

# Design and Analysis of Circular Patch Micro-Strip UWB Antenna for Breast cancer Detection

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**ABSTRACT:** This research presents a novel Omni-directional micro-strip UWB antenna with enhanced bandwidth design to be used in breast cancer detection. The antenna consists of a circular radiating patch fed by inset feeding technique. Certain miniaturization techniques such as partial ground plane for expansion of bandwidth in order to achieve our intention. Details of antenna design and simulation results such as return loss and radiation patterns are discussed in this paper. The final antenna structure exhibits good UWB characteristics and has surpassed the bandwidth requirements. Proposed antenna has the advantages of wide bandwidth, compact size and low cost, good Omni-directional radiation patterns for using in microwave imaging applications. The maximum measured gain for the fabricated antenna is around 6.1 dBi with an average efficiency above 88% throughout the bandwidth.

**KEYWORDS:** Ultra Wide Band (UWB), microwave imaging system, Miniaturization, Microstrip Antenna, Breast Cancer Detection

## I. INTRODUCTION

Breast cancer is the most common non-skin related malignancy and the second leading cause of cancer death among women in the world [1]. It is the most common malignancy in women after skin cancer and the second leading cause of female cancer mortality [2]. Early detection of cancer is an important aspect for effective treatment. Widely used detection techniques include X-ray mammography, magnetic resonance imaging (MRI), and ultrasound technique [3]. Microwave imaging provides an alternative detection technique that requires simple configuration. The objective is to detect the variations in the dielectric properties of a tumour from the surrounding healthy tissue [4]. The dielectric properties of human body tissue at microwave frequencies are sensitive to physiological factors of clinical interest, including water content, temperature, and vascularization. The dielectric properties of healthy and cancerous tissues at microwave frequencies revealed that dielectric constant and conductivity for cancerous tissue are three or four times greater than that of normal tissue [5]. For a long time, microwave engineers have dreamed of using nonionizing electromagnetic waves to image the human body in order to detect cancers. The breast can easily be accessed from outside, while internal organs are much less accessible. Normal breast tissue is also more translucent to microwaves than many other tissues, such as muscle or brain. The limitations of X-ray mammography provide clear motivation for the development of a complementary breast-imaging tool to assist in detection and diagnosis. According to the IOM report, an ideal breast screening tool:

- has low health risk
- is sensitive to tumours and specific to malignancies
- detects breast cancer at a curable stage
- is cost effective and widely available
- involves minimal discomfort, so the procedure is acceptable to women
- provides easy to interpret, objective, and consistent results.

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For reliable detection of small malignant tumours, a significant and consistent contrast between malignant and other breast tissues is required.

## II. RELATED WORK

Dielectric properties of biological tissues at radio and microwave frequencies have been the subject of research by many groups and comprehensive surveys have been published and could be used as a base to evaluate the behaviour of microwaves in human's tissue. In the next decade, microwave systems are likely to become a viable diagnostic option for many women. Active microwave imaging (MWI) of the human body involves transmitting low-power, non-ionizing narrowband or wideband microwave signals into the area of interest using an antenna system, which in turn measures the scattered microwave signals. For this purpose, two active types of microwave imaging techniques - tomography and radar based are being used to measure the scattered microwave signals.

Microwave tomography is based on diffraction based imaging. The dielectric properties are reconstructed back from the measurements based on the signals transmitted through UWB antennas into the human body. Reconstruction of images is based on iterative model procedures which are computationally extensive, as they always try to minimize the errors between measured and calculated electric fields.

Radar based approach tries to identify the difference in the permittivity due to scattering of small objects such as tumours. The scattered signals are processed to generate a map of backscattered microwave energy based on simple sum and delay algorithm approach. This technique offers good resolution, uses non-ionizing radiation and is relatively low cost and more comfortable, in comparison with the traditional X-ray mammography [6].

Microwave tomography and radar based microwave imaging techniques have been investigated in cancer detection [7-9]. UWB antennas used in medical imaging should be planar, compact, with high radiation efficiency and stability over the entire operation band. Most of UWB antennas presented in the literature exhibit Omni-directional radiation patterns with low gain. Several kinds of antennas can be used, for instance, micro-strip, Vivaldi, Bowtie and circular patch antennas. [10-15].

Basic Breast Structure: The female breast has three major breast structures:

- Adipose tissue
- Glandular tissue and
- Connective tissue

The dielectric properties of breast tissue are primarily determined by the adipose content. For the purposes of microwave imaging; biological tissues can be classified as high water-content and low water-content, High water-content tissue consists of approximately 60-80% of water, including muscle and skin. Low water-content tissue includes bone and adipose tissue consisting of approximately 40% and 10% water respectively. The normal breast largely consists of adipose tissue, and the presence of infiltrating neoplastic tissues of high water content will certainly lead to pronounced changes in the dielectric properties of breast tissue. A good understanding of the dielectric properties of malignant and healthy tissues is important for the development of diagnostic and therapeutic technologies that utilize the microwave frequency range. It has been shown that dielectric properties of malignant tissues differ from normal tissues by varying amounts due to variations in water content between normal and malignant tissues. Generally malignant tumours develop an extensive network of blood vessels to aid their growth, resulting in increased water content in the region of the malignant tumour. Dielectric property is modelled by using Debye dispersion [16]-[17], and can be obtained normal breast (fatty) and tumour dielectric property that shown in Table I at 6 GHz [17&18].

Table I. Dielectric Property & Conductivity of Breast & Tumour Model at 6GHz

	Normal Breast Tissue	Breast Skin	Tumour
$\epsilon_r$	9.5	35.7	50
$\sigma$	0.4	3.17	4

This paper presents a planar circular patch antenna which is designed using Ansoft's High Frequency Structure Software (HFSS). Section II presents the geometry, the antenna model and various antenna dimensions. Section III

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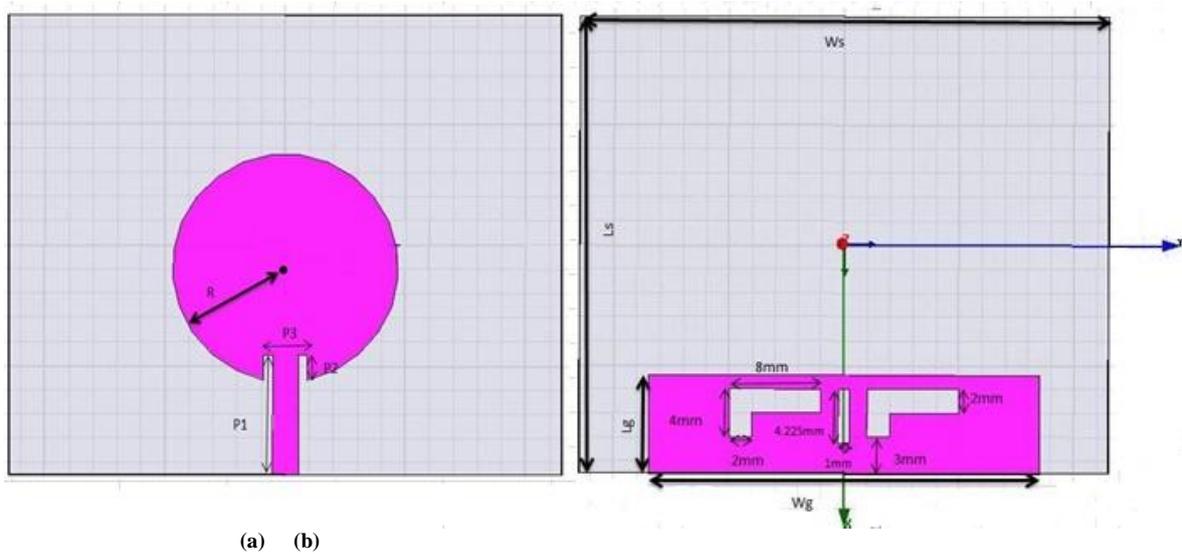
Vol. 4, Issue 12, December 2015

discusses the simulated and the experimental results performed and Section IV is summarized the final conclusions of this study.

### III. ANTENNA DESIGN

#### a. Antenna geometry

Figure 1 show the top and bottom view of the proposed antenna with partial ground plane.



(a) (b)

Figure 1 Geometry of proposed antenna (a) Top-View (b) Bottom View

The proposed antenna consists of a circular radiating patch and a ground plane fed by inset feeding technique for perfect impedance matching. The patch is connected to a micro-strip feed-line with the width of  $W_f$  and length of  $L_f$ . In the micro-strip feed line, the impedance of the micro-strip line is given by [19]-

$$Z_c = \frac{120 \pi}{\sqrt{\epsilon_{eff}}} \left[ \frac{1}{\frac{W_f}{h} + 1.393 + 0.667 \ln\left(\frac{W_f}{h} + 1.444\right)} \right] \quad (1)$$

The antenna is realized on FR-4 substrate with dielectric permittivity  $\epsilon_r = 4.4$  and thickness  $h = 0.5$  mm. Its width and length denoted by  $W$  and  $L$  are respectively 46 mm and 38 mm. The origin of the coordinate system is taken at the centre of the structure. The geometrical parameters of the proposed antenna structure are tabulated in Table2.

Table 2: Dimension of the designed antenna

Parameter	Dimension(mm)
R	10.4564
P1	9.909
P2	2.05
P3	3.582
Ws	46
Ls	38
Wg	34
Lg	8.2598

## International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 12, December 2015

The analysis of the proposed antenna structure is based on transmission line modal analysis.

### DESIGNING EQUATIONS

- (1) Resonant frequency for the TM<sub>mn0</sub> modes can be written as-

$$(fr)mn0 = \frac{1}{2\pi\sqrt{\mu\epsilon}} \left[ \frac{X' mn0}{a} \right] \quad [2]$$

$$(fr)mn0 = \frac{1.8412 v_0}{2\pi a e \sqrt{\epsilon_r}} \quad [3]$$

- (2) Effective Radius

$$ae = a \left\{ 1 + \frac{2h}{\pi\epsilon_r a} \left[ \ln \left( \frac{\pi a}{2h} \right) + 1.7726 \right] \right\}^{1/2} \quad [4]$$

- (3) Radius of circular patch

$$a = \frac{F}{\left( 1 + \frac{2h}{\pi\epsilon_r F} \left[ \ln \left( \frac{\pi F}{2h} \right) + 1.7726 \right] \right)^{-1/2}} \quad [5]$$

$$F = \frac{8.791 \times 10^9}{fr \sqrt{\epsilon_r}} \quad [6]$$

- (4) Effective dielectric constant is given by-

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left[ 1 + 12 \frac{h}{a \sqrt{\pi}} \right]^{-1/2} \quad [7]$$

Where,

- h = substrate thickness
- a = radius of circular patch
- a<sub>eff</sub> = effective radius of circular patch
- v<sub>0</sub> = speed of light
- f<sub>r</sub> = resonant frequency
- ε<sub>r</sub> = relative permittivity
- ε<sub>eff</sub> = effective permittivity

In the design of the proposed antenna structure, to create impedance matching that results in bandwidth enhancement, we embedded a pair of rectangular shaped slots fig. 2(b), another rectangular shaped slot placed in the middle of the pair slots in the ground plane fig. 2(c) and L-shaped pair slots with rectangular slot in between them fig. 2(d). Figure 2 shows the step by step development of the antenna structure used for simulation in next section.

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(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 12, December 2015

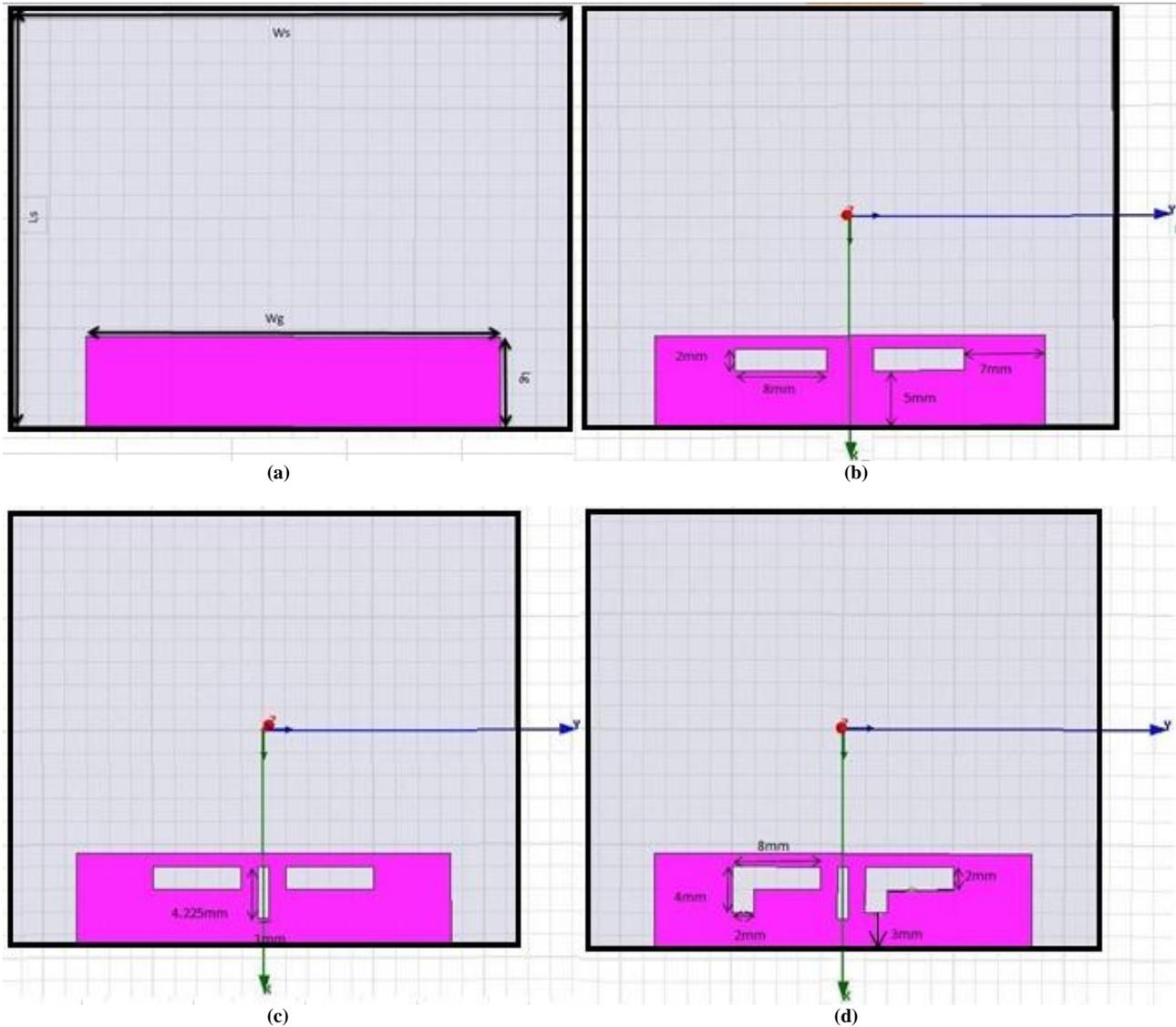


Fig.2 the step by step development of the proposed antenna structure used for simulation

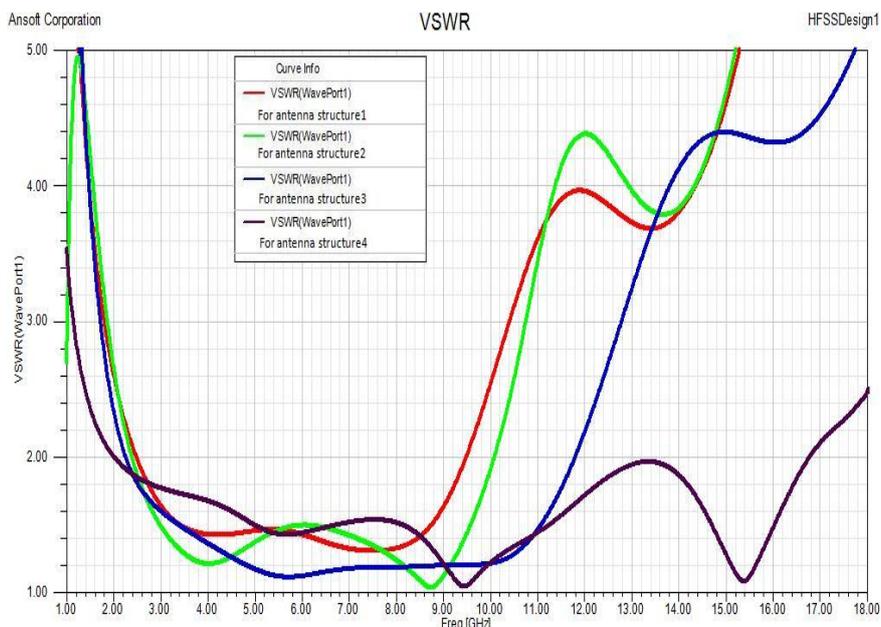
### III. SIMULATION RESULTS AND DISCUSSION

The analysis of proposed antenna is done using the simulation performed on Ansys HFSS EM simulator for the frequency range of 1 to 20 GHz. Figure 3 shows the simulated VSWR of various structures shown in Figure1 and 2.

## International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 12, December 2015



**Fig.3 Graph of simulated VSWR characteristics of the various structures**

**Structure 1: Antenna structure without any slot in ground plane**

**Structure 2: With rectangular pair slot**

**Structure 3: With rectangular pair slot added with another slot between pair slot**

**Structure 4: With L shaped pair slot in addition with rectangular slot between them (Proposed antenna structure)**

From the plot of simulated VSWR Vs. frequency of proposed antenna structure, it is seen that the antenna has a bandwidth ranging from 2.01 to 16.78GHz for VSWR < 2 dB, which is very attractive for UWB microwave imaging application. It is clearly seen from the graph and table 3 that addition of slots in ground plane improves impedance matching and there is a considerable amount of enhancement in bandwidth.

**Table 3: Bandwidth covered for various antenna structures**

Antenna Structure	Bandwidth(MHz)
Structure 1	6990
Structure 2	7690
Structure 3	9530
Structure 4	14770

Figure 4 given below showing the Group delays vs. frequency curve. Group delay is a measure of transit time of a signal through a device versus frequency. All signals are delayed while passing through a device or medium. If the delay is the same for all frequencies in a signal the antenna does not affect the shape of the signal. Group Delay is “the derivative of radian phase ( $\phi$ ) with respect to radian frequency ( $\omega$ ). It is equal to the phase delay for an ideal non-dispersive delay device, but may differ greatly in actual devices where there is a ripple in the phase versus frequency characteristic.”

## International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 12, December 2015

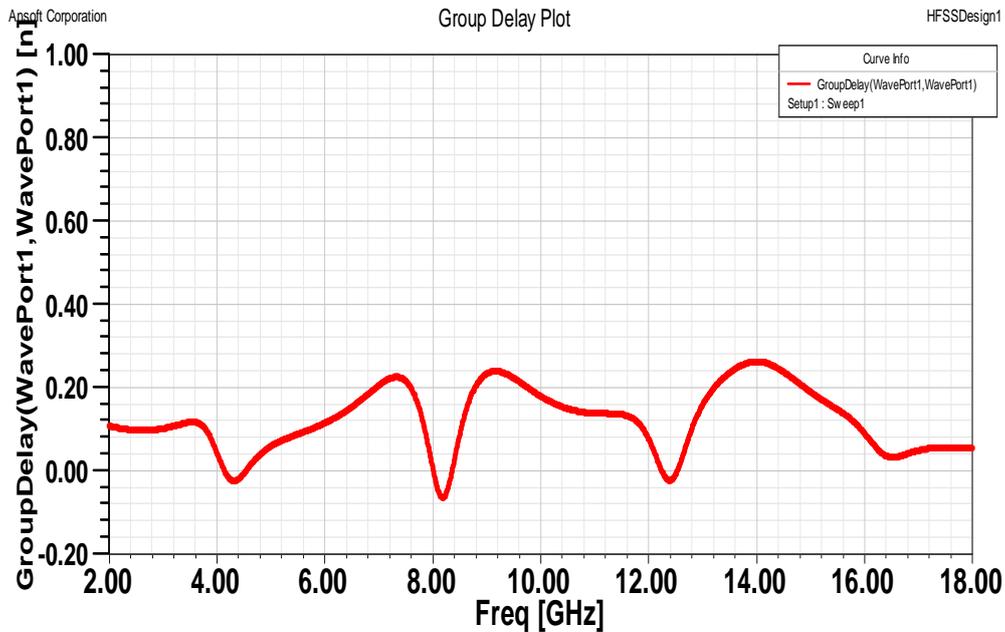


Fig.4 Group Delay vs. Frequency plot

From the figure, group delay variations of up to 0.3 ns can be observed within the operating bandwidth. Simulation results indicate that the antenna has the potential to detect breast tumours.

Radiation efficiency of the proposed antenna is shown in Figure 5. As can be seen from the below given figure, the radiation efficiency of the propose antenna is greater than 86% across the operation band. Simulation results shows that the antenna operates in the desired frequency bands with suitable radiation efficiency.

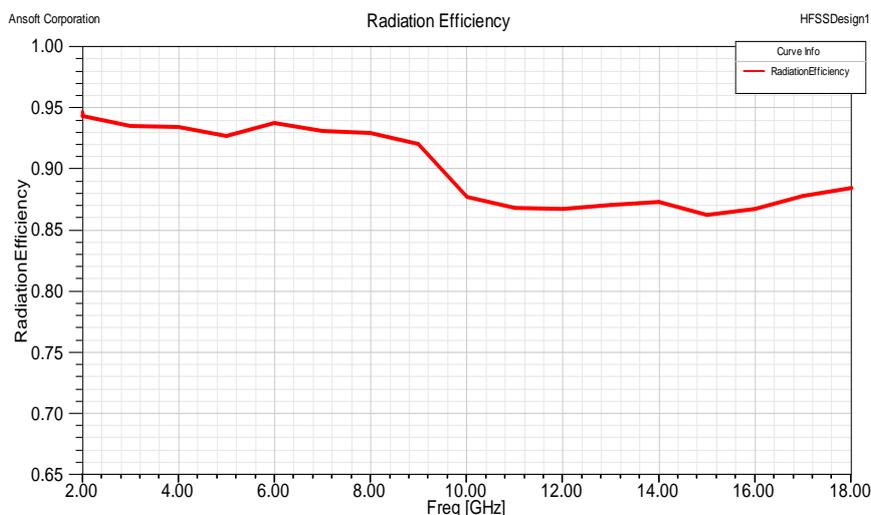


Fig.5. Radiation Efficiency of proposed antenna structure

The far field radiation pattern of the final structure is also simulated by HFSS which is illustrated by Fig. 6 for the frequency 8.4GHz. It can be seen that the patterns in the *H*-plane are Omni-directional as expected, whereas in the *E*-plane, radiation patterns have a dumbbell shape.

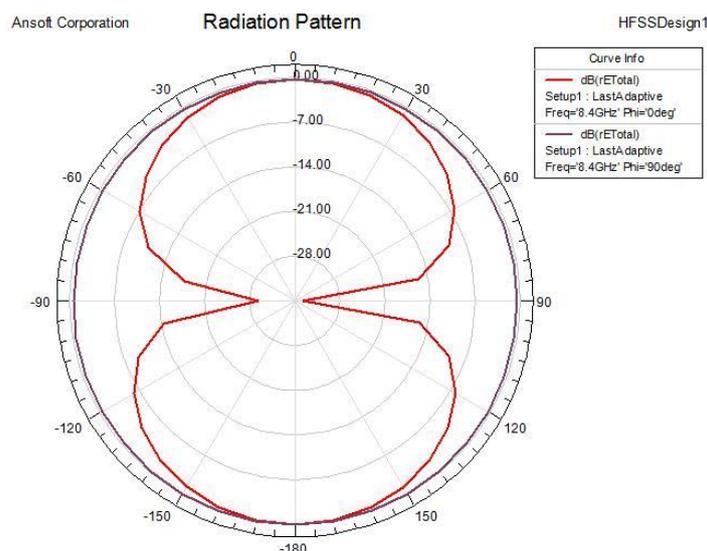


Fig.6.Simulated radiation pattern at 8.4 GHz

#### IV. CONCLUSION

Microwave breast imaging has been an active research area over the past two decades and has received considerable recent attention. In this paper in new compact UWB antenna design has been presented. The operating bandwidth of antenna at a minimum workable return loss of 10 dB achieved was 2.01 GHz to 16.78 GHz. This antenna has the advantages of wide bandwidth, compact size, low cost and good Omni-directional radiation patterns with acceptable gain of 9 dBi with an average efficiency above 86% throughout the bandwidth considered as preferred for microwave imaging application such as breast cancer detection.

A prototype antenna is planned to be fabricated by the authors using low-cost FR4-Epoxy substrate for further work relating to this Paper. Addition, further investigations are still needed to be carried out in order to be agreed clinically.

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