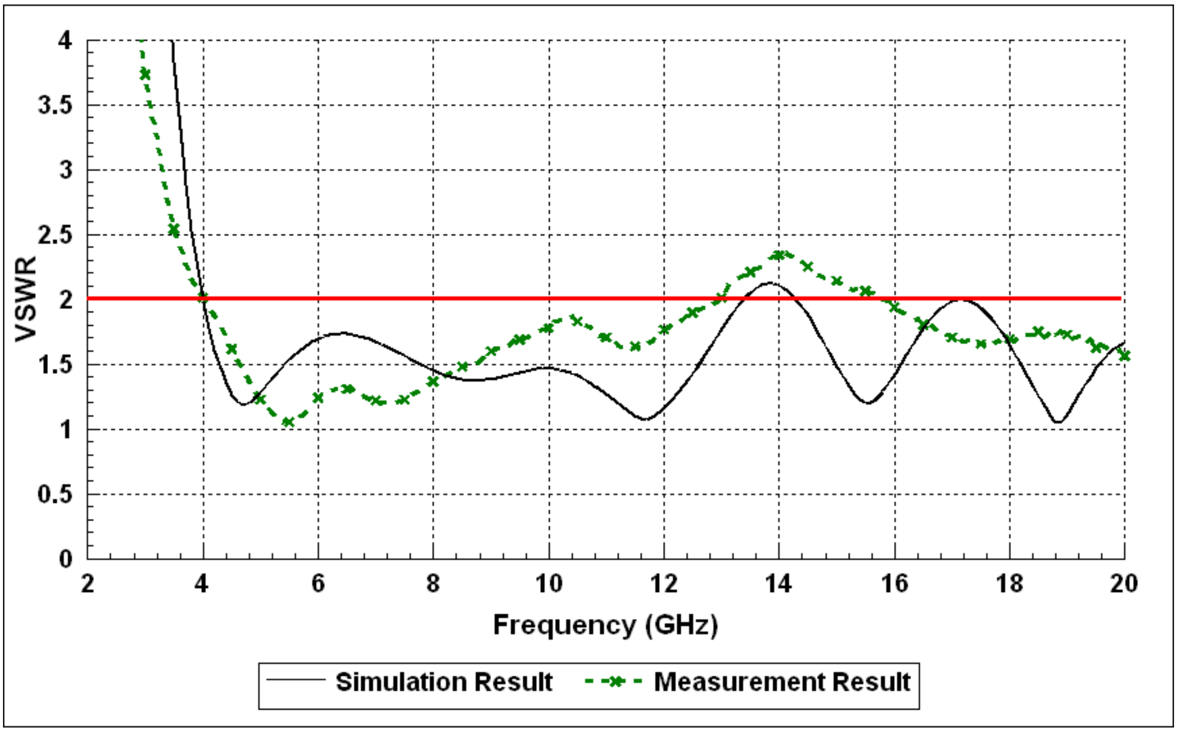


Figure 5.3. Simulation and measurement results comparison of VSWR

As it seen from the Figure 5.3, measurement and simulated results have same characteristics between the frequency ranges from 4 GHz to 19.1 GHz. However small frequency range, measured values of VSWR are higher than simulation, but still those values are acceptable range. Since the characteristic of simulated antenna is same with measurement results, the difference is because of small size realization difficulties. This Figure shows that measurement result is roughly similar to simulation result. Even with that discrepancy, very large broadband antenna performance is observed. Since we did not have the ability to measure system gain, we relied on simulated values which were higher than 0dBi over the target frequency band.

6. CONCLUSION

In this thesis, heart shape ultra wideband antenna was designed by using a 3D full wave electromagnetic simulation program. The simulation results obtained from simulation program were compared with each other and tabled to make a comment on the results.

To overcome the narrow band characteristics of patch antenna, the structure of the radiation part is designed with elliptical and rectangular patch. Also triangular patches are used edge of the antenna to enhance the VSWR and gain of the antenna. In addition, modified ground of the presented antenna also consists of two elliptical patches with a small segment of arc at the middle of the ground. With the help of the triangular patch on the modified ground, enhanced gain and impedance matching is achieved.

According to design, maximum VSWR of 2 and minimum system gain 0 dBi are the design criteria of this thesis. Numerical simulation shows that the antenna has a bandwidth ratio of 5:1 within the frequency range of 4 GHz – 19.1 GHz with a 25x26 mm^2 Heart shape UWB antenna.

Measurement and simulated results have same characteristics between the frequency ranges from 4 GHz to 19.1 GHz. Since antenna measurement environment is not under perfect conditions, measurement results are not exactly matching with simulation results. Even with some discrepancy, very large ultra wide band antenna performance is observed. As an outcome of this thesis we have proved that the structure we designed, Heart shape UWB antenna can be used for ultra wide band and wireless communications. We designed and made a prototype of an antenna that has not been realized before.

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