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DEPARTMENT OF ELECTRONICS & TELECOMMUNICATION ENGINEERING

Rajshahi University of Engineering & Technology, Bangladesh

Early Breast Cancer detection with microwave imaging Technique by using Spiral PIFA Antenna

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A THESIS REPORT

ON

TITLE

Early breast cancer detection with microwave imaging technique by using Spiral PIFA Antenna

This thesis report is submitted to Department of Electronics and Telecommunication Engineering, Rajshahi University of Engineering and Technology (RUET), for the partial fulfillment of the requirement for the degree of Bachelor of Science in Electronics and Telecommunication Engineering.

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DEPARTMENT OF ELECTRONICS & TELECOMMUNICATION ENGINEERING

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CERTIFICATE

This is to certify that the thesis paper entitled ***" Early Breast Cancer detection with microwave imaging technique by using Spiral PIFA antenna"*** *has been done by* ***Nusrat Aziza*** *under the supervision of* ***Dr. Mst. Fateha Samad,*** *Associate Professor, Department of Electronics & Telecommunication Engineering, Rajshahi University of Engineering and Technology.*

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ABSTRCT

Breast cancer is the top cancer in woman both in developing and developed countries of the world. Early detection technique is necessary to detect and interfere cancer tissues. Microwave detection method is a promising technique which offers a contrast between the electrical properties between normal and malignant breast tissues. The dielectric property of various tissues vary due to the variation of the tissue properties. All materials have different permittivity and conductivity. Cancerous tissues have dielectric permittivity's and conductivities that are different from healthy tissues. Therefore when an incident wave is exerted , cancerous tissues will scatter differently. This proves their presence in the tissue. Taking advantage of microwave imaging technique a Spiral PIFA antenna is designed for early breast cancer detection. The operating frequency of the proposed antenna is 2.8 GHz to 3.8 GHz.. A breast model is designed with the resemblance to the realistic one. The breast model consists of two layer , skin and fat. Each layer have different dielectric properties. The tumor in the breast has also different permittivity and conductivity than the healthier one. The study of the antenna and breast model was carried out using CST Microwave Studio. The substrate material is FR-4 substrate. The ground is made of copper. The patches of the antenna are also composed of copper. The feeding used in this work is coaxial feeding. The material of the feeding is perfect electrical conductor (PEC). Simulated result in terms of return loss, radiation pattern, bandwidth, gain, VSWR are presented to validate the usefulness of the proposed design. There was a good matching impedance of 50 ohm. Due to high impedance matching -21 dB of reflection coefficients has been achieved. Maximum achieved gain of the antenna is above 5dB. The VSWR of the antenna is less than 2. The antenna is analyzed in free space. The antenna is also analyzed by placing on the breast phantom model with tumor and without tumor. The results are evaluated and discussed as well. By comparing the results the tumor can be detected.

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Chapter 1

Introduction

1.1 Introduction:

Breast cancer is the most common cancer in women and the second most common cancer overall cancers. There were about two million new cases in 2018. Cancer in general initiates when a cell starts to grow and act in an unnatural way. In the case of breast cancer specifically the malignant tumor starts in the cell of the breast [1]. Most probably it starts in the ducts or lobules hence the name Ductal carcinoma situ (DCIS) and lobular carcinoma in situ respectively [27]. Malignant tumors are first confined in an area and invade the surrounding tissues. Eventually the tumor evolve and spread to distant body parts. Breast cancer is considered as the prime cause of unwanted death of women because of not diagnosing at early with the presence of malignant cell. Most of the women get to know about their disease at a stage when it is too late to be cured and nothing can be done to save their life. So early detection is very important in this aspect. If detection can be done in time there is a huge chance for the patient to survive. Early breast cancer identification and treatment can give the survival rate which shows the requirement of a decent and highly efficient method of early breast cancer exposure.

Conventional techniques for detecting breast cancer are X-ray mammogram, magnetic resonance imaging (MRI) and ultrasound. However these techniques have some limitations and restrictions such as lack of accuracy and reliability, huge cost and physical risk such as exposure to EM fields [3]. Also it has been investigated that between 4% and 34% of all breast cancers are missed as a result of poorly detected cell [1]. In X-ray mammogram technique there is ionizing radiation which results the death of cell, mutation of cell and fatal damage within the body as well as originates significant number of false negative and false positive results[4].

For early detection of breast cancer which increases the chance of successful detection, results in lucrative and long period survival rate of cells is required. Such technology is microwave imaging detection technique which is efficient, new, nonionizing, portable and comfortable. Compared with the X-ray technique, microwave imaging systems have some advantages such as low cost, high data rate, low complexity and low spectral power density [3]. That's why microwave imaging technique has become popular method in early detection of breast cancer.

The working principle of microwave imaging method depends on the dielectric contrast between the healthy tissues and the cancer affected ones. In order to identify the pathology, the electrical properties as conductivity and dielectric parameters are utilized. These parameters are utilized to differentiate between the normal and defected tissues through contrast distribution maps. In recent times many researchers are done for breast cancer cell detection by microwave imaging technique, where different types of antenna are being used. In today's world the use of antenna in medical application is increasing day by day due to it's huge advantage. It offers feasibility, low cost as well as comfort. In recent time researchers are concerned to contribute the welfare of humans, reduce invasive surgeries, and offering better diagnosis and treatment for them. Studies have shown that an antenna can be used in disease detection, diagnosis even treatment in some diseases. With the modern wireless technology it became possible to integrate an antenna and place inside the human body. Thus the term antenna is becoming more familiar and popular.

In this work we will design a Planer Inverted-F antenna for early detection of breast cancer. It is also called quarter wavelength antenna. These antennas are widely used for wireless communication as well as in medical application due to easy integration, light weight, low profile, low SAR values and good gain [7]. In this work a pifa antenna is designed for the purpose of microwave imaging over detecting cancerous tissue into breast structure and so, a simple 3D breast structure is exhibited to define cancerous tissues . All the simulations are implemented in CST Studio Suite and better simulations results are obtained.

1.2 Motivation:

The diagnosis of diseases for the patients nowadays requires painless and less time, less cost consuming methods. Breast cancer is a threat to women and has deadly consequence. As we know prevention is better than cure, so to prevent this disease proper diagnosis should be done. Microwave imaging is a noninvasive and suitable technique to detect the cancer in the tissues. This technique is very popular in recent times and the researcher are taking a lot of interest in this field as it offers no harm to the patient and can give great results. Pifa antenna will be designed in this regard. A breast phantom model is also designed which resembles the real ones and has the same dielectric property and conductivity.

There are four stages of breast cancer. According to American Joint Committee on Cancer (AJCC) staging of breast cancer is related to the size of the tumor [27]. In stage T-1 the size of the tumor is from 0 up to 2 cm, whereas stage T-2 has the tumor size is from 2cm up to 5cm. The third stage's tumor size by then is greater then 5cm. Finally stage T-4s any tumor whose size became with direct extention to the chest wall or skin. So it is needed to detect the tumor at very early stage so that it can not spread much and it can be cured.

The integration of microwave imaging in large varieties of biomedical applications is quite promising. The technique is also very lucrative to apply for the construction of breast cancer detection peripheral. The ultimate design of the medical detection and monitoring model is highly possible to be very low complexity, compact antenna, users friendly and inexpensive cost. This method in imaging techniques employs the antenna stuff to radiate microwave signals on to the breast surface. Backscattered signal generated from the breast tumors will be captured and processed by the antenna unit and the signal processing part, respectively, to determine the tumor presence and its location on the breast [2].

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1.3 Objective Of The Thesis:

The objectives of this thesis work is given below:

1. To design a spiral PIFA antenna as a transmitting antenna for early breast cancer detection.
2. To measure the antenna parameter properly and Optimize the parameter into certain point.
3. To design a breast phantom model without tumor and with tumor
4. To simulate the antenna within the breast phantom model without tumor and to simulate the antenna within the breast phantom model with tumor
5. Compare the simulated results and observe the existence of the tumor

1.4 Structure Of The Thesis:

The thesis includes some chapters and explain the whole topic step by step. Here they are:

Chapter 1 represents the introduction, motivation, structure of the thesis and summary. This chapter explains thesis idea, the working principle, applications and benefits and limitations of the proposed work.

Chapter 2 comprises literature review, discussion and comparison between existing works, summary and conclusion. This chapter describes all the recent previous work based on microwave imaging with its corresponding results and performance. This chapter is all about previous works in this field.

Chapter 3 signifies the proposed design description, the materials which are used for the design, the theory and the model of antennas. This chapter is all about the structure and broad description of the proposed design.

Chapter 4 includes the design, the simulation in the corresponding software, the description of the simulated results, analysis of the figures getting from the simulation. This chapter is all about the results and performance analysis of the proposed design .

Chapter 5 includes the conclusion and future work. The whole summary of the thesis work is demonstrated and future development of the work is also included.

And at last there are list of references which includes the references used for completing the whole thesis work.

1.5 Summary

Microwave imaging technique by utilizing a PIFA antenna is probably one of the best medthod to detect cancer. Without removing tissues from the body part it can examine whether there is tumor or not. PIFA is easy to fabricate and use. There is no ionizing radiation in this technique. This technique will help a lots of woman who has reach their menopause as they have the higher chance of breast cancer. Early detection of breast cancer can bring them again to life. It is a technique which is contributing a lot in medical science. The desired results largely depends on antenna design. Return loss, reflection coefficient, radaiation pattern, gain are the most important parameters to evaluate the performance of the PIFA antenna. The antenna should have a good bandwith and the miniaturization of antenna is also necessary.

Chapter 2

Literature Review

2.1 Introduction:

The first chapter had a discussion about the application and advantages of the microwave imaging (MI) technique. This chapter is about the previous and recent works done on microwave imaging technique for detecting breast cancer. Researchers have been done and still experimenting a wide range of research in this field. They have designed and used different types of antenna regarding this field. So the literature review of the microwave imaging technique to detect breast cancer are discussing below.

2.2 Literature Review:

Caliskan et al. [3] developed a model where a rectangular microstrip patch antenna is used for the purpose of microwave imaging for detecting cancerous tissues into breast structure. The antenna structures are investigated with a view to diagnosis breast cancer early. The antenna structure operating at 2.45 GHz are simulated with basic 3D breast structure. Different antenna design are evaluated by modifying ground plane and slotting on microstrip patch by using HFSS. In this work, the substrate material of the antenna was FR-4 (lossy). Substrate dimension length is 65.4 mm width is 88.99 mm and thickness is 1.588mm. The proposed antenna is placed under the breast structure. In this model dielectric (ε) and conductivity of normal breast tissue is 9 and 0.4 accordingly. But for cancerous breast tissues the dielectric and conductivity value is 50 and 4 respectively. Basic breast structure is modelled according to this parameters. After modeling the structure the antenna is simulated into it and results are obtained.

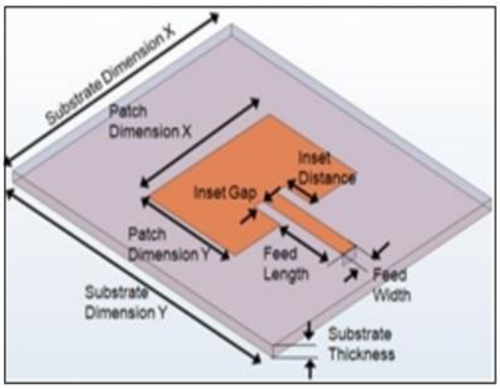


Fig. 2.1: Antenna Structure [3]

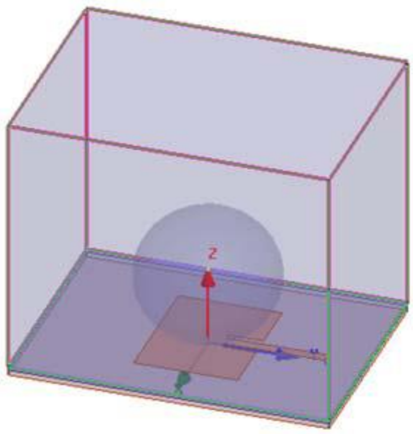


Fig. 2.2: Design with antenna and breast structure [3]

In this work, by investigating electromagnetic field values over the breast tissues with tumor and without tumor, evaluations are presented. There were five antenna structure which are evaluated by modifying ground plane and slotting on microstrip patch. For the fourth antenna structure , electric field, magnetic field and current density values in the situation of breast structure with tumor were 137.36 v/m. 0.786 A/m and 54.946 A/m2 respectively. While the values in the situation of breast structure without tumor were different from them. That's how the author proved the presence of tumor.

A stairs shaped microstrip antenna was successfully designed by Dewini et al. [4] on the basis of the movement effect of the dielectric properties during breast tumor diagnostic scanning. The antenna performance shows that the antenna is well operated in the frequency range from 4 to 7.3 GHz when it is simulated in CST Microwave Studio. To validate the actual operation of the constructed breast cancer detector a homogeneous breast phantom was generated in close proximity of the antenna system at various different locations. The study was performed by altering the antenna positions to cover the whole surface of breast phantom with a variety of tumor size. The antenna movement affected the electrical properties of the medical diagnostic instrument such as radiation pattern, current distribution, VSWR and S11.

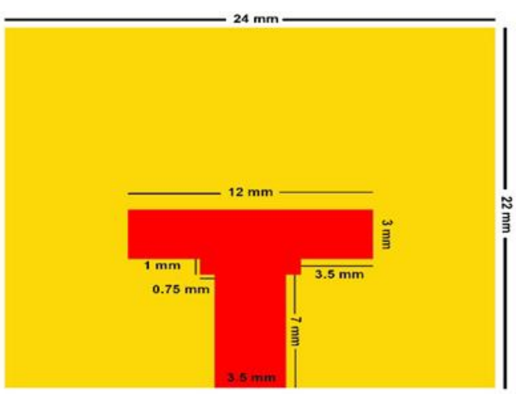


Fig. 2.3: Antenna Structure [4]

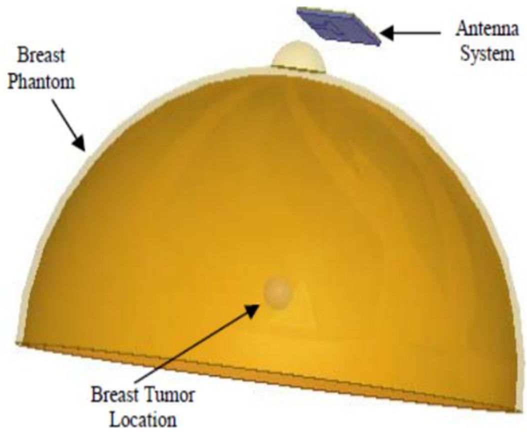


Fig. 2.4: Antenna on breast phantom model [4]

A wearable microstrip patch antenna is used in breast cancer detection designed by Alsharif and Kurnaz [5]. The antenna was operating at frequency range 1.6 GHz to 11.2 GHz. The substrate material was 100% cotton with dielectric constant 1.6. Patch and ground which are transmitting component are composed of copper. The analysis of the antenna and breast model was carried out using CST microwave studio. The proposed antenna has a permittivity of (1.6) and thickness of 1.6 mm for the substrate. The antenna can be incorporated into attire. The step by step development of the antenna in this work is shown below.

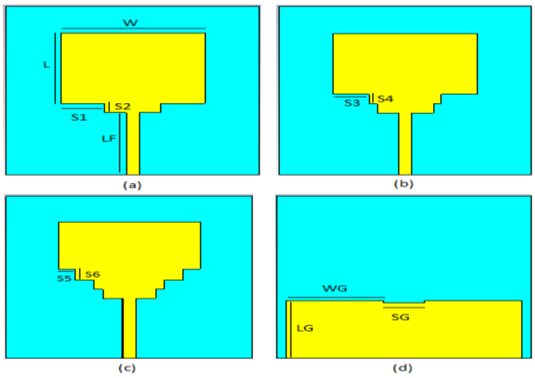
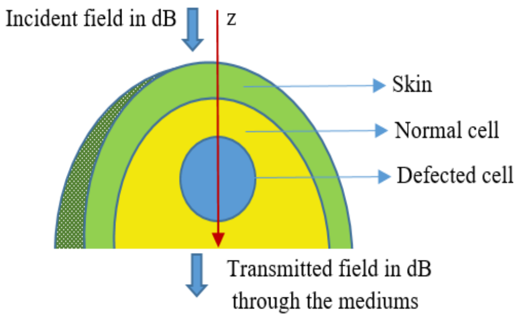


Fig. 2.5: Geometry of the antenna a) structure1, b)structure 2; c) structure 3, d) ground plane [5]

The antenna was verified at different bending conditions. They designed a replica of human breast. The half sphere model contained a skin layer of 3 mm and it's outer radius is 25mm. A fibro glandular breast fatty tissue layer situated inside the the skin layer had radius of 22mm. Dielectric contrast and conductivity of the defected tissue is 50 (F/m) and 0.7 (S/m) respectively. The result of multipath propagation signal is different when there is a tumor present in the tissues.



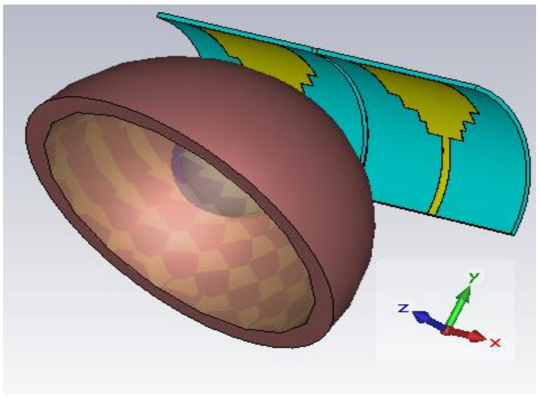
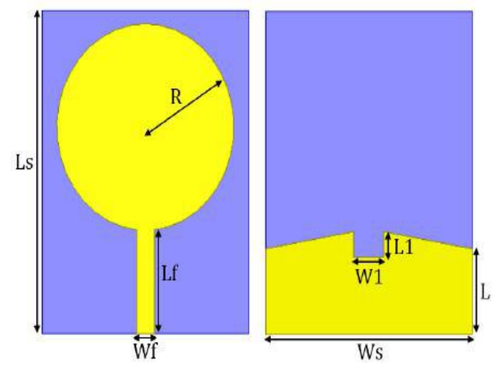


Fig 2.6: Breast model with tumor [5]

Fig. 2.7: Breast model with tumor [5]

Fatimi et al. [6] experimented another research of UWB cicular patch microstrip antenna to detect early breast cancer. The operating frequency of the antenna is 3.1 to 10.6 GHz. The substrate of the antenna is FR4 epoxy and the dielectric permittivity is 4.4. The thickness of the antenna is 1.6 mm. The authors validates the performance of the performance of the antenna by using two methods. The methods are Finite Element Method (FEM) and Finite Integration Method (FIT). The designed breast model was hemispherical in shape of 55 mm radius. A layer of skin, a layer of breast tissues and tumors comprises it. To check the presence of early tumor the size of the tumors was varied and it was 3mm, 4mm and 5mm accordingly.



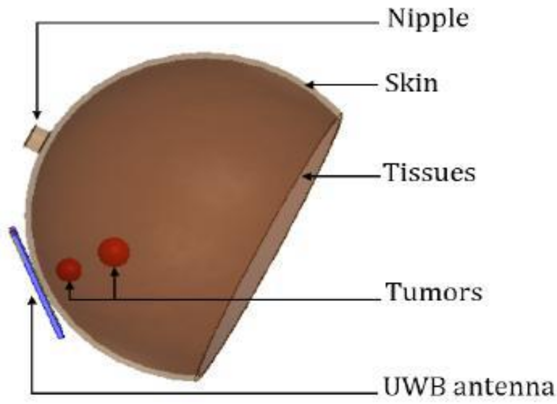


Fig. 2.8: Geometry of the Antenna
a) top view b) bottom view [6]

Fig. 2.9: Breast model with two tumor [6]

Ouerghi et al. [7] described the comparative study of five microstrip patch antenns for microwave imaging. From the five antenna structure, one antenna was chosen based on it's performance. By using the antenna an antenna array is generated which is composed of 8 antennas. The performance of the antenna was measured by studying electric field, magnetic field and current density in the healthy breast tissues and in the affected ones. The hemispherical breast model is composed of skin with 70 mm outer radius, with 2 mm thickness. The healthy tissue has 68 mm outer radius and 10mm tumor is placed inside the healthy tissues.

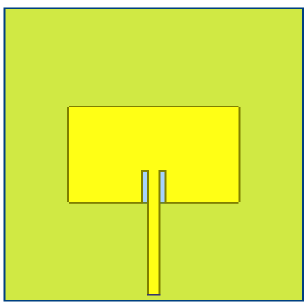


Fig. 2.10: Antenna structure [7]

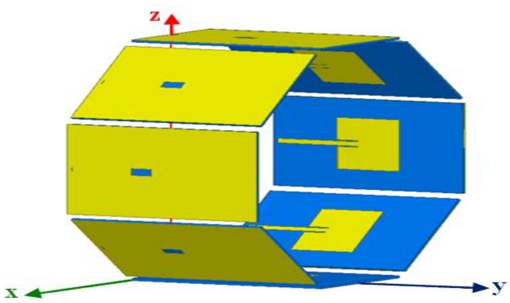
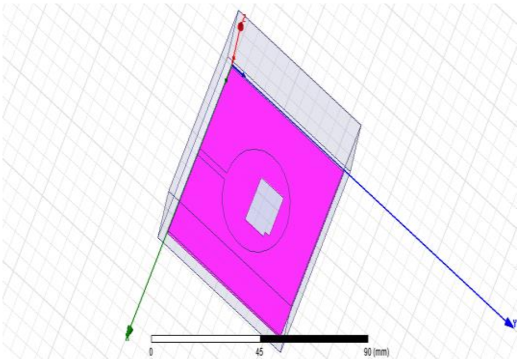


Fig. 2.11: Circular Antenna array [7]

Banu et al. [8] developed model called cicular patch antenna to detect breast cancer early by microwave imaging technique. The circular patch antenna with rectangular shaped slot in ground is designed in Ansoft HFSS software. It operates over a frequency range of 2.5 GHz. The radius of the circular patch is 14.5 mm and the substrate is FR-4 substrate. The simulated return loss is -21 dB and directivity is 4.48 dB. The breast phantom model is designed on the basis of skin conductivity and resistivity. The designed breast model was 0.05 cm wide and 4 cm high cone with eight facets. It was designed in HFSS and it has two layers. The outer is nothing but the skin and the inner layer is the fatty tissues and cancerous tissues. The dielectric coefficients of the breast skin is 39 and conductivity 1.1 S/m. The tumor is 5mm, dielectric permittivity is 50 and conductivity is 4 S/m. The antenna was optimized to operate at 2.5 GHz to minimize the effect of the breast skin contact with the antenna. A hexagonal microstrip patch antenna along with a breast phantom model are designed and simulated by Kahwaji et al. in order to detect breast cancer. There is a hexagon slot in the center of the patch of the antenna. The design and simulation was carried out in HFSS software.



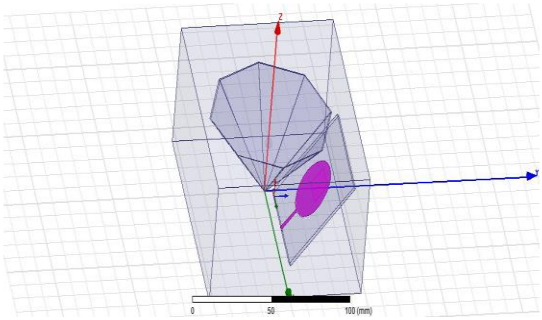


Fig. 2.12: Circular patch antenna [8] Fig. 2.13: Breast skin model with antenna [8]

The length of the substrate is 25mm, width is 20 mm and thickness is 1.6 mm. The substrate material is FR-4 Epoxy. The phantom consists of two layers. The first layer is skin, second layer is fat and third layer is tumor. The skin layer relative permittivity is 38, bulk conductivity is 1.49 S/m and mass density is 1109. The fat layer relative permittivity is 5.14, bulk conductivity is 0.141 S/m and mass density is 911. In the case of tumor the relative permittivity is 67, bulk conductivity is 49 S/m and mass density is 84. The tumor size was generated from 1 cm to 4 cm. By varying the tumor size different types of results were obtained. The simulation is completed by finding the difference between breast without tumor and the breast with tumor

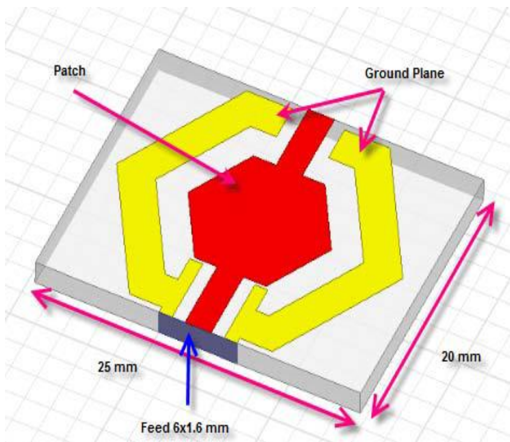


Fig. 2.14: Hexagonal Microstrip patch antenna [9]

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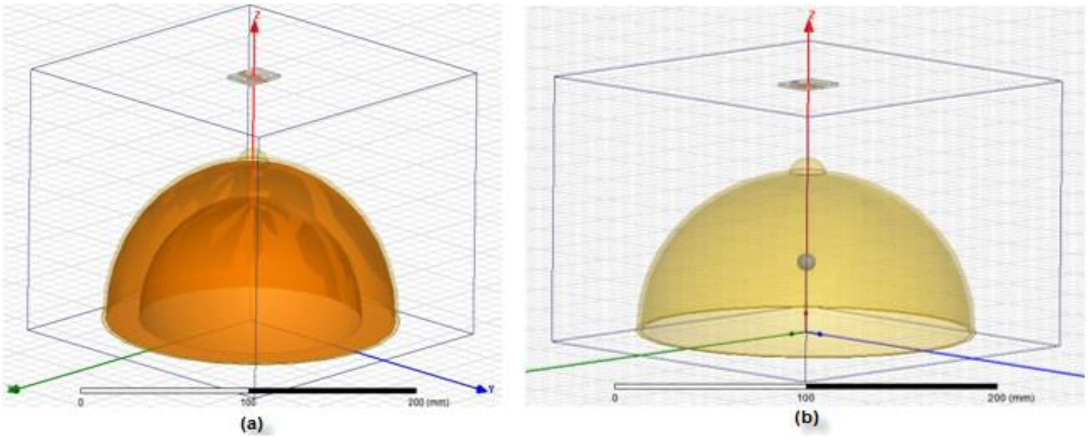


Fig. 2.15: Design of phantom

a) without tumor and b) with tumor ~1cm in diameter [9]

A PIFA antenna has been introduced for the diagnosis of breast tumor by Engy Alaa and Abdelmegid Allam. It can detect the dissimilarities between normal and malevolent tissues of breast. The researchers of recent times are trying hard for lessening the hassle of treatments and offering easy diagnosis. So, from this context the mechanism of the antenna has been built in spiral shape where the frequency range is 402 to 405 MHz.

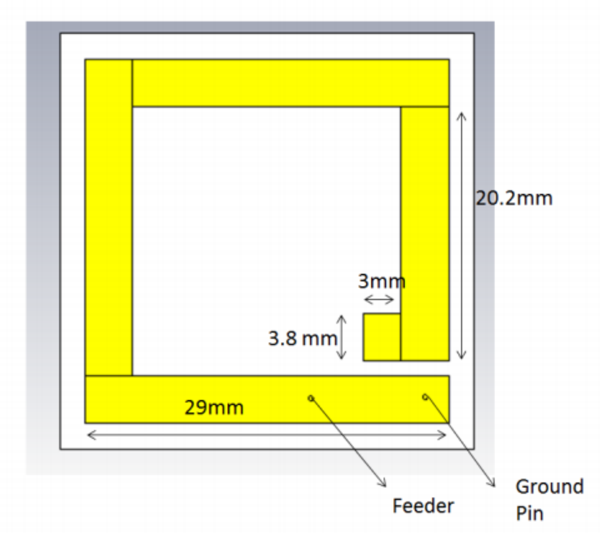


Fig. 2.16: Front view of the PIFA [27]

Firstly, normal tissues were tested by the antenna to secure the results of the mechanism. After that, fibro-glandular tissues were examined to the task for determining the difference between normal and malignant tissues of breast. Finally, the entire simulation is done through the CST Microwave Studio when Network Analyzer carries out the measurements.

Nahalingam and Sharma [34] designed ultra bandwith microstrip slot antenna in the investigation of malignant breast tumor detection. Two antennas based breast model with and without tumor was realized and measured. Scattered field results were generated by full wave analysis for compressed breast model with two antennas and six antennas. As improvement towards the subtracted scattered field results, averaging of the signal returns at each of the antennas was performed and the simulation rsults were shown.

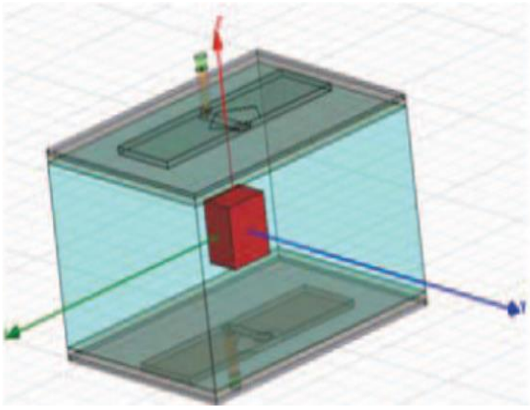


Fig. 2.17: 3D view of compressed breast model with two antennas [34]

Al-Joumayly et al. [35] proposed Dual-Band Miniaturized Patch Antennas for Microwave Breast Imaging. The author described **a** miniaturized, dual-band patch antenna array element that was designed for use in a three-dimensional (3-D) microwave tomography system for breast imaging. Miniaturization and tuning of the resonant frequencies were achieved by loading the antenna with non radiating slots at strategic locations along the patch. This results in a compact, dual-band antenna with symmetric radiation patterns and similar radiation characteristics at both bands of operation. The performance of the antenna in a biocompatible immersion medium was verified experimentally.

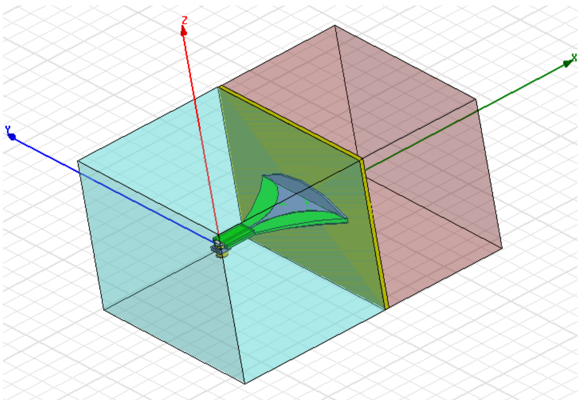
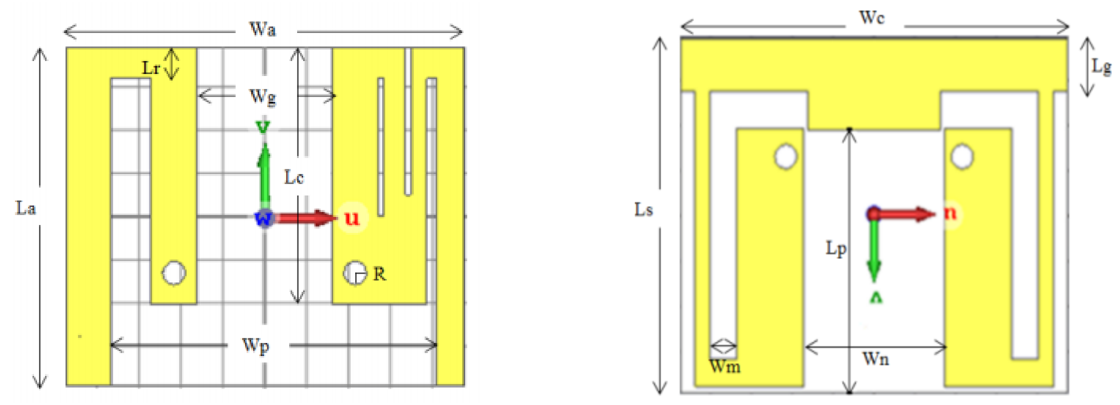


Fig. 2.18: The breast phantom with skin and breast fat layer with the proposed UWB antenna [35]

Ahmad et al. [28] proposed an implementable PIFA antenna for the application of biomedical sector which is quite optimized. Most importantly, the antenna is safe for human body for the quality of nursing. 2.4GHz-2.48 GHz is the range of ISM Band in which the antenna will operate suitably. Copper and Rogers RO3010 are used as patch and substrate to design the antenna properly.



(a) (b)

Fig. 2.19: Antenna Structure (a) front and (b) back views [28]

Rectangular and cylindrical shaped panthom human skin tissue setup do the all simulations in CST whereas the result of the final test expressed the successfulness of the antenna to work perfectly in human arms and chests. The antenna can also go through curved condition and deliver the optimum results. SAR analysis is also a part after the comlpletion of test for the safety of human body.

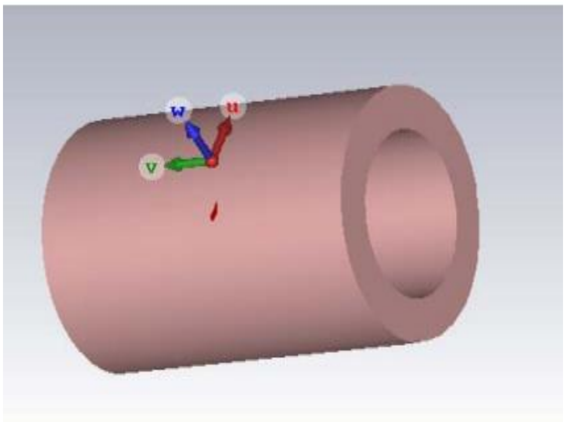


Fig 2.20: Cylindrical shaped phantom model [28]

Omar K. and Prof. Dr. A. M. M. [29] have designed an antenna for the detection of oral cancers. The antenna has been made to measure the normal mouth tissues at the 2.4-2.5 GHz ISM Band and compare this phenomena with the abnormal tissues of mouth if patients have. Left cheek, right cheek and under chin are the prominent three places for testing to map the criteria of the antenna. The antenna is made-up on the Roger4350 material having thickness of 1.5 mm approximately.

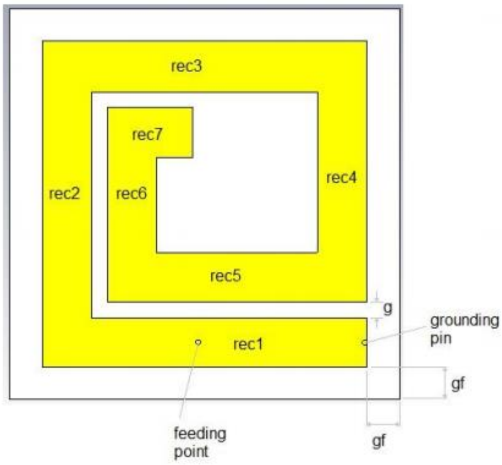
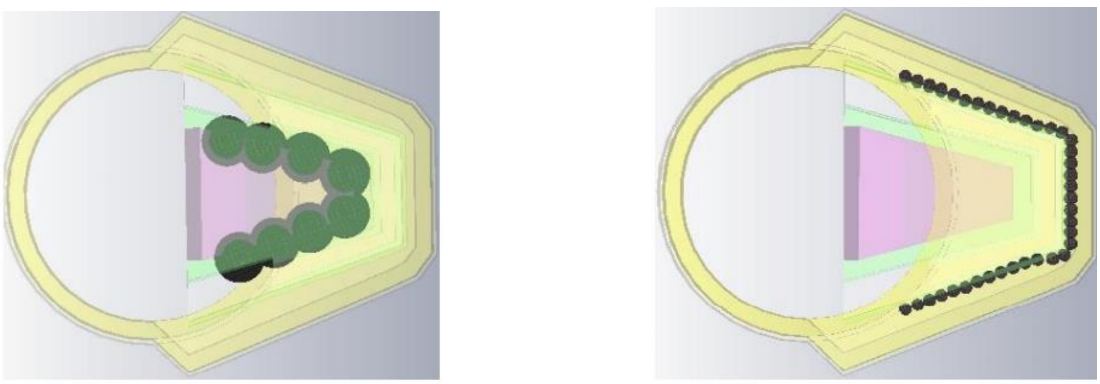


Fig 2.21: Fig: Top view of the spiral PIFA [29]

The antenna has been contrived to search a tumor in the human mouth. The antenna anticipates the presence of the tumor by comparing the normal frequency of mouth tissues. The spiral shaped antenna is simulated through CST where network analyzer tested two separate persons while manufacturing the antenna scheme.



(a) (b)

Fig. 2.22: (a) Top view of mouth model, cancer cells surround the tongue

(b) Top view of mouth model, cancer cells on inner cheeks and lips walls [29]

2.3 Comparison Between Existing Works

TABLE 2.1: Comparison of existing research works

Reference No.	Type of antenna	Frequency band	Material	S parameter	Gain
Alsharif and Cetin Kurnaz[1]	Microstrip patch	1.6-11.2 GHz	Copper	<-10dB	6.17dB
Hirano and Kikkawa[30]	Pentagonal Patch	2.2 GHz	FR-4	-20dB	
Caliskan et al.[3]	Microstrip patch	2.4 GHz	FR-4		
Hanafy [27]	PIFA	402-405 MHz	Rogers 4350b	<-10 dB	
Oerghi et al.[7]	Circular Antenna array	2.45 GHz	FR-4 Substrate	-21.88 dB	3.34dB
Dewaini et al. [4]	UWB antenna	4-7.3 GHz	Copper	-20 dB	
R. Nilavalan,	Patch antenna	4-9.5 GHz	copper		4dB
S.Banu et al. [8]	Circular patch	2.45 GHz	FR-4	-21dB	4.04dB
Fatimi et al. [6]	Circular Patch	3.1-10.6 GHz	FR-4 Epoxy	-21.26 dB	

From this table we can see that different types of researches have been done recently. They use different types of material such as copper, FR-4 substrate, Rogers-4350B etc. They designed microstrip patch antennas, pifa antennas for different operating frequencies in several bands like C, Ku, Ka band etc. Many of them are also designed in megahertz range. Several bands antennas have alternating length. There are different types of law and mathematical background for measuring the length. For example the patch of the pifa antenna is in quarter length. For some times, there are more variations in length calculations regarding variation frequencies. It is seen that there is a variation in patch shape of the antennas in previous works. Rectangular and circular patch antennas have been analyzed. It is seen that most of the previous researches have reflection coefficient less than -10 dB. It is relatively acceptable S parameters. Some of the papers have loss parameters less than -20dB, which have good reflection coefficients. The gain is defined as the ratio of output power to input power. So the gain should be as high as possible. Generally for biomedical application the gain should be higher than 3 dB for better performance. In this table 2.1, we can see that Ref. paper No. 1 has relatively higher gain. Some papers define directivity as the directive gain for some reasons because the directivity also defines the antenna performance. Another important parameter of antenna is voltage standing wave ratio (VSWR) means the input output relationship between the feeding port and the conductor. The VSWR should be as low as possible. The value of VSWR needs to be less than 2 for better performance of antenna.

2.4 Conclusion

The whole chapter explains the literature reviews which are the existing work based on breast cancer detection. The parameters and designs are observed and a table is formed for the ease of comparison. The comparison comprises of similarities and dissimilarities. This helps to understand the gradual development of MI technique and apply accordingly.

Chapter 03

Theoretical Background

3.1 Introduction

The microwave imaging technique using antenna to detect cancer has become one of the interesting field in research work. In this research field various types of antennas are used. Such as microstrip patch antenna, monopole antenna, Vivaldi antenna, slot antenna , PIFA antenna and many more antennas has been proposed. The working principle of different is different. To design an antenna there are several parameters which should be calculated and measured. Proper knowledge about antenna is needed in this regard. The theory of working principle of PIF antenna and their parameters have been discussed below.

3.2 Microwave Imaging Technique

Microwave imaging for medical applications initiated as a feasibility study by imaging organs by Larson and Jacobi [12] in the 1980s. Over the years this technology has become more and more popular in medical science. It is a non invasive method to portrait the internal image of the body both healthy and unhealthy subjects. Microwave Imaging technique uses nonionizing electromagnetic (EM) signals in the frequency range of 300 MHz to 300 GHz [13]. As it provides nonionizing, low power EM signals, it is a low health-risk method. Microwave source, receiver, antenna are the equipment of microwave imaging. The equipment is portable and the method is very cost effective in comparison with other method.

3.3: The Working principle of Microwave Imaging method

As we have mentioned before the MI method depends on the dielectric contrast of tissues. Dielectric contrast is used to regenerate images using radar-based or tomographic imaging algorithms. Different tissues of the different body parts have different dielectric properties that are defined by relative permittivity and conductivity. If the tissues become tumorous, it will have different dielectric properties than the healthier ones. For this variation, the interaction of the EM signals will be different to different tissues. Different reconstruction algorithms to construct a map or an image, either 2D or 3D, that demonstrates different tissues dielectric properties or the location of a tumor inside the body. The reconstruction algorithms are classified into two types. They are quantitative image algorithms and qualitative image algorithm. A map or the image of the distribution of the different tissues with the values of dielectric properties in the body can be constructed by quantitative imaging algorithms [14]. It is based on the inverse EM scattering problem. Qualitative imaging algorithms use radar like techniques for image generation to differentiate the tumorous tissues from the normal tissues. Malignant or tumorous tissues generally scatter EM signals stronger than other healthy tissues and the malignant tissues can be detected by qualitative imaging algorithms [14]. There are some application of this method where there is no need to determine the electrical properties of tissues but to determine the existence and location of the tumor. This is the case in breast cancer detection. In such cases qualitative imaging algorithms can be applied. In medical microwave imaging , the tumorous tissues is a strong scatterer due to higher dielectric properties than the surrounding tissues. In qualitative imaging each antenna transmits a short pulse at a time and the backscatter response is received by the same antenna. The backscatter response comprises of the tumor response, scatter from the skin and backscatter from other tissues. Signal decrease the effect of the skin and the backscatter from other tissues, to increase signal backscattered by the tumor. There are many radar-based algorithms to focus the tumor, such as confocal microwave imaging [15], beamforming [16] and tissue sensing adaptive radar [17] are used. Ultra-wideband (UWB) signal is used for qualitative imaging to have a good time resolution.

3.4: Dielectric Properties

Dielectric property holds a great importance in the method of microwave imaging. It is used to regenerate images using radar-based or tomographic imaging techniques. Both malignant and normal tissues have dielectric properties that are different from each other. The dielectric properties of the tissue consist of the relative permittivity and conductivity. The variation happens due to the variation in the water content in the tissues [16]. Such as fat is a lower water content tissues having low relative permittivity and conductivity. But muscle is a high water content tissue having high relative permittivity and conductivity. In the case of malignant or tumorous tissues ,it has a higher rate of metabolism which results in more blood flowing through it. This changes the electrical properties of the tissues from the normal ones. There are some other factors which can describe the difference in electrical properties between healthy tissues and malignant tissues. They are necrosis and inflammation causing breakdown of cell membrane [17], charging the cell membrane [18], change in the dielectric relaxation time [19], and difference in the sodium content [18]. This variation in the electrical properties of the tissues results in the variation in the scattered field by the different tissues. This is the fundamental notion of microwave imaging. Gabriel et al. provided a summary of measurements for various healthy tissues [20]. The measured electrical properties of various healthy and malignant tissues from 50 to 900 MHz are presented in [21] and shown in percentage in figure 3.1 and 3.2

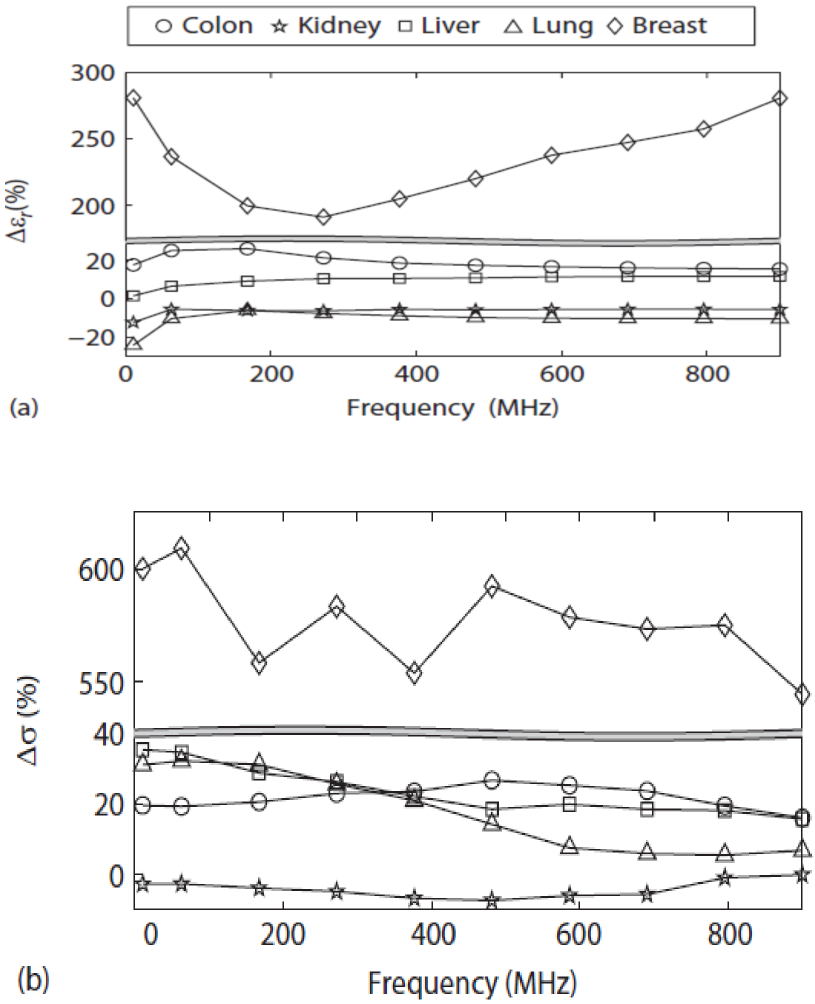


Fig. 3.1: Percentage change in the dielectric properties of malignant tissues, with respect to the healthy tissue from 50 to 900 MHz: (a) percentage change in the relative permittivity (b) percentage change in the conductivity [31]

3.5 PIFA Antenna

An antenna is a metallic structure that captures radio electromagnetic wave. A high frequency alternating current is given to the antenna's terminals. The antenna radiates the energy in the form of radio waves from current. In reception, an antenna intercepts some of the power of a radio wave in order to produce a small voltage at its terminals, that is applied to a receiver, amplified with the help of amplifier. Wireless communications and services continue to enjoy rapid growth in Industral, Scientific, and Medical (ISM) band.
The wireless communications have progressed in recent time a lot. The modern technology requires small multiband antenna to transmit different types of data. For optimum system performance the antenna must have small SAR and high radiation efficiency [21]. Planar inverted-F antenna (PIFA) has now become one of the most widely used antenna elements in mobile handset and wireless terminal application [22]. A great number of designs of PIFA configuration is proposed and reported in the literature [22-24].

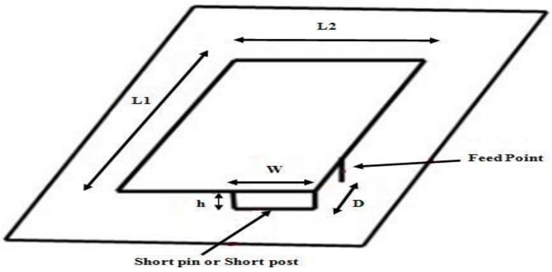


Fig. 3.2: Structure of PIFA [26]

There is a huge demand of miniaturized and cost effective antenna in biomedical application. PIFA can meet the demand. The PIFA antenna are resonant at quarter wavelength. It is also called quarter wavelength resonators. PIFA is developed from the patch antenna by introducing a short pin from the patch to the ground. It comprises of a rectangular planer radiating element located above the ground. As Planar Inverted Antenna resonates at quarter wavelength, hence it requires less space than other antennas. The shape of the antenna is like inverted F , and hence it is called Planar Inverted F antenna. The PIFA has an omnidirectional pattern and provides high gain in vertical and horizontal direction [10]. Planar inverted F antenna is a type of Inverted F antenna (IFA) in which a wire radiator is replaced by a plate to increase the bandwith. Bandwith plays an important role while designing PIFA. The size of the ground plane is the contributing factor in this regard. By varying the size of the ground plane, the bandwith of PIFA can be adjusted. PIFA is a low profile, light weight ,simple antenna which provides higher gain [11]. PIFAs are mostly used in mobile handset and wireless application due to their compactness and suitable performance. But the use of PIFAs are increasing in the biomedical sector. The applications are quite noteworthy in this sector.

3.6 Performance Parameter of PIFA

There are some parameters which can measure the performance of the antenna. These are called performance parameters. These parameters are very important to detect the tumor in breast. Good performance of antenna is required for microwave imaging technique. The performance parameters are given below:

3.6.1 Return Loss

The S-parameter is known as return loss or reflection coefficient of antenna. Return loss is an important parameter of antenna. Return loss is the ratio of the reflected power signal to the transmitted signal. Return loss measure is the measure of how small the return or reflection is. Smaller return loss is not good, it means less energy is going to the antenna. Better return loss is indicated by bigger return loss number, which is better for antenna. It is measured dB logarithmic scale. It shows the cut off frequency of the antenna. Antenna operates at cut-off frequency. Upper and lower frequency can be obtained from the cut-off frequency of the antenna. The difference of the upper and lower frequency is called the bandwidth.

$$RL\ (dB) = 10 \log_{10} \frac{Incident\ Power\ (pi)}{Reflected\ Power\ (\mathrm{pr})} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

3.6.2: Directivity

Directivity is a fundamental parameter of an antenna. It shows how directional the radiation pattern of that antenna. Directivity measure the power density in specific direction versus the power density radiated by an ideal isotropic radiator. Therefore it is defined as the ratio of radiation intensity in particular direction from the antenna to the radiation intensity averaged over all directions [32]. An antenna that radiates equally in all directions would have effectively zero directionality, and the directivity of this type of antenna would be zero. The more the directivity the radiated beam will be more focused and narrow.

$$D = D\ (\theta, \varphi) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

3.6.3 Gain

Gain is a parameter which combines the antenna's directivity and electrical efficiency. Gain is the ratio of intensity, in a given direction, to the radiation intensity that would be obtained if the power accepted by the antenna were radiated isotropically [32]. In a transmitting antenna, the gain describes how well the antenna converts input power into radio waves headed in a specified direction. In a receiving antenna, the gain describes how well the antenna converts radio waves arriving from a specified direction into electrical power.

$$Gain = 4\pi\ \frac{Radiation\ intensity}{Total\ input\ radiated\ power} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

3.6.4 Radiation Pattern

A radiation pattern defines the variation of the power radiated by an antenna as a function of the direction away from the antenna. An antenna radiation pattern or antenna pattern is defined as a mathematical function or a graphical representation of the radiation properties of the antenna as a function of space coordinates [33]. It is defined for the far fields. There is a radiation lobe for every radiation pattern. There are main lobe direction, minor lobe direction, side lobe direction and back lobes.

3.6.5 Radiation Intensity

Radiation intensity in a given direction defined as the power radiated from an antenna per unit solid angle. The radiation intensity is a far-field parameter, and it can be obtained by simply multiplying the radiation density by the square of the distance.

3.6.6 Polarization

Polarization is the curve traced by the end point of the arrow (vector) representing the instantaneous electric field. The field must be observed along the direction of propagation. It is classified as linear, circular and elliptical.

3.6.7 Beamwidth

Beamwidth is the angle from which the majority of the antenna's power radiates. The beamwidth of a pattern is defined as the angular separation between two identical points on opposite side of the pattern maximum. It may be measure in the horizontal or vertical planes and is the distance between two points where the power is less than half of the maximum..

3.6.8 VSWR

Voltage Standing Wave Ratio is a measure of how efficiently radio frequency power is transmitted from a power source, through a transmission line into a load [32].VSWR is a function of the reflection coefficient, which describes the power reflected from the antenna.

$$\text{VSWR}= \frac{1+\gamma}{1-\gamma} \qquad (4)$$

3.6.9: Input Impedence

The impedence presented by an antenna at its terminals or the ratio of the voltage to current at a pair of terminals or the ratio of the appropriate components of the electric to magnetic fields at a point is called input impedence [33].

3.7 Breast Phantom Model

There are two types of phantom model. One is homogeneous phantom model and other is heterogeneous phantom model. In homogeneous phantom model a single layer of tissue is required. But in heterogeneous phantom model there are more than one layer. The breast phantom in this work comprises of skin, muscle and fat tissues. The phantom model can be in any shape.

3.8 Conclusion

This chapter describes the theoretical background of the research work. The designing parameters are described in this chapter. The performance of the MI system depends on the antenna used for signal transmission. So the parameters are important to obtain better performance antenna.

Chapter 4

Design And Simulation

4.1 Introduction:

In previous chapter we discussed about the performance parameters of the antenna. The PIFA antenna can be designed by following some rules. To get a better performance antenna, the length, width should be calculated according to the operating frequency of the antenna. The feeding should be given properly to the antenna. The proposed antenna is analyzed at free space first. Then within the breast phantom.

4.2 Design of the PIFA Antenna

The frequency at which PIFA resonantes can be calculated by using a formula as given below
L1+L2-W= λg

Where L1= Top Patch length
L2= Top Patch Width

The wavelength to the corresponding resonant-frequency λ
The guided wavelength is λg.

$\lambda g = \lambda_0/\mathcal{E}_r$ ……………………………………………………………………………………(5)

But $\lambda_0 = c/f$……………………………………………………………………(6)

PIFA sits on top of a dielectric substrate with permittivity $\mathcal{E}r$.

Therefore the above equation can be written as
L1+L2-W= $c/4f\sqrt{\mathcal{E}r}$…………………………………………………………..(7)

Here c is the speed of light
And f is the resonant frequency

The equation represents that the frequency is dependent on width and length of the antenna. If the height of the PIFA is considered and permittivity is considered as effective permittivity the the equation can be modified as

L1+L2-W= $c/4f\sqrt{\mathcal{E}eff}$ ……………………………………………………………(8)

The effective permittivity can be calculated as
$\mathcal{E}eff = \mathcal{E}r+1/2$……………………………………………………………………..(9)

By using the above equation the design parameters of PIFA are calculated. After calculating the parameters the antenna is designed in CST Microwave studio. To design the antenna different materials are used and analyzed.

4.3: Material of the Proposed Antenna

There are some materials used for the proposed design which play a vital rule in the simulation of antenna. Each material has its own effect on the antenna. For getting a better performance antenna the materials should be chosen properly. The substrate material of PIFA is FR-4. FR-4 is mostly use in designing of patch antenna due to its low cost and good dielectric properties. For PCB applications this material is one of the first choice. As PCB fabrication is comparatively easy and inexpensive. The main focus of microwave imaging is to reduce the cost as much as possible. So it is a good choice of substrate material. The ground and patches are made of copper. There are many advantages of copper over other materials. Copper is two times conductive than aluminum and six times conductive than steel. Copper is very efficient conductor for electrical energy. In any voltage power like low, high, medium copper can be used. These are the reasons copper is used as the conducting material. layer. The feeding of the antenna is made with PEC (perfect electric conductor). The feeding is the coaxial feeding.

.

4.4 Structure of the Proposed Antenna:

The dimensions in millimeter of the antenna are given below

Table 4.1: Dimensions of the Proposed Antenna

Parameter	Unit (mm)
Ground Length	40
Ground Width	40
Substrate Length	40
Substrate Width	40
Ground Thickness	0.035
Substrate Thickness	1.6
Width of the patch	3
Radius of feed pin	0.7
Radius of short pin	0.3

.

By using pifa antenna equations the parameter of the spiral pifa antenna is calculated and measured. Here the antenna has dimension of 40x40 mm^2 . The thickness of the substrate is 1.6 mm. The patches of the spiral pifa is of 3mm width. Here the feeding is the coaxial feeding. The feed is made of perfect electric conductor (PEC) material. The outer radius of the feeding is 1.4

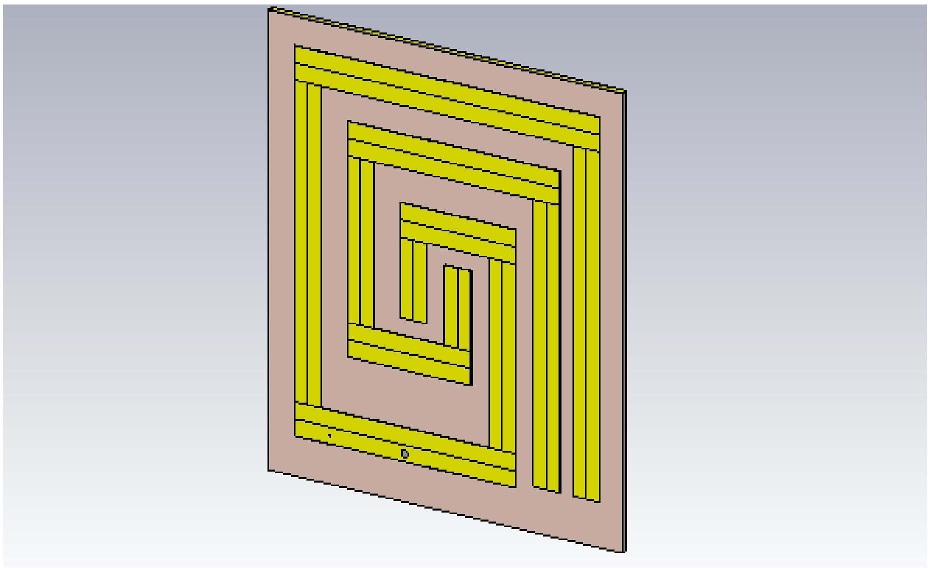


Fig. 4.1: Structure of the Designed Antenna

4.5 Material of the Proposed Breast Phantom

The proposed model of the breast phantom consist of three layer as it is a heterogeneous model. The skin and fat have different permittivity, conductance and density [15]. The tumor has it own properties. The hemisphere breast model is designed in the CST Microwave Studio suite.

Table 4.2: Properties of the Breast Phantom

Tissue	Permittivity (F/m)	Electrical Conductance	Density (Kg/m$^{3)}$
Skin	36.7	2.34	1109
Fat	4.84	0.262	911
Tumor	54.9	4	1058

The breast model consists of two layer. Evey layer has its own properties. Here the permittivity of skin is 36.7 F/m. The electrical conductance of skin is 2.34. Again the density of the skin tissue is 1109 kg/m3. But the fat layer has different dielectric properties. The permittivity of fat layer is 4.84 F/m. The electrical conductance of fat layer is 0.262. The density of fat layer tissue is 911 kg/m3. These are the properties of healthy breast tissues. But as there is a tumor present in the breast, the dielectric properties will not be the same. The permittivity of the tumor is 54.9 F/m. The electrical conductance of tumor tissue is 4 and the density of tumor tissue is 1058 kg/m. A breast phantom model is designed in CST Studio suite by taking these values accordingly. The breast model is shown below.

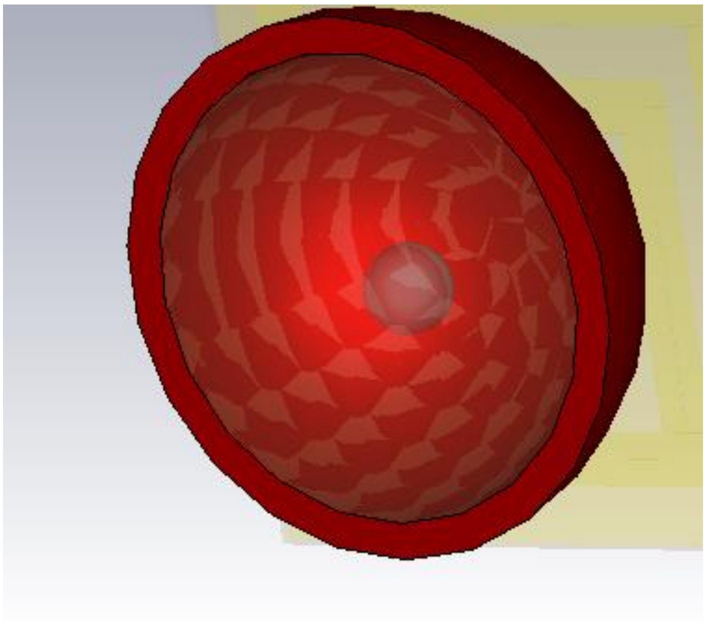


Fig 4.2: Designed Breast Phantom with tumor

The figure shows the breast phantom model with a tumor. The tumor has radius of 5 mm. The size of the tumor has an effect on the simulation results. If the size of the tumor increases then the simulated results will also change. In next section we will see how the size of the tumor can affect the result.

4.6 Analysis of the Simulation

After designing the antenna and the breast phantom model. It needs to be simulated. The simulation is doen in CST studio. The simulation is done in three steps. First the antenna is simulated. Then it is simulated with the phantom model without tumor. Next it is simulated with the phantom model with tumor. The simulation results are presented and discussed below.

4.6.1: Reflection Co-efficient of the Antenna:

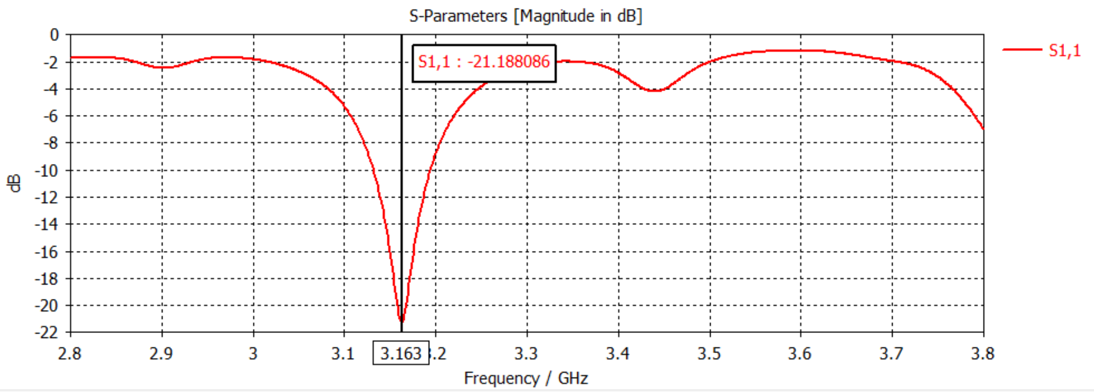


Fig. 4.3: Reflection co-efficient of the Designed Antenna

During the simulation the resonant frequency was 3.163 GHz. The antenna was set simulate from 2.8 GHz to 3.8 GHz. The s parameter was received at 3.163 GHz band. The reflection coefficient got at -21.18 dB. The reflection coefficient is close to the resonant frequency. The reflection coefficient is said to be better if the the value lower than -10dB. The lower the value than -10 dB, the better the antenna performance. As the spiral pifa antenna has value lower than -10 dB and lower than -20 dB as well, thus the designed antenna is a good performance antenna.

4.6.2: VSWR of the Antenna

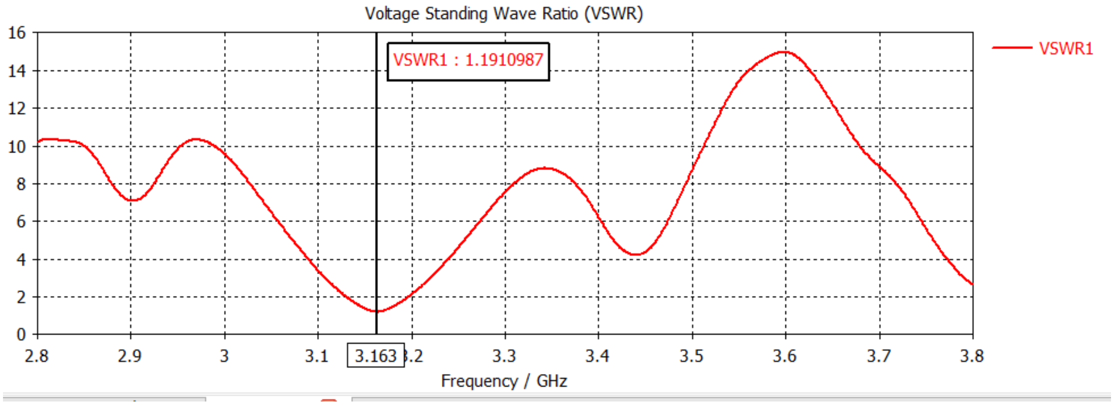


Fig 4.4: VSWR of the Designed Antenna

Here the VSWR of the designed antenna is 1.19 at frequency 3.162GHz. VSWR is a function of the reflection coefficient, which describes the power reflected from the antenna. VSWR stands for Voltage Standing Wave Ratio. The VSWR is a positive number for antenna. Antenna shows good performance if the measured VSWR is < 2. Here the value of VSWR of the designed antenna is 1.19 which is much lower than 2. So it can be said the antenna shows good perdormance.

4.6.3 : Farfield Directivity

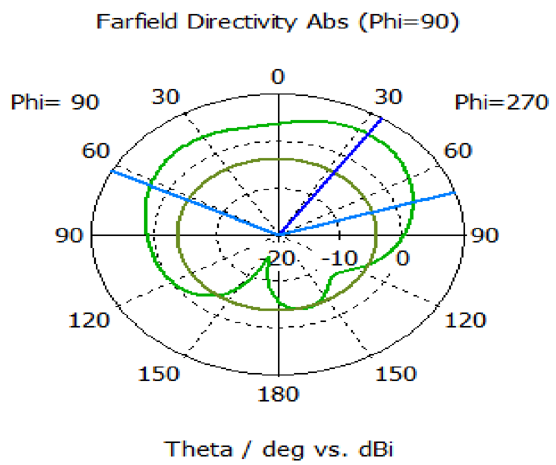


Fig. 4.5 : Farfield Directivity of the antenna

4.6.4 Simulated Results with Breast Phantom Without Tumor:

The breast phantom model is simulated with the PIFA antenna. The breast model is already designed . The breast model is now simulated with the designed antenna and we will observe the difference in the simulated results. The simulated results will be different as the antenna is placed on the phantom. Earlier the antenna was simulated in free space. But due to the definite properties of the breast phantom the antenna will receive different kinds of signal. The figure 4.6 shows the healthy breast or breast without any tumor. The model is simulated with the antenna and the results are analyzed as well.

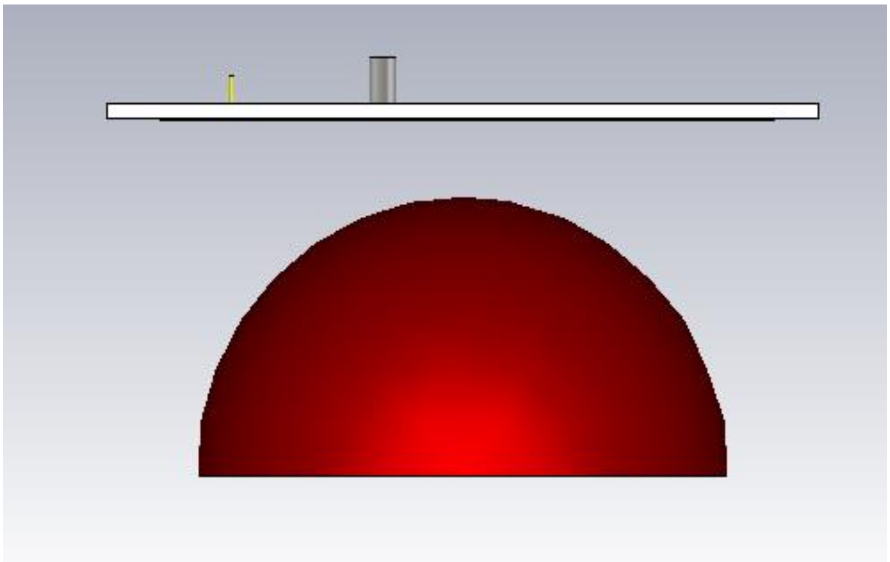


Fig. 4.6: Breast Phantom with Designed antenna

4.6.5: Reflection Co-efficient Without Tumor

We have analyzed the antenna in free space. The obtained reflection coefficient was approximately -21dB. But the obtained reflection coefficient will be different after simulating the antenna placed on the breast model. The value of the reflection coefficient will increase due to the dielectric properties of breast phantom. The reflection co-efficient with phantom model without tumor shows the result below

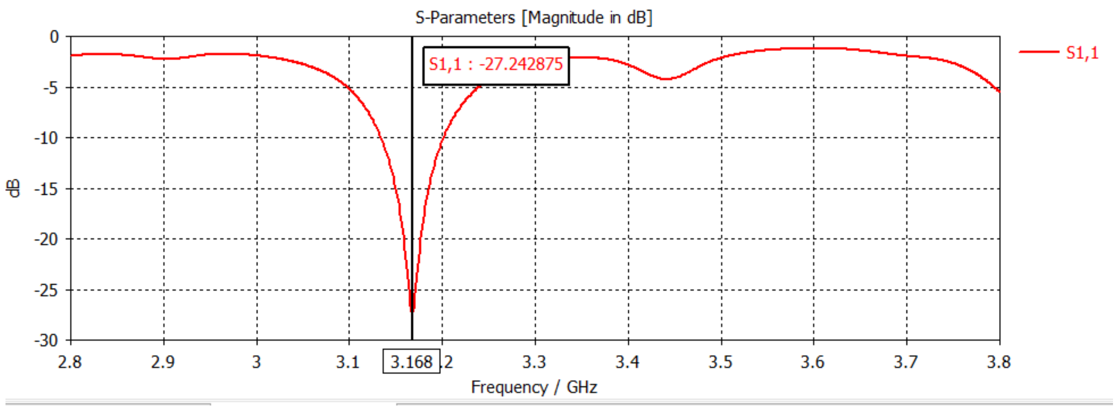


Fig. 4.7: Reflection coefficient without tumor

From fig. 4.7 we can clearly see the difference between the simulated result when the antenna was in free space and when the antenna was placed on the breast phantom model without tumor. The return loss value was -21dB but now we can see the return loss value is -27.24 dB. It happened because of dielectric property of breast model. The antenna performance has increased as the value of return loss decrease. The more the value the decrease the better the antenna performance is.

4.6.6 VSWR without Tumor

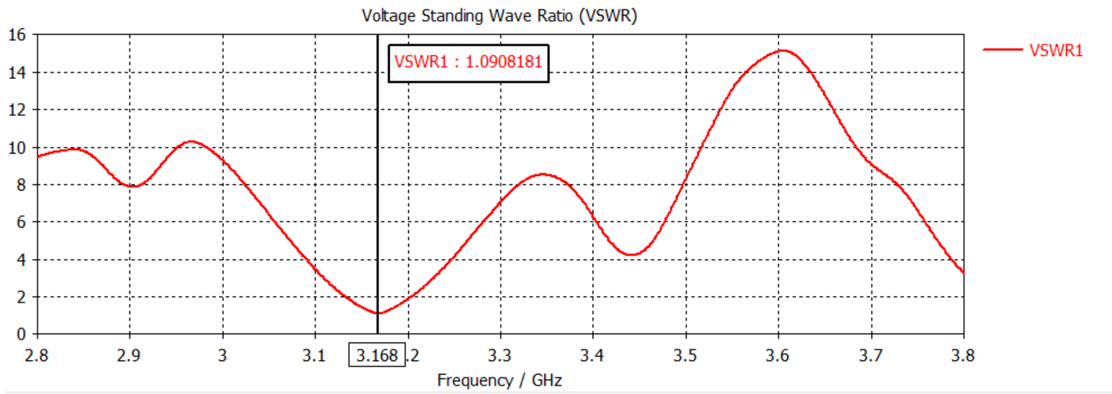


Fig. 4.8: VSWR without tumor

There is a difference in the value of VSWR when the antenna is simulated with breast phantom model. When the antenna was simulated in free space the value of the VSWR was 1.19 at frequency 3.168 GHz. But when the antenna placed on the breast phantom model the obtained VSWR is 1.09. The dielectric properties of the breast tissue makes the difference here. As it is lower than 2, thus the antenna shows good performance .

4.6.7 Farfield Directivity Without Tumor:

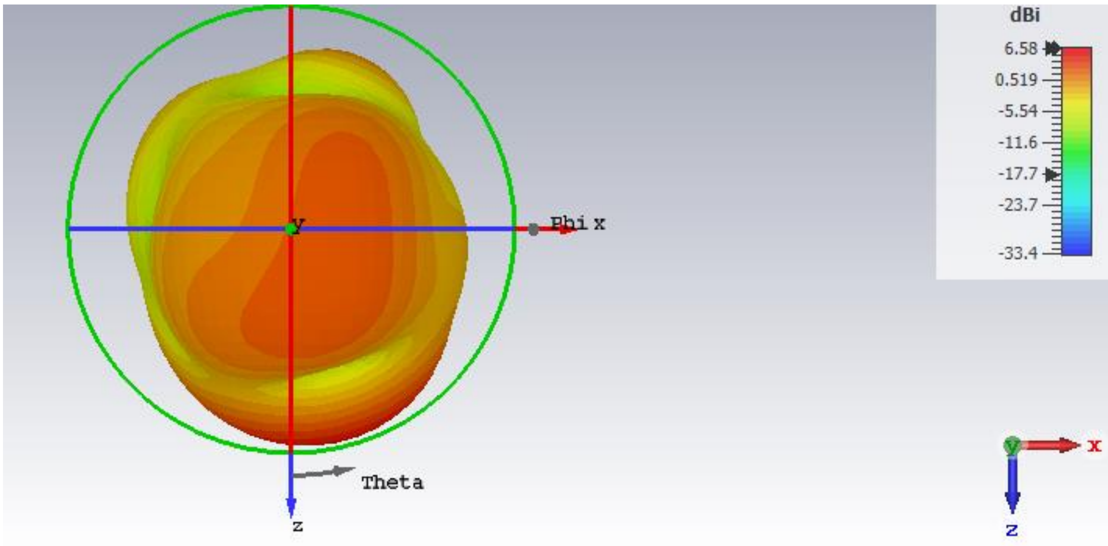


Fig. 4.9: Directivity of the Antenna

4.6.8 Simulated Results with Breast Phantom With Tumor

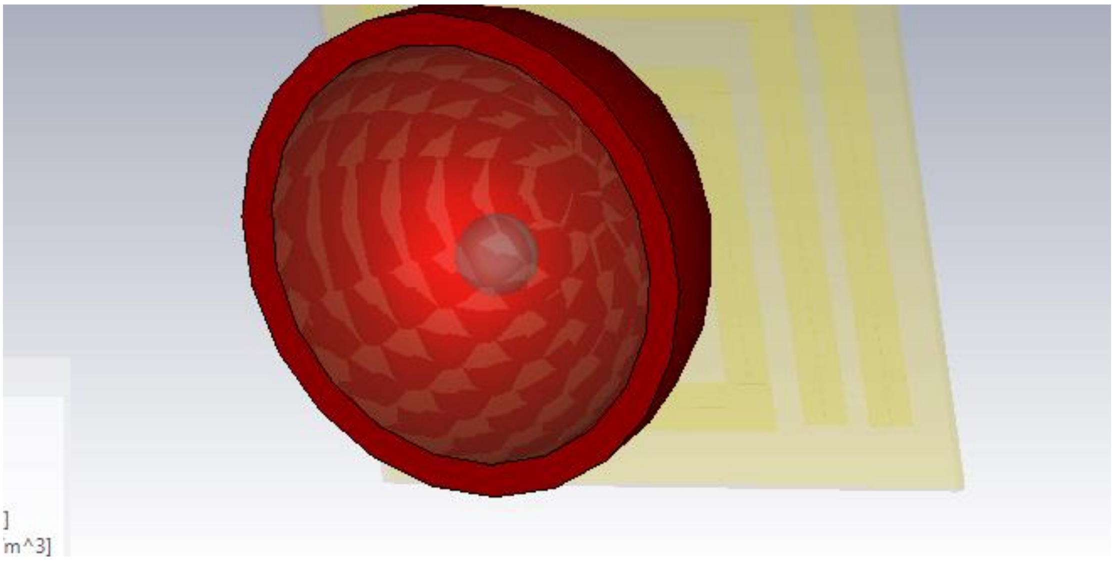


Fig. 4.10: Simulation of Phantom model

From the figure 4.10 we can see that the phantom model has a tumor in it. The tumor size is 6 mm. The simulated result will not be the same as the breast has a tumor in it. So the output will be different from the earlier results. We will now see how the performance parameter vary with presence of tumor.

4.6.9: Reflection Coefficient with tumor size 6mm

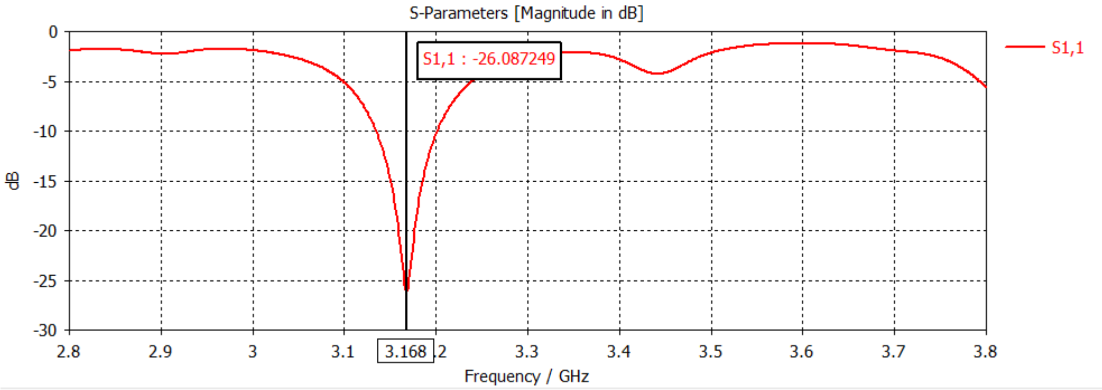


Fig. 4.11: Reflection Coefficient with tumor size 6 (mm)

If we observe figure 4.7 and figure 4.11 we can clearly see the difference between the output result. In figure 4.7 the value of the reflection coefficient was -27 dB when there was no tumor in the breast phantom model. But in figure 4.11 the value of the reflection coefficient is -26 dB at frequency 3.168 GHz. So the existence of the tumor differs the result.

4.6.10 VSWR with tumor size 6mm

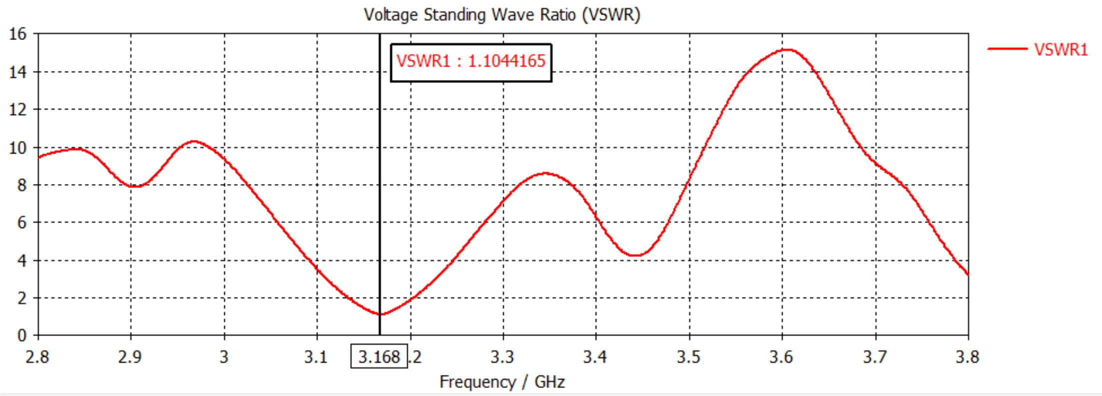


Fig. 4.12: VSWR with tumor size 6 mm

There is a small difference in the value of VSWR when there is a tumor in phantom model. In figure 4.12 we can observe that.

4.6.11 Farfield Directivity

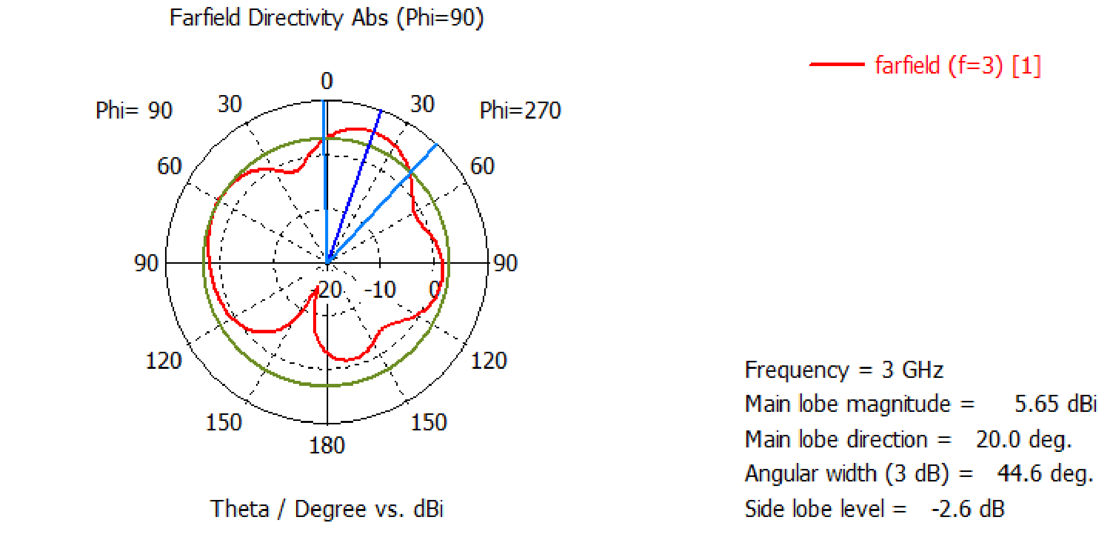


Fig. 4.13: Directivity of the antenna

4.7 Comparison among the Existing Work

The PIFA antenna is a well known antenna in the wireless communication field. As it is very popular in mobile handset. In biomedical application researchers have been trying to utilize the antenna in recent times. For breast cancer detection PIFA can be good choice. Though the research topic is still growing, there are some existing work which can be compared to this work. They are shown below:

Table 4.3: Comparison among author's work and existing work

Design Parameter	Author's work	Existing Work[27]
Frequency Band	2.8GHz-3.8GHz	402MHz- 405 MHz
Material	FR-4, Copper	Rogers 4035b
Tumor size	6mm	2cm, 3cm, 5cm
Return loss	-27 dB	-20 to -22dB

The performance difference between the designed antenna with the existing antenna can be evaluated from the following table. The materials as well as the frequency bands are different from the existing antenna. The existing PIFA measured the tumor in centimeter size. But the designed antenna measures the tumor from millimeter size. This is the great advantage of the designed antenna. As it can detect the tumor in very early stage when the tumor is in millimeter size. Next the obtained reflection coefficient with breast phantom model with tumor in this work is better than the existing antenna's reflection coefficient with tumor. So the designed antenna has a great advantage over the existing antenna.

4.8: Conclusion

This chapter describes the antenna and the breast phantom model design and simulation in the required software. The results were presented one by one and shows the can be successfully applicable in breast cancer detection. The antenna gives better performances in various parametrs which is helpful in Microwave Imaging method for breast cancer detection.

Chapter 05

Conclusion

5.1 Conclusion:

The work is based on the microwave imaging system for early breast cancer detection. We have designed a Spiral PIFA antenna and measure its performance to detect the cancer. We have also design a breast phantom model with or without tumor. The designs and simulations are done CST Microwave Studio software. The antenna is a good performance antenna and applicable for this application. The antenna has high gain .By varying the size of the tumor the parameters can be evaluated. The spiral pifa has a gain above 5. The reflection coefficient of the antenna is -21dB. It means it is a good performance antenna.

5.2 Future work

The proposed design shows a good result for the microwave imaging system to detect early stage breast cancer. The designed Spiral PIFA can be fabricated in future and can be applied in real life application. As the fabrication of PIFA is quite easy it can be done in near future. The pcb of PIFA is ver popular nowadays. So by fabricating it on the PCB it can be applied practically. It is a low cost and nonionizing method. So it will reduce the pain of people.

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