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Designing The Antenna For Ism Band Application

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ABSTRACT
Breast cancer is a second leading cause of cancer in women today after lung cancer and is the most common cancer among women according to World Health Organization (WHO). Different techniques are currently used to detect breast cancer, e.g., X-ray mammography ultrasound, magnetic resonance imaging (MRI), microwave imaging, etc. The basic idea of using the microwave imaging system for breast cancer detection is to transmit electromagnetic waves from a transmitting antenna to the breast and receive the scattered waves at a receiving antenna. These received waves contain vital information regarding the tumour location, shape, size, and electrical properties. A critical part of any detection scheme is the antenna design. In order to obtain high resolution, accurate images the antennas must be able to radiate signals over a wide band of frequencies while maintaining the fidelity of the waveform over a large angular range.

Keywords: Industrial Scientific and Medical band (ISM); Micro strip patch; MRI; Polarization; UWB.

INTRODUCTION

The work present in this paper is based on a project which intended for the design, fabricate and testing of micro strip patch antenna by using high frequency structure simulator software for ISM band application The ISM stands for Industrial, Scientific, and Medical radio band. It refers to a group of radio bands or parts of the radio spectrum that are internationally reserved for the use of radio frequency (RF) energy intended for scientific, medical and industrial requirements rather than for communications. ISM bands are generally open frequency bands, which vary according to different regions and permits. ISM band frequency range is 902-928 MHZ. The ISM band center frequency is 915MHZ
The 2.54 GHz ISM band is a commonly accepted band for worldwide operations. Microwave ovens, cordless phones, medical diathermy machines, military radars and industrial heaters are just some of the equipment that makes use of this ISM band.ISM bands are also called unlicensed bands.
The use of ISM equipment generates electromagnetic interference that interrupts radio communications that make use of the same frequency. Therefore, this equipment was restricted to specific frequency bands. Generally, the communication equipment that operates in these bands should tolerate the interference created by ISM equipment, and therefore users do not have any regulatory protection from the use of ISM equipment. In paper [1]-[3], they designed and developed the stacked patch antenna for breast cancer detection. The Microwave Tomography method was used to detect the Breast cancer [4]. UWB Micro strip patch antenna with simple capacitive feed for breast cancer detection was discussed in paper [5]-[6].
From biological investigation one can observe that there exists a contrast between the electrical properties of normal and malignant breast tissues. Taking advantage from such observation a spiral PIFA antenna was designed to help in the detection of breast cancer [7]. The antenna is intended to operate in the industrial, scientific, and medical (ISM) frequency band. A heterogeneous breast model was designed with more resemblance to the real case. On paper [8], the Radiation properties of the planer UWB dipole antenna in the proximity of dispersive Body Models were discussed. These types of antennas are designed to be used as a stethoscope. The whole structure is simulated on CST Microwave Studio and measurements are carried using Network Analyzer. The Micro strip patch antenna is used for body communication with the wearable Vivaldi UWB planer antenna in paper [9]
The reminder of this paper is organized as follows. In section A, discussed about the basics of antenna. In section B, discussed about the Micro strip patch antenna. In section C, we are calculating the antenna width and length. The proposed methodology is discussed in section D.
Proposed antenna geometry is depicted is section E, Simulation results are discussed in section F. In Section G shows the conclusion.

A. Antenna Fundamentals

Antennas are a very important component of communication systems. By definition, an antenna is a device used to transform an RF signal, travelling on a conductor, into an electromagnetic wave in free space. Antennas demonstrate a property known as reciprocity, which means that an antenna will maintain the same characteristics regardless if it is transmitting or receiving. When a signal is fed into an antenna, the antenna will emit radiation distributed in space in a certain way. A graphical representation of the relative distribution of the radiated power in space is called a radiation pattern.
There are several types of antenna which made depends on the application for example dipole antenna, monopole antenna, micro strip antenna, horn antenna, antenna array and etc.

B. Introduction to Microstrip Antenna

There are several types if micro strip antennas (also known as a printed antenna) the most common of which is the micro strip patch antenna or patch antenna. A patch antenna is a narrow band, wide-beam antenna fabricated by etching the antenna element pattern in metal trace bonded to an insulating dielectric substrate with a continuous metal layer bonded to the opposite side of the substrate which forms a ground plane Micro strip transmission lines consist of a conductive strip of width (W) and thickness "H".

a. Antenna Design and Implementation

To detect the cancer tumours, while using TEM horn antenna placed in a solid dielectric medium for microwave imaging of the breast, the antenna couples the microwave energy into the tissue without being immersed itself in a coupling medium[5].It is crucial for the sensitivity and the EMI immunity of the microwave breast imaging system also by using the bowtie antenna, contrast can be detected by use of microwave energy with an array of antennas that illuminate the breast through coupling medium and by measuring the scattered fields.

Ultra wide band dipole antenna is investigated both in the proximity of two different dispersive body tissue models and in free space, the patterns were noticed to be rough i.e.) uneven surface, because of the reflections from the body [8]. Prototype of antenna is already fabricated and verified. The measurements will not be provided. On-body measurement further verifies the impedance matching of the proposed Vivaldi antenna [9]. Diversity reception configuration and performance evaluation including space diversity and polarization diversity have been carried out based on the proposed Vivaldi element as well as an optimized linear polarized Omni directional capsule antenna. The problem of this work is more power can be received using more receiver elements given that the coupling between elements is not too high.

Existing antenna designs either use resistive loading to improve their UWB performance, e.g., resistively loaded monopoles dipoles bow-tie or horn antennas, which result in lower efficiencies, or antennas are unsatisfactory [4]. A patch antenna is presented which has been designed to radiate into human breast tissue [5]. The antenna is best suited because it possesses a wide input bandwidth, stable radiation patterns and a good front-to-back ratio.

This process depends on overcoming the following three problems

1. Achieving high resolution, overcoming the high attenuation in human tissue
2. To permit the detection of relatively deep- seated tumours
3. Preventing reflections from skin, bones and other anatomical features (clutter) obscuring the signals from tumours.

b. Microstrip Patch Antenna Design Procedure

The three essential parameters for the design of a rectangular Micro strip Patch Antenna is:

1. Frequency of operation (F_O):

The resonant frequency of the antenna must be selected appropriately.

2. Dielectric constant of the substrate (ε_r):

The dielectric material selected for my design is FR4 which has a dielectric constant of 4.4. A substrate with a high dielectric constant has been selected since it reduces the dimensions of the antenna.

3. Height of dielectric substrate (*h*):

For the micro strip patch antenna to be used in medical application, it is essential that the antenna is not bulky and it is shown in Figure 1. Hence, the height of the dielectric substrate is selected as 1.5 mm.

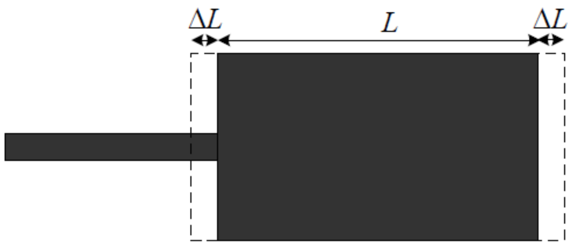

Figure 1 Basic structure of micro strip patch.

C. Antenna Width and Length Calculation:

Step 1: Calculation of the Width **(*W*):** The width of the Micro strip patch antenna is given

$$w = \frac{c}{2fo\sqrt{\frac{(\epsilon r+1)}{2}}}\text{m} \quad (1)$$

Step 2: Calculation of Effective dielectric constant **(**ε *reff***):** the effective dielectric constant as:

$$\epsilon reff = \frac{\epsilon r+1}{2} + \frac{\epsilon r-1}{2}\left(1+12\frac{h}{w}\right)^{-1/2} \quad (2)$$

Step 3: Calculation of the Effective length $(L\,eff)$: gives the effective length as:

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon reff}} \quad (3)$$

Step 4: Calculation of the length extension (ΔL)*:* the length extension as:

$$\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{reff}-0.258)\left(\frac{W}{h}+0.8\right)} \quad (4)$$

Step 5: Calculation of actual length of patch (*L*): The actual length is obtained by re-writing as:

$$L = L_{eff} - 2\Delta L \quad (5)$$

D. Proposed Methodology

Body area network (BAN) consists of wearable or implantable sensors that can establish two way wireless communications with a controller node that could be either worn or located in the vicinity of the body [9]. Inhomogeneity of the propagation medium in these networks could have a great impact on the sensor node's antenna characteristics. This in turn could affect the quality of the communication links unless the impact of the body has been properly considered the design phase of the antenna. For wearable sensor nodes, the antennas adjacency to the body and more precisely its location (e.g. head, chest, waist and wrist) and distance to the body surface can affect the radiation pattern, radiation efficiency, and resonance frequency. This could directly impact communication link between the sensors and communication node in the body area network. But better results are obtained only by placing in the chest.

The difficulties arise from the X-ray mammography is the small intrinsic contrast between diseased and normal tissue at X-ray frequencies. Breast compression is required to reduce image blurring and to create uniformity of tissue between the source and receiver located on the breast. The association of X-ray mammography with uncomfortable or ionizing radiation may reduce patients' compliance with screening recommendations. These concerns motivate to develop the microwave imaging technique for detecting breast cancer is the significant contrast in the dielectric properties at microwave frequencies of normal and malignant tissue. While microwave technology does not offer the potential for high spatial resolution provided by X-rays, it does offer high contrast with respect to physical or physiological factors, such as water content, vascularisation, blood-flow rate, temperature. Furthermore, microwave attenuation in normal breast tissue is low enough to make signal propagation quite feasible.

Two different methods of active microwave imaging techniques exploit the contrast in dielectric properties: Tomography methods and backscatter methods. The goal of microwave tomography is the recovery of dielectric properties of the object from measurements of microwave energy transmitted through the object. The challenge of it involves the solution of an ill conditioned nonlinear inverse scattering problem. As a result, these are inherently limited by vulnerability to small experimental uncertainties and noise. Furthermore reconstruction, the inverse scattering problem requires an image reconstruction algorithm that may be computationally intensive.

Considering the backscatter methods, it uses the measured reflected signals to interfere the locations of significant microwave scatters. Scattering arises from significant contrasts in dielectric properties. This is unsuccessful because a single antenna location was used for transmitting and receiving, eliminating the possibility of spatially focusing the signal. Without the spatial selectivity obtained by focusing, the tumour signature can be easily masked from adjacent breast regions. The relative arrival times and amplitudes of the backscattered signals provide information that is used to determine the location. It only seeks the location of strong scatters rather than attempting to completely reconstruct the dielectric properties.

*E. **Proposed Antenna Geometry***

The planar monopole antenna with various design parameters were constructed, and the numerical and experimental results of the input impedance and radiation characteristics are presented. The simulated results are obtained using the A soft simulation software high-frequency structure simulator (HFSS). The basic antenna structure consists of a square patch, a feed line, and a ground plane. The square patch has a width *W*. The patch is connected to a feed line of width *Wf* and length *Lf*.

The optimal dimensions of the designed antenna are as follows:

$Wsub$ = 12 mm, $Lsub$ = 18 mm, W = 10 mm, W_f = 2 mm, L_f = 7 mm, L_{PS} = 2 mm, L_{S3} = 5 mm, W_{S2} = 6 mm, L_{S2} = 1 mm, W_{S1} = 2 mm, L_{S1} = 3 mm, W_S = 1 mm, L_S = 2 mm, W_P = 1 mm, L_P = 2:5 mm, W_{P1} = 3 mm, L_{P1} = 2 mm, W_{P2} = 10 mm, L_{P2} = 3:5 mm, L_{gS} = 4:5 mm, and $L_{\ gnd}$ = 3:5 mm. Geometry of proposed antenna model is shown in Figure 2.

The current concentrated on the edges of the interior and exterior of the W-shaped slot. As a result, the desired high attenuation near the desired frequency can be produced. The variable characteristics can be achieved by carefully choosing the parameters (L_{S1} and W_{S2})for the W-shaped slot. In this structure, the width W_{S2}, is the critical parameter to control the bandwidth. On the other hand, the centre frequency of the notched band is insensitive to the change of W_{S2}. The resonant frequency of the band is determined byL_{S1}

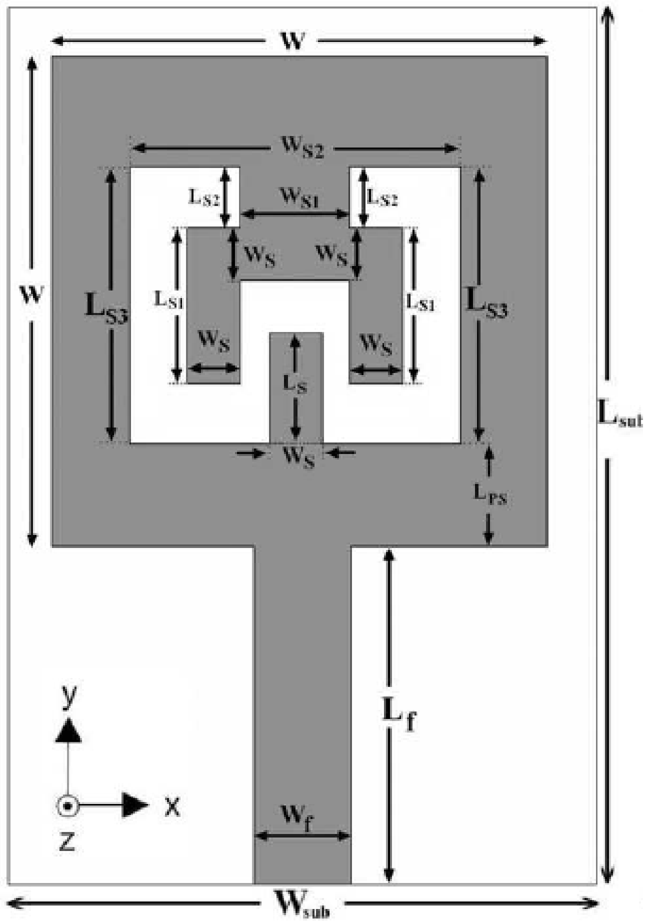

Figure 2 Geometry of proposed antenna model

F. Simulation and Results

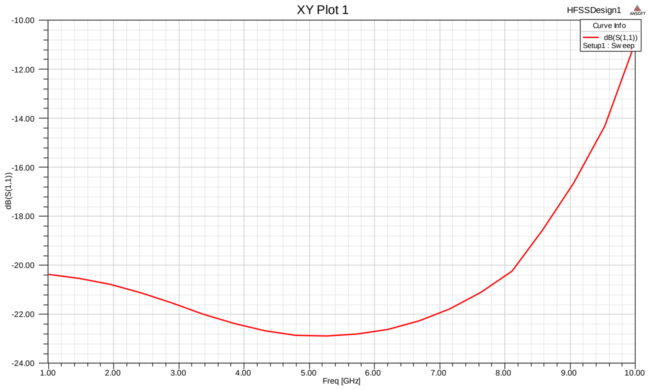

Figure 3 return loss plot

Based on the design parameters proposed antenna was first modelled and simulated using soft simulation software High-Frequency Structure Simulator (HFSS) and its characteristics were analyzed. The measured return loss curve of proposed antenna is shown in Figure 3 has < -10 dB return loss from 4.5GHz to 11.6GHz

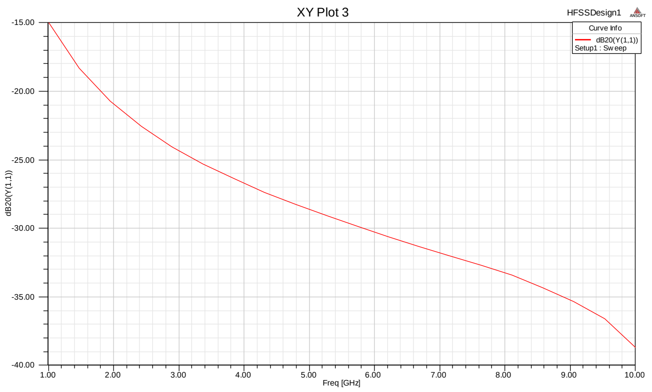

Figure 4 Y Parameter plot

Measured Y parameter plot for the proposed antenna was shown in Figure.4, which achieve a better result in the frequency range 4.5GHz to 11.6 GHz.

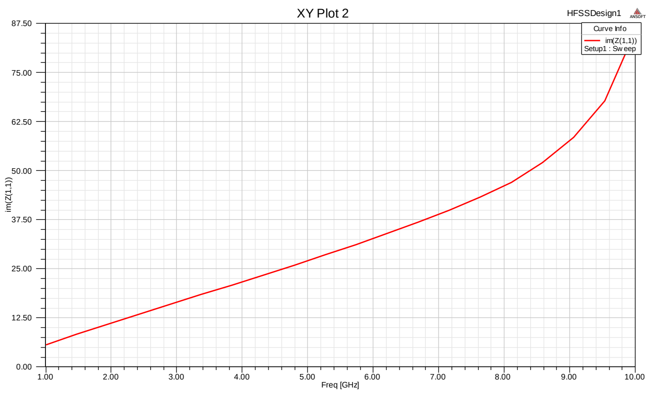

Figure 5 Z parameter plot

Measured Z-Parameter plot for the proposed antenna are shown in Figure 5 shows that the antenna has nearly 50 ohm impedance for the majority of the region (real part) and the reactive part at almost zero

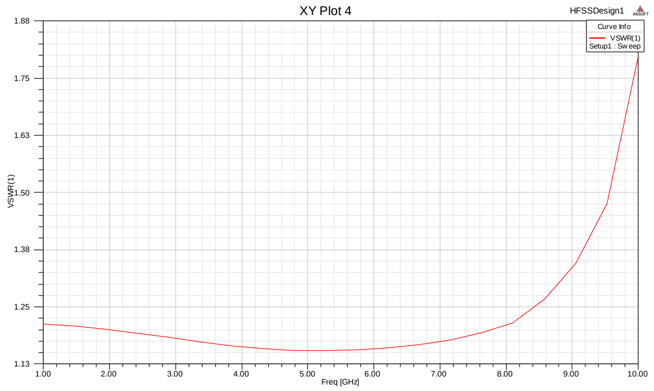

Figure 6 VSWR plot

Measured VSWR for the proposed antenna are shown in Figure 6. The value of VSWR is approximately one in the range between 4.5GHz and 11.6 GHz. It shows that the antenna has good performance in minimizing standing waves with better impedance matching.

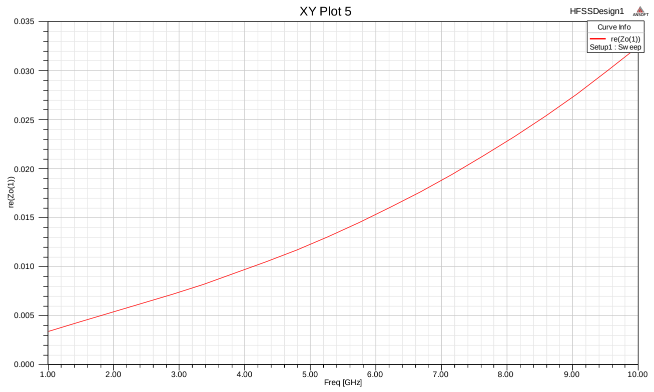

Figure 7 Z_o parameter plot

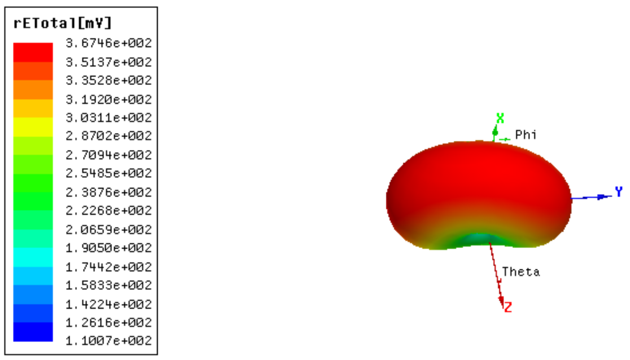

Figure 8 Radiation pattern measurements

Measured radiation patterns of the proposed antenna are shown in Figure 7. The radiation patterns in the azimuth plane

(x-y plane) are Omni directional and it is shown in Figure 8.
The energy radiated by any antenna is contained in a transverse electromagnetic wave that is comprised of an electric and magnetic field. These fields are always orthogonal to one another and orthogonal to the direction of propagation. The electric field of an electromagnetic wave is used to describe its polarization and hence, the polarization of the antenna. In general, all electromagnetic waves are elliptically polarized. In this general case, the total electric field of the wave is comprised of two linear components, which are orthogonal to one another. Each of these components has a different magnitude and phase. At any fixed point along the direction of propagation, the total electric field would trace out an ellipse as a function of time.

Generally the polarization is categorized into two types such as

1. Linear polarization
i. Horizontal and Vertical polarization
2. Circular polarization
i. Left hand side and right hand side polarization. (Figure 9 and Figure 10)

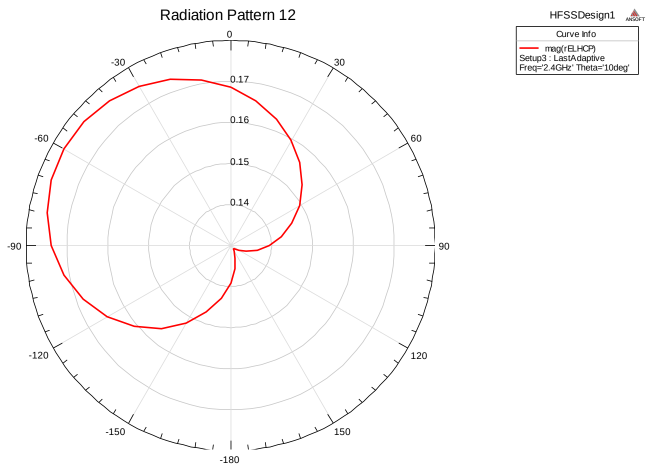

Figure 9 Left Hand Side Circular Polarization

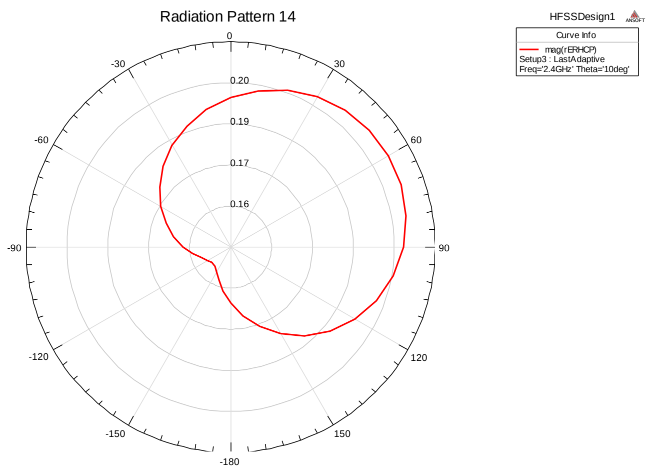

Figure 10 Right Hand Side Circular Polarization

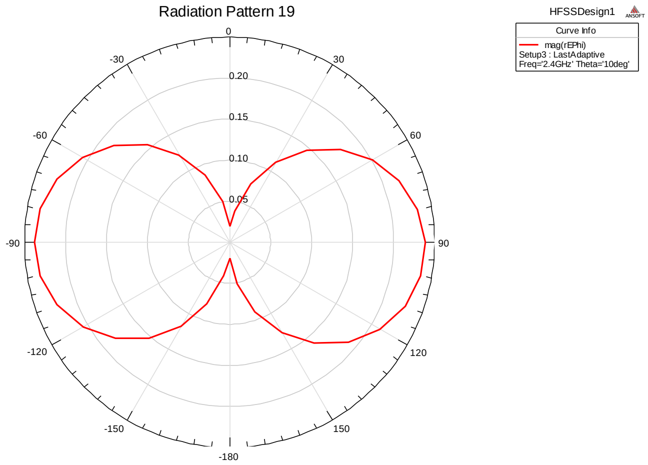

Figure11. End fire array

The end fire array is defined as the direction of the radiation pattern is parallel to the array axis shown in Figure 11.

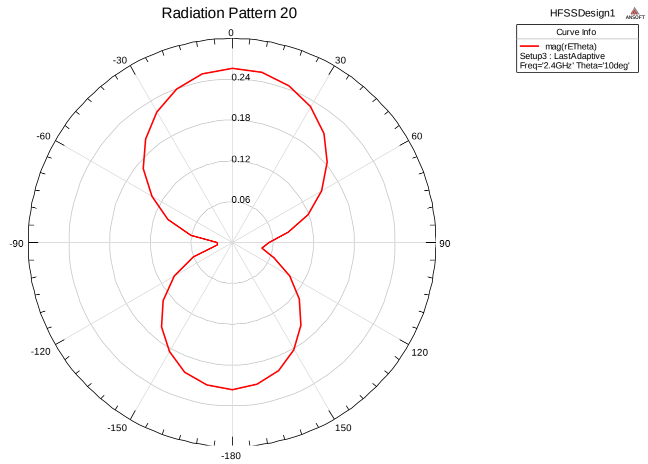

Figure 12. Broad side array

The broad side array is defined as the direction of the radiation pattern is perpendicular to the array axis as shown in Figure 12.

G. Conclusion and Future Work

The influence of the human body on the radiation pattern of a wearable antenna for different antenna locations on the body surface was studied. Other than the location of the antenna, other factors consider in our study were antenna separation from the body surface (0 to 20mm range) the antenna gain pattern depends on the exact location and distance of the antenna from the body. Intelligent antenna design is the key to establish communication links to adequate range and acceptable quality. Also the deeply seated tumours of less than 0.5mm were detected successfully in the frequency range 4.5GHz to 11.6 GHZ. While investigating SAR issues for wearable node communication, the micro strip patch antenna design was modified by including band gap to achieve better results. The distance between the antenna and tumor will affect the accuracy of detection due to the specific absorption ratio of human body. Further experimental studies and comparison with phantom models are required to validate the results obtained here.

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