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Breast Cancer Detection Using Circular Microstrip Patch Antenna

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Breast Cancer Detection Using Circular Microstrip Patch Antenna

by

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ABSTRACT

Breast Cancer Detection Using Circular Microstrip Patch Antenna

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In this report an ultra-wideband (UWB) microstrip antenna for early detection of breast cancer has been proposed. The design has been made using the CST software, FR-4 has been used as a substrate, with a peak gain of 4.431 dBi, this antenna works within 1.6 GHz to 10 GHz which gives a bandwidth of 8.4 GHz. A breast phantom model has been designed containing a tumor placed in a specific location. The detection is made using SAR analysis. The results display the ability to detect the tumor presence inside the breast and reveal its location with high accuracy.

Keywords: Ultra-Wide-Band antenna; CST; breast cancer detection; wearable devices.

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LIST OF ABBREVIATIONS

WHO	:	World health organization 7
UWB	:	Ultra-Wideband
RFID	:	Radio Frequency Identification
WBANs	:	Wireless Body Area Networks
SAR	:	Specific Absorption Rate
UWB	:	Ultra-Wideband
CPW	:	Coplanar Waveguide
SMA	:	Subminiature Version A

LIST OF SYMBOLS

μ	: Mobility of electron
λ	: Wavelength
ω	: Angle frequency
$\sigma(r,\omega)$	: Material conductivity
r	: Position Vector
ρÏ'(r)	: Mass Density of The Dielectric Material at r
$E(r,\omega)$	: Electric Field Within the Tissue
V	: Volume

1. INTRODUCTION

As it defined by world health organization (WHO), cancer is the abnormal grow of a cell in an uncontrollable way. It can start in almost any organ or tissue of the body; cells start to invade adjoining tissues and near organs and spread more and more within the body and the reason that cancer causes death is metastasizing process that happens later.

Breast cancer happens often among women approximately 2.1 million women yearly, the estimated number of deaths in 2018 was 627,000 women, which is 15% of the total, and those numbers are increasing linearly [1].

Many lives can be saved if tumors are detected in early stages, which can result in a bigger chance for recovery. Many patients find it irritating to get regular checkups since most of the monitoring systems are complicated, not available everywhere and not mobile. Furthermore, for medical field applications, micro-strip antennas are efficient and have flexible properties that are utilized in imaging, diagnosis, and treatment. It is known that is the most common type of cancer in the world is the breast cancer, and the early detection plays an important role in treating it. In the early stages of breast cancer, getting rid of the tumors are much easier and more guaranteed. However, many patients find it irritating to get regular checkups since the majority of the monitoring systems are complicated and not mobile.

1.1 PROBLEM STATEMENT

Cancer is one of the deadliest diseases especially when it goes malignant and start takes over the body and spreads to the other organs. It happens when a growth process of a cell goes wrong, and it have been hard to detect since ages despite the presence of the modern technologies. One of the worldwide commonly type of cancer is the breast cancer which harness the lives of a lot of women and that arises the need of finding solution, addressing this subject, start working on a cure and more important a way to detect the presence of it. Years of research proved that the most important element of curing cancer is to detect it on its early stages before it goes wild and spreads to more organs. For detecting this tumors many techniques have been proposed like mammography [2], MRI [3], and ultrasound [4], and those technologies has limitations for early detection mostly because of the poor contrast, which does not provide an early detection and therefore the late detection of the cancer reduces the probability of curing it. This research addresses the usage of a microwave imaging which proved to be promising detection technique [5], radar based techniques and usage of microwave in tomography have been used in cancer detection [6-8].

1.2 AIM OF STUDY

Designing a micro strip patch Wearable antenna to detect breast cancer at early stages with low cost and high efficiency is the aim of this work.

1.3 OBJECTIVES

1- How the antenna will help to detect the breast cancer.

2- Investigation of existing the antennas strategy for MICS and ISM bands.

3- Study microwave imaging techniques as a various alternative for the detection of breast cancer.

4- Design an UWB microstrip patch antenna.

5- Having the desired data for the design of the human breast tissues, to be able to test the efficiency of the detection.

2. ANTENNA APPLICATIONS

The antenna is a device that transmits and receives signals in the shape of electromagnetic waves. It is also known as a transducer device as it can converts between electrical signals and electromagnetic energy to be able to be a transmitter and receiver at the same time. Figure 2.1 can explain the path of the transmission line from the transmitter to the receiver and shows that it connects between the wires which is the transmission line and the wireless which is the free space.

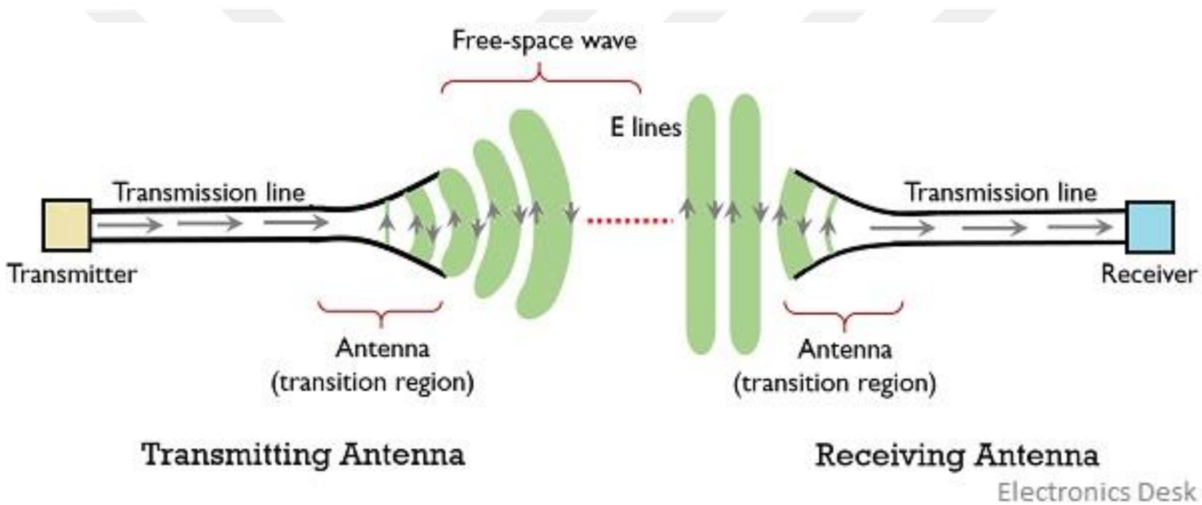

Figure 2.1: Transmitting and Receiving Antenna.

Antenna has been implemented in the medical field in general and application of cancer more specifically. It has been used for diagnosis and treatment and sometimes only for information transmission, the Radio Frequency Identification (RFID) has been used in monitoring systems and medical implants, and microwave imaging so in general antennas can be used as communication and/or a treatment device.

Nowadays, minimizing the antenna size and reducing the complexity is the major purpose of the antenna research. The study that tries to connect between human body and the electronic devices is known as the Wireless Body Area Networks (WBANSs), in this study a tiny nodes group that are equipped with a sensor, or a motion detector and a wireless device, which uses techniques similar to the ones used in wireless systems [9-20].

In the human body, it is known that the frequency of the microwave band increases therefore to ensure the safety of the human body from being affected by the radio waves a Specific Absorption Rate (SAR) usually used to test the in wireless devices. Flexible antennas with compact size, low impact on the human body and small SAR are always preferable in WBAN, communication patch antenna is used because of their small size and simple design and high gain, an obstacle in patch antenna is the huge back radiation [21-32].

2.1 INTRODUCTION

Breast cancer is better to be detected at early stages because the time of knowing that there is a cancer is essential for the treatment plan, X-ray imaging is one of the most conventional means of detection of breast cancer known as the X-ray mammography. However, it has some limits. Thus, researcher now looking for a new way for cancer detection at early stages.

Microwaves were widely used for breast cancer detection. The detection usually done by illuminating the target using electromagnetic wave at a specific frequency then it would be possible to view the internal parts of the target.

Two approaches found in breast cancer detection using microwave radiation in order to detect the presence of a tumor. First approach is the tomography, a single transmitter is usually used to radiate in the direction of the breast, and Having multiple antennas placed around the breast in order to collect the waves, which would be scattered and diffracted, according to the data received processes are usually take place in order to get an image of the breast in 2-D or 3-D.

Second approach is the radar-based microwave, a single ultra-wideband (UWB) antenna is needed to transmit a short pulse to the breast and then receive the scattered signal back and repeat the process in various locations around the breast. If it reads, a high scattering that will indicate that there is a tumor. This method provides more details about the tumor when compared to the tomography.

The UWB antenna should provide high resolution. Thus, the most important characteristics that must be taken into consideration is the bandwidth. Where the antenna designed for the detection should have a high fractional bandwidth. Also, it should have a low side-lobes and low mutual coupling, to decrease the reflections between the free space and the breast. The metallic sensors must be placed in a matching medium that must have a permittivity similar to the tissue of the breast; however, the implementation of the matching medium in real life around the patient's breast is difficult [33].

2.2 WEARABLE TECHONOLGY

The technology of wearable devices is a technology of electronic and computer devices incorporated into clothes. It can be worn on in everyday life. Those devices can be watches, glasses, earring, caps and fabrics. Those devices are capable to do various tasks, it can work normally like a mobile phone and computer but also can work as a sensor or a tracker or even work as a scanning device. It is considered as a major step in the trend of pervasive computing where everybody can access information anywhere. In general, wearable devices have a very broad application. Before introducing, it the consumers those devices were used in military technology. Then, we see application in education, gaming, music, transportation fitness and health. The main task of such wearable devices is to incorporate the functions needed to be done in daily life.

For the medical field, those devices are either embedded inside the body or be worn to capture and process the patient's data, do the required calculations, and provide the feedback to patient [34].

2.3 WEARABLE ANTENNA DESIGN CHALANGES

Limitation is to be found in any work, therefore it must be evaluated and analyzed to obtain the required outcomes. The lossy conducting materials found in the human body is one of the main reasons of these limitations which leads to the following challenges:

2.3.1 Size Limitations

The size limitations arise because of the relationship between the performance and the size of the antenna; therefore, the dielectric constant must be reduced to have a better performance and that is done by having the thickness of the substrate increased, therefore increasing the antenna size is important to have a larger bandwidth.

2.3.2 Life of the Battery

Significant performance, speed and quality requires power therefore the battery will be consumed through time, moreover the size of the battery in some wearable antennas might cause a problem since it might affect the sensor performance, therefore, to create a system efficient to perform the required task, a larger battery will be needed to provide power to the small sensors.

2.3.3 Lossy Environment and Multipath Losses

One of the human bodies characteristics is having a lossy conducting material, which will dissipate the energy, therefore when implementing the antenna in the body its behavior and the radiation pattern will be affected as illustrated in following Figures [35].

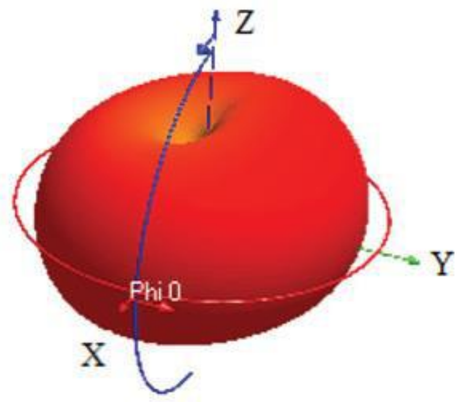

Figure 2.2: Radiation Pattern

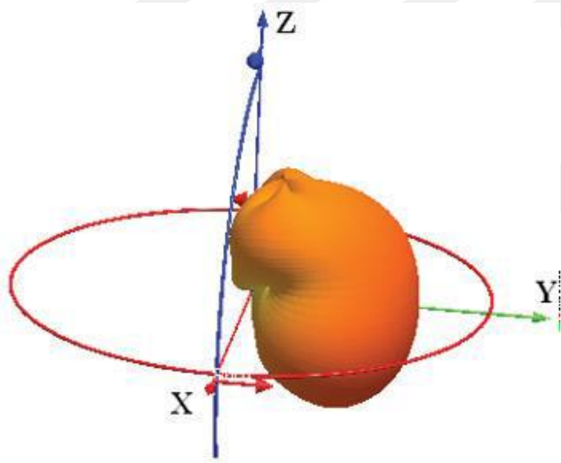

Figure 2.3: Defected Radiation Pattern

The difference between the two figures is clear the Figure 2.2 shows a radiation pattern obtained by HFSS while the Figure 2.3 shows an antenna implemented in the skin tissue of a head model of a human

2.4 MICROSTRIP PATCH ANTENNA

In the medical field and specifically in imaging, diagnosis, and treatment micro-strip antennas are widely used. Moreover, it is easy to install on the human body due to its flexibility.

Micros-strip antenna usually consists of three main parts, as seen in Figure 2.4 below.

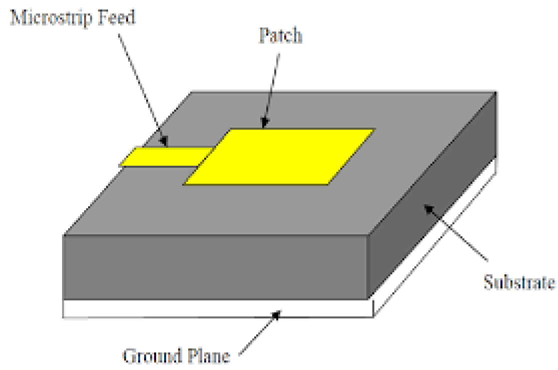

Figure 2.4: Micro-Strip Patch Antenna [33]

It consists of a conductor which is the ground plane, a dielectric which is the substrate and finally a patch which is going to be the conductor. For the design to be made the ground plane and the substrate of the antenna are going to be over each other having the same size, and the metal patch will be placed over them having a size of roughly half of their sizes [33].

The power will be provided to the antenna through a feeder of copper, the feeder will be attached to the patch, the current will flow through them reaching the middle point of the patch, and due to the open circuit, the antenna will radiate [36].

2.5 DESIGN OF PATCH ANTENNA

Due to the unique properties of the Microstrip patch antennas it became increasingly useful it is easy to fabricate and can be printed easily on a circuit board, the low profile and the low profile also make it widely spread in mobile phones and medical application.

Microstrip patch antenna have three parts which made of conductive materials most commonly copper, those parts are the patch, transmission line and ground plane, the dimensions of the patch from it's length L, width W and thickness h are critically important since it affect the antenna efficiency (Figure 2.5) [37].

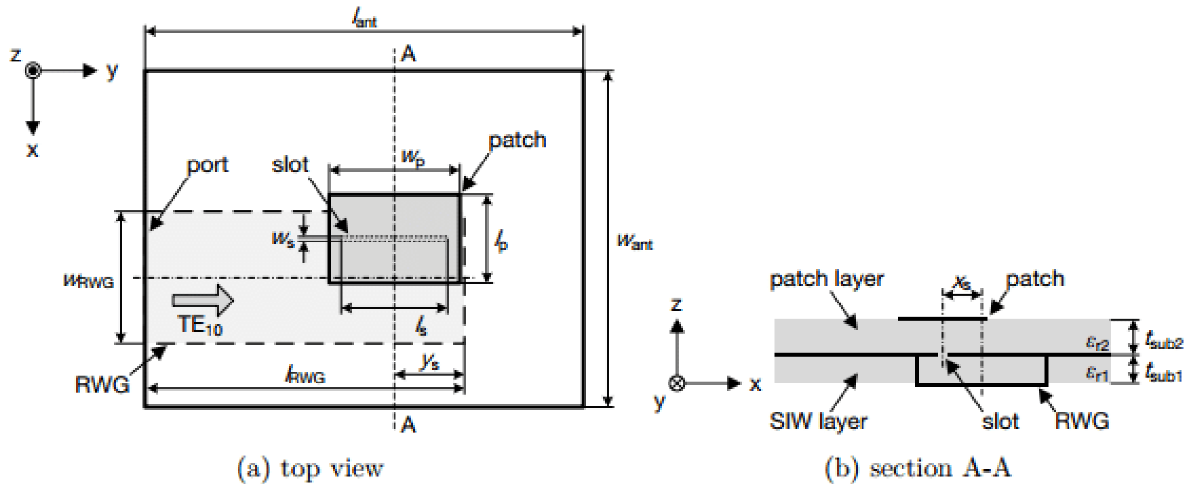

Figure 2.5 Micro-Strip Antenna [37]

When designing the antenna, the ground plane and the substrate are placed over each other and they should both be having exact size, and the patch finally placed over the substrate, which commonly have almost half the size of the substrate [38].

The power provided for the antenna by a feeder linked to the patch. The current will flow, and the voltage will appear. Then it will approach zero at the center of the antenna, the current will have zero value at the end points, due to the very small patch it will work as an open circuit, thus the current will be zero [39].

2.6 MICROSTRIP ANTENNA IN BREAST CANCER

Microwave imaging is used for early detection of breast cancer. Due to its unique features starting from the size which is considerably small and light weighted, and the low cost of manufacturing. Therefore, patch microstrip patch antenna became famous for imaging, as it will be useful for the early detection of the cancer and it will help locate suspicious cells for biopsy procedures for the breast [40].

2.7 MULTI-BAND ANTENNA IN WEARABLE ANTENNAS

The multiband antenna is an antenna designed to work in many bands. Multiband frequency help increase the antenna efficiency. The design of the multiband antenna is made to make one part active in one band, on the other hand another band will be active by the other part, the gain of multiband usually low, and physically have a larger compensation [41].

The existence of a dual antenna is very important in medical field applications, due to the ability of the dual band to scan and expose different parameters at the same time. For example, it can take the temperature of the body and the pressure of the blood at the same time. These properties can help in saving people lives [42].

Dual-band antenna designed and simulated in the shape of rectangle, therefore two rectangular shapes connected using arms. Different ways used to design a dual-band, such as designing two rectangular shapes with different frequencies and close the gap between them by bridging them together.

The figures below illustrate simulated and measured reflection coefficient for three types of multiband antenna, which are tri-band, dual-band and quad-band [43].

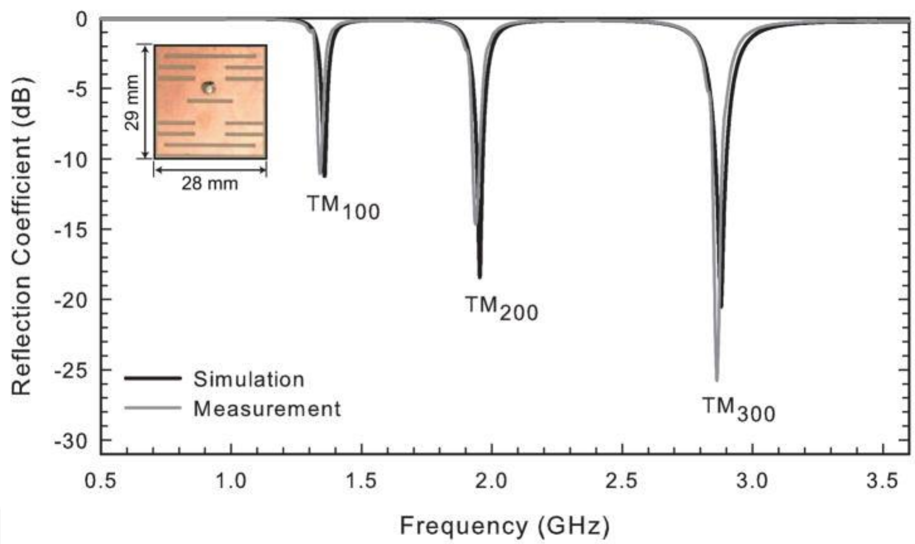

Figure 2.6 Dual-Band Result [43]

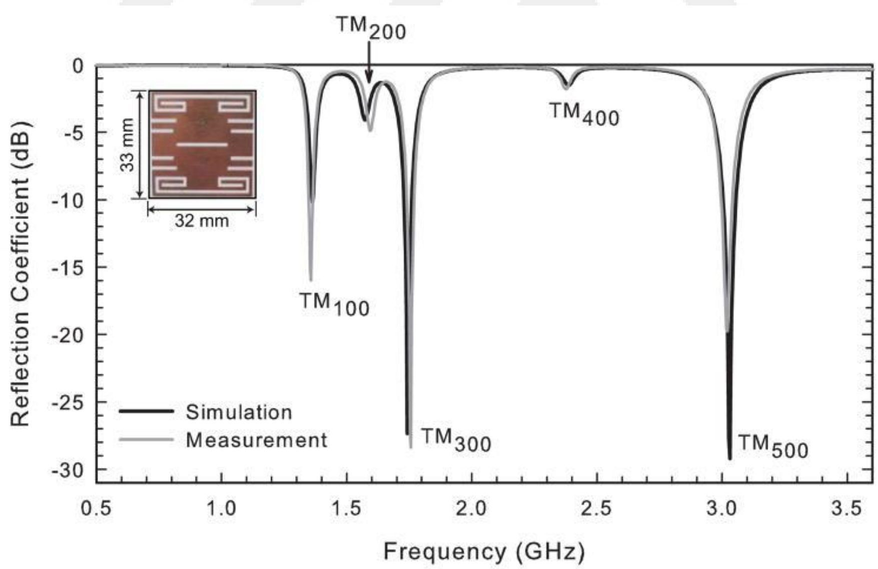

Figure 2.7 Tri-Band Result [43]

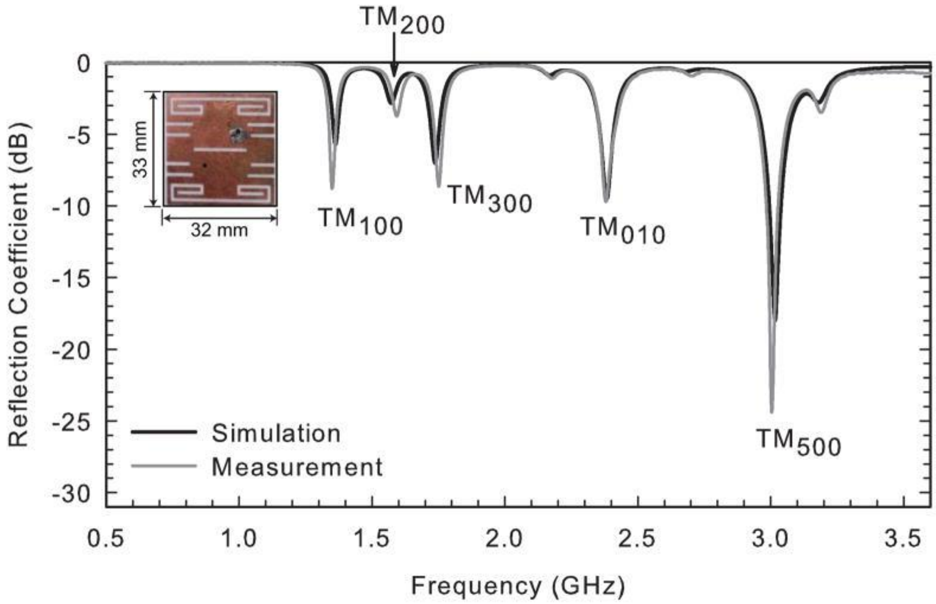

Figure 2.8 Quad-Band Result [43]

3. LITERETURE REVIEW

3.1 OVERVIEW

Breast cancer detection using microwave imaging principal and especially wearable antennas is wide research area and have a lot of impact over the cancer detection techniques. that is why a lot of research can be seen in this area, for example John P. Stang and his team tried to design a 3D antenna array for cancer detection [44]. Another example is breast cancer detection using symmetrical antenna array done by M. Klemm and his team [45]. In UK, Bristol, at University of Bristol, a team proposed a symmetrical antenna array for breast cancer detection [47]. Moreover, Hamed M. Jafari, M. Jamal Deen, did an interested study of Ultrawideband antennas for Near-Field Imaging. In the following chapter, we will discuss these applications advantages and disadvantages.

3.2 3-D ANTENNA ARRAY DESIGN

At Duke University, they designed a 3D antenna array for the purpose of early cancer detection [44]. After measuring the performance of the antennas, the modeled scattered field information of the small tumor and the parameters, that were already known associated with the other components, they found that the screening of the tumor with the clinical microwave-imaging array is certainly possible. Since the previous experimental data with 3D imaging system with the successful inversion of phantoms demonstrate that, the inversion of their previously developed algorithm at Duke University is also possible. In addition, they only thing will remain is finishing the implementation of the hardware system and design the prototype and start clinical trials.

Their major challenges were the assumption that the antenna will radiate in free space because that is what researchers usually assume when designing a fixed 3D array antenna. However, for designing an antenna for breast cancer detection radiation should be toward the tumor so it can copy the dielectric properties of the tumor. However, the breast cancer antenna should be designed to enhance in order to radiate directly into higher dielectric media. moreover, sampling resolution have to be considered, because the antenna gives the ability to know the characteristics of the field distribution within the imaging volume, that is going to be in order to remodel the dielectric properties of the area that it radiated in. therefore, it is better to increase the covered surface by increasing the number of antennas. Additionally, it is not preferable because increasing the number of antennas will cause an increasing of the coupling between them.

Additively, few negative effects of the mutual impedance on the performance of the antenna, such as the shifting effect on the resonant frequency, alter radiation pattern and reducing the matching performance. Furthermore, different impact due to those effects occurs on each antenna in the array due to their locations. Therefore, the design of the array must be done in a way that decrease the mutual coupling between the antennas and repeat the simulation and measurements to enhance and develop the design.

They developed a tapered patch-imaging chamber for the client to use, the chamber is in the shape of a bra to make it easier as can be seen in Figure 3.1, and the chamber consists of six array of patch antenna and placed in a lossless dielectric material [44].

Figure 3.2 illustrate the return loss for the simulation of the HFSS.

The simulation of the HFSS is similar to the real measurement for the operating antenna, which makes HFSS simulation software reliable.

Figure 3.3 shows the model of healthy breast and a breast with a tumor created depending on the dielectric properties for both; Figure 3.4 shows the antenna radiation.

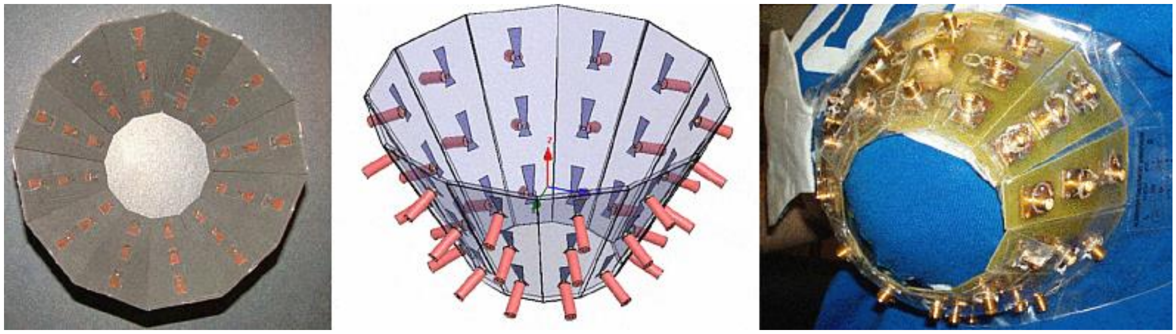

Figure 3.1: Imaging Chamber and The HFSS Model [44]

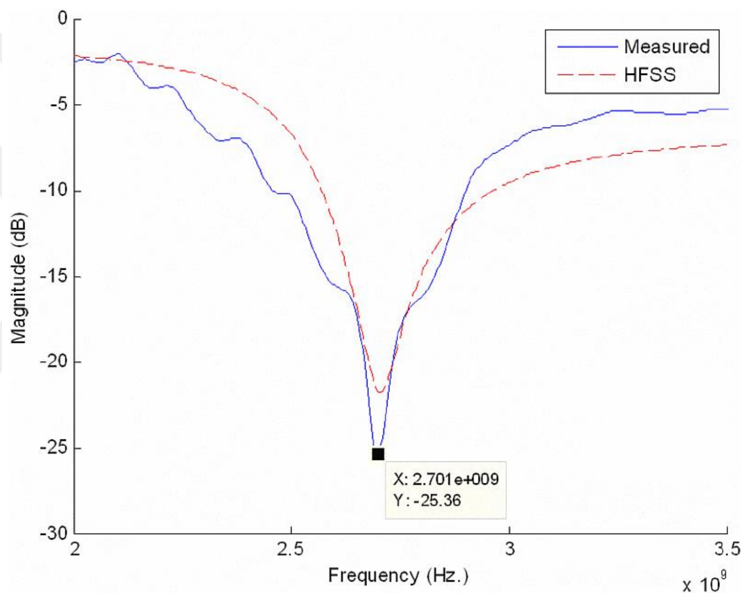

Figure 3.2: Return Loss Comparison [44]

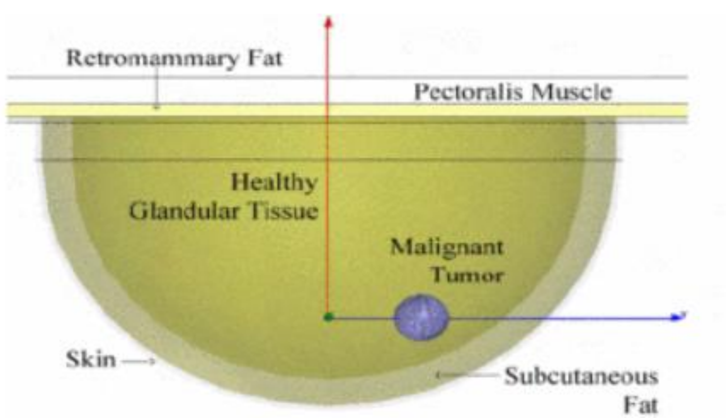

Figure 3.3: Human Breast Model [44]

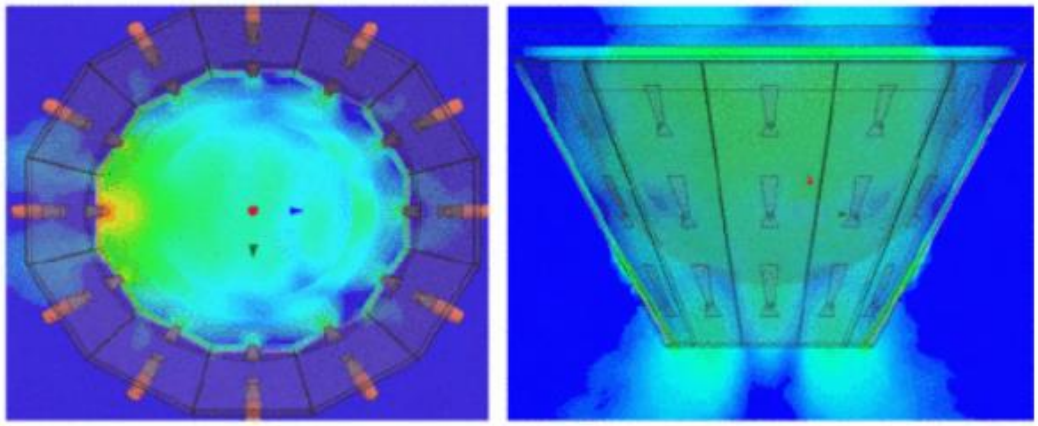

Figure 3.4: Antenna's Radiation in The Breast Model [44]

3.3 WEARABLE MICROSTRIP PATCH ULTRA WIDE BAND ANTENNA FOR BREAST CANCER DETECTION

A design of an ultrawide band microstrip patch antenna for the purpose of breast cancer detection is presented by Alsharif and coworkers. The design supports the wearability and can be easily placed over the body.

Their antenna has dimensions of 70mm × 60 mm that is fed through a miniature adapter connecter known as MMCX. After several material comparison Cotton was used as a substrate with a permittivity of 1.6. the antenna has been designed using CST Microsoft studio [46]. The structural development of the antenna is shown in Figure 3.5.

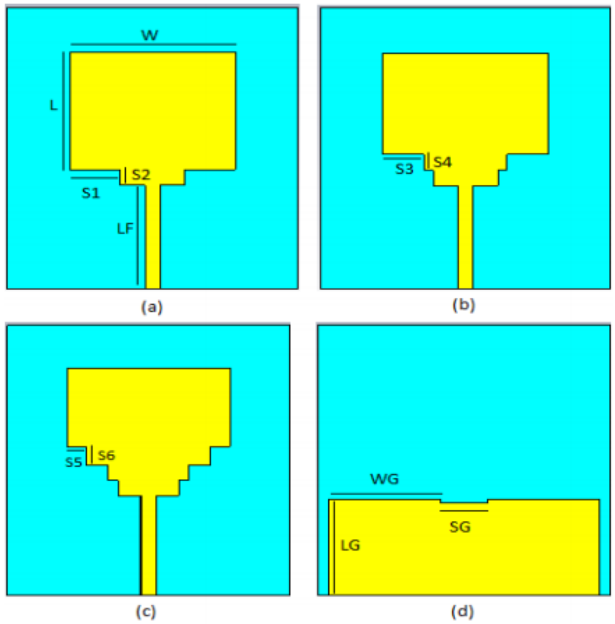

Figure 3.5: The Structural Development of The Antenna.

The return loss -10 dB (S11) shown in Figure 3.6, it covers a 1.6 GHz to 11.2 GHz bandwidth, almost 9.6 GHz is achieved by the final structure.

Figure 3.7 shows the 2D radiation pattern at several frequencies 2.5 GHz, 4.5 GHz, 6.8 GHz, 9.8 GHz. The antenna has a total efficiency of 93% at 9.8 GHz, and a directional radiation pattern with a 6.17 dBi.

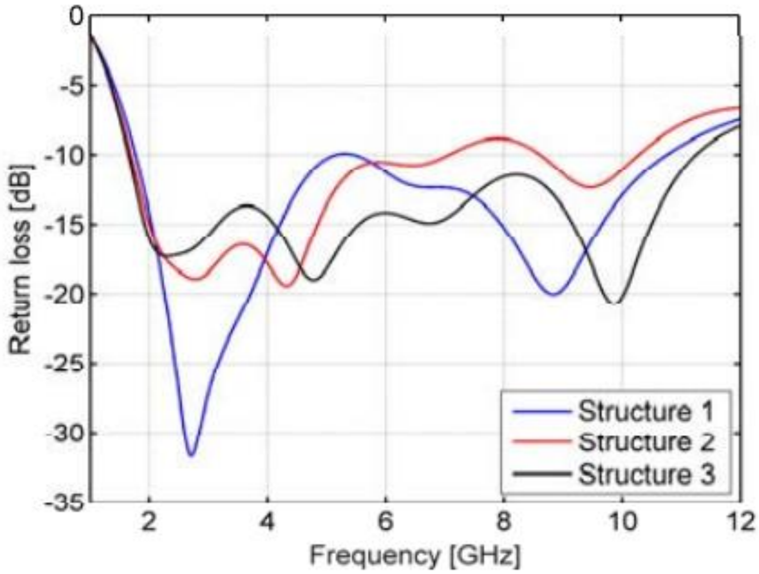

Figure 3.6: Return Loss.

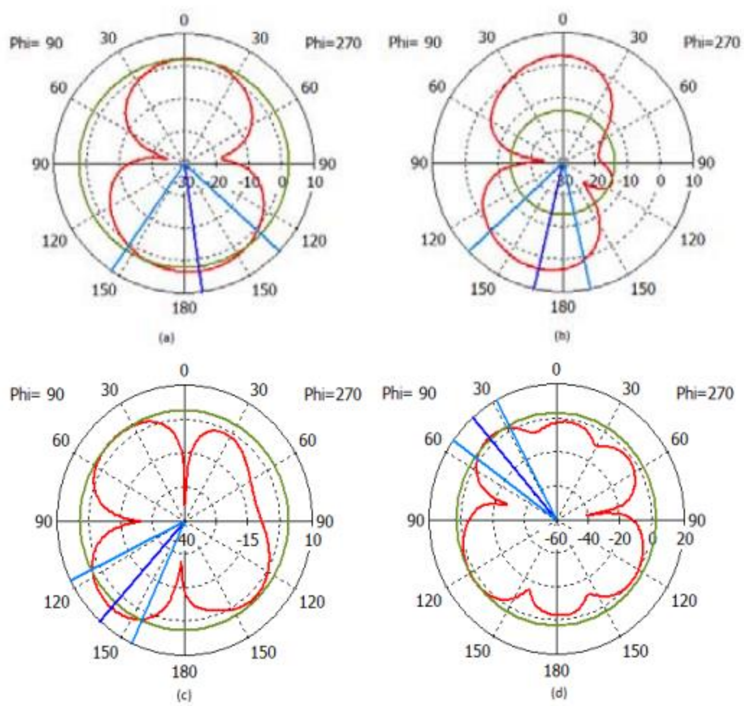

Figure 3.7: Radiation Pattern a) 2.5 Ghz, b) 4.5 Ghz, c) 6.8 Ghz, d) 9.8 Ghz.

Furthermore, their research focus on the substrate materiel and their relative permittivity.

The detection of cancer is done by detecting the variation of the amplitude and time of the reflected signal knowing that the amplitude and time of the reflected signal of the tumor will be different because of multipath propagation and distance of the antenna and tumor.

Their design has a conservative size with low cost and good directional radiation patterns, wearability and the ability to be functional under different bending conditions. Furthermore, adjusting the design will acquire better outcomes.

3.4 SYMMETRICAL ANTENNA ARRAY

The microwave radar antenna array based has a curved surface, which can be used for real 3D breast models. The Figure 3.8 shows geometry from a sideview with breast phantom, also the top view is shown in Figure 3.9.

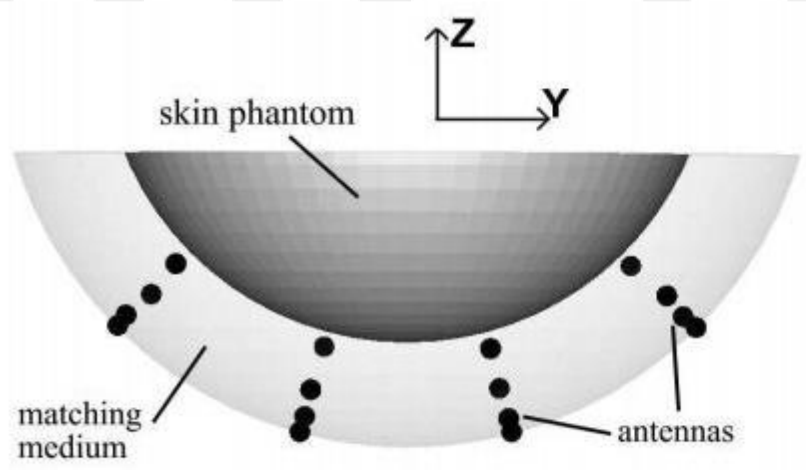

Figure 3.8: The Sideview for Antenna Array Geometry with the Curved Spherical Skin Model [47]

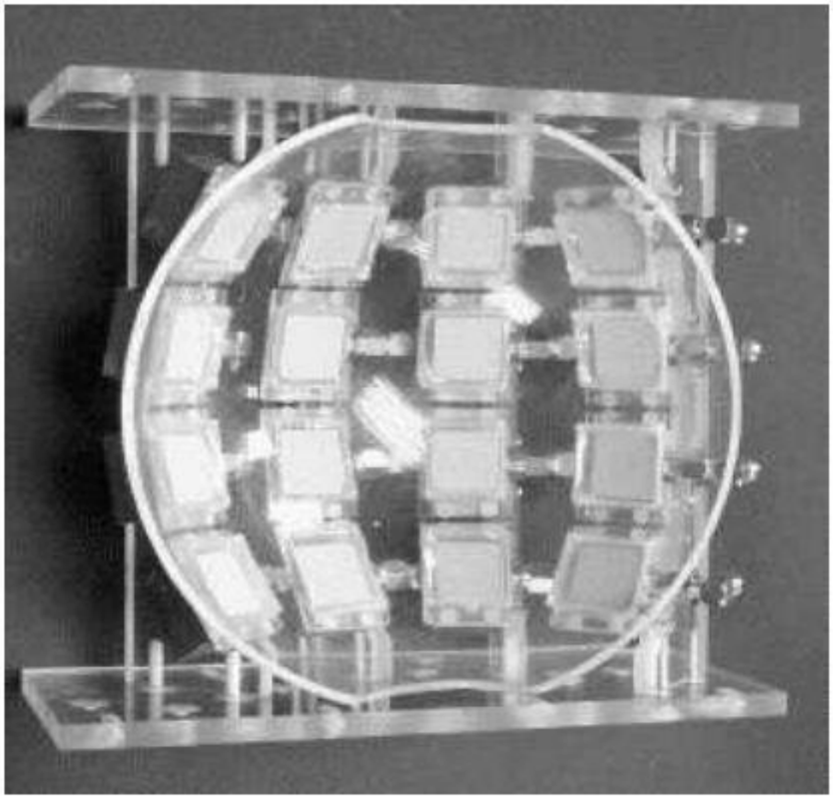

Figure 3.9: The Top View of The Curved Spherical Skin Model with the Antenna Array [47].

Four antennas in four rows in the lower part (78 mm radius sphere). Which allow symmetrical array geometry.

The phantom materials have electrical properties that demonstrate realistic curved breast with values of real breast [47].

Table 3.1: Permittivity and Attenuation at Freq. of 6 Ghz.

	Breast fat/matching medium	Skin phantom	Tumor phantom
Permittivity	Close to 10	30	Close to 50
Attenuation	0.8 dB/cm	16 dB/cm	-

During their experiments, the array was filled with matching medium while in the right position the curved phantom takes place, attached to top of the antenna a tank to fill it with fat of the breast equivalent to the matching medium.

The steps before processing for the measured radar signal of the signal processing, first the tumor response will be taken form measured data, then equalization of tissue losses and the radial spread.

Post-reception to obtain 3D image of the energy scattering, their algorithm depends on beam forming and classical delay.

Results for different phantom tumor detection experiments shown in different graphical formats [47]

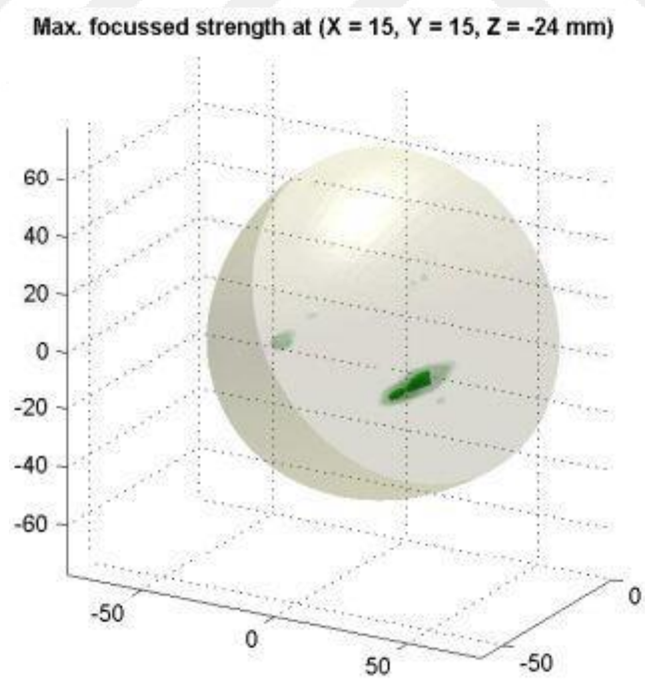

Figure 3.10: 3D Contour Map of Scattering Energy [47].

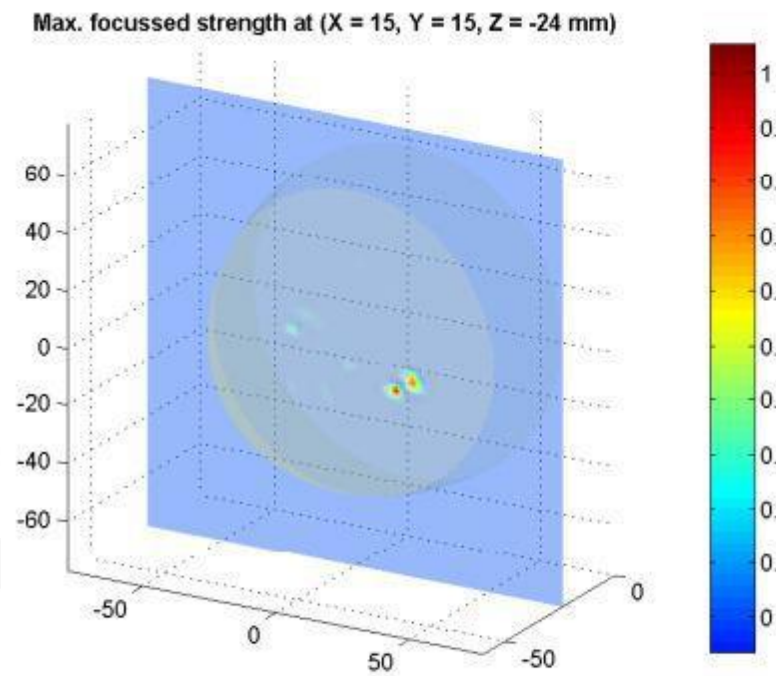

Figure 3.11: 2D Planar Slice [47].

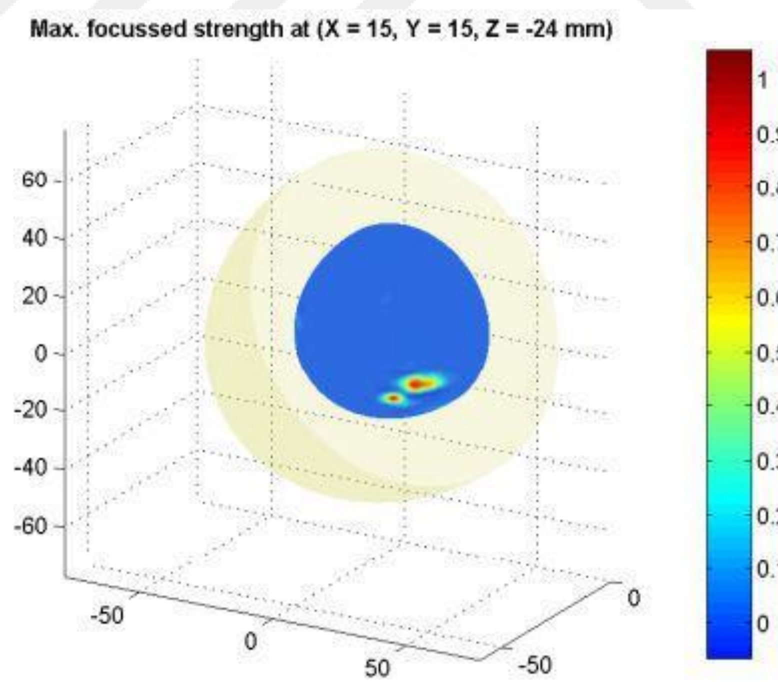

Figure 3.12: 2D Radial Slice [47]

The detection of 10mm spherical tumor phantom was made, as it is located far from the skin layer by 26 mm

3.5 UWB ANTENNAS FOR NEAR –FIELD IMAGING

This monopole antenna fed by a 50 Ω coplanar waveguide (CPW) which is able to work in lossy coupling medium. Figure 3.13 shows the geometry, which this antenna was designed on.

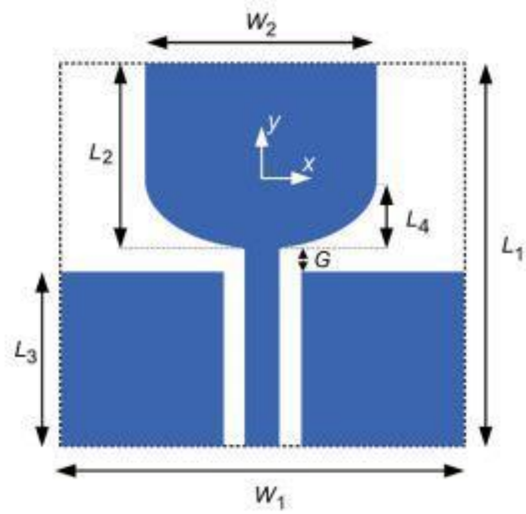

Figure 3.13: Printed Monopole Antenna Geometry [48].

the rectangular patch is the element of radiation, and the antennas is designed to have a semicircle base that gives the antenna a different resonant mode and a good impedance match of a wide range of frequencies can be achieved (Eq. (3.**1**)).

$$L_2 = 6.2 \times 10^7 / (f_L \times \sqrt{\varepsilon_r}) \quad [m] \tag{3.1}$$

The lowest operating frequency is f_L.

The antenna's length is L_2.

The relative permittivity of the medium around the antenna is ε_r.

One of the issues that comes with designing a UWB imaging system is the air-skin interface reflection. The design was done by using conformal mapping method. Using HFSS software and its optimization tools to achieve a good input matching.

Figure 3.14 shows the simulation of the antenna. Two different feed models were presented. Lumped gap source with 50 Ω and a Subminiature version A (SMA) connector.

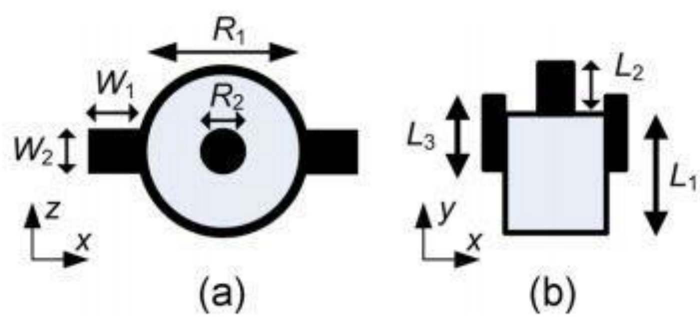

Figure 3.14: SMA connector geometry: (a) x-z plane cross section, (b) x-y plane cross section [48]

The antenna return loss for various models is simulated and measured using network analyzer as shown in Figure 3.15. The return loss was -9.6 dB.

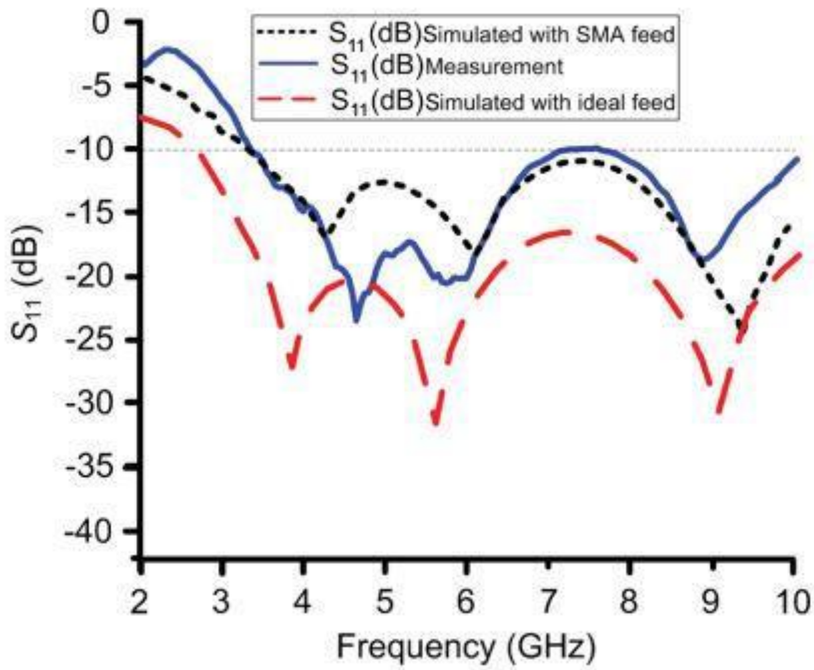

Figure 3.15: S11 For Two Different Feed Models [48]

To detect the tumor the array contains two antennas placed alongside in the x-y plane in the coupling medium a pulse generator is connected to the antenna that will work as a transmitter. While a wide bandwidth oscilloscope is connected to the antenna which will work as a receiver, the transmitter antenna has 200 ps of Gaussian pulse with 1 V, and the receiving antenna will detect the backscattered signal by utilizing the wide bandwidth oscilloscope.

A plastic cylinder, which will work as a mimicked tumor, inside that cylinder there is distilled water with 0.8 cm diameter and length of 1 cm. However, there is a variation in the depth of the tumor starting from 0 to 6 cm. the computation will take place by subtracting the backscattered signal when no tumor is placed from the recorded backscattered signal when the tumor is placed. Figure 3.16 shows the system gain, which is tumor response energy, normalized to the transmitted pulse energy.

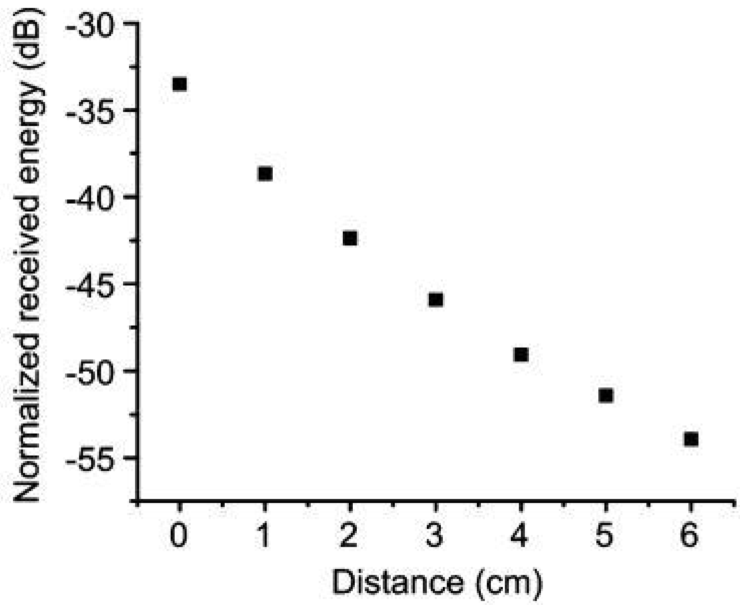

Figure 3.16: Normalized Received Measured Energy for Various Tumor Depths [48].

Furthermore, the system gains of so called the tumor response normalized energy is -33 dB while a reduction of 4 dB for every cm when increasing the tumor depth.

3.6 CONCLUSION

Seeing the applications regarding this topic and the effort of the researchers to design a wearable device which can be used to detect cancer cells shows the importance of this topic and the need behind carrying out a research to reach the ideal wearable device that can detect cancer cells inside the breast. Moreover, a lot of work needed to enhance the efficiency of the detection also more work needed to increase the bandwidth to have more accuracy of the cancer cells detection and find an approach to have the exact location of the tumor.

4. SIMULATION AND DESIGN

4.1 OVERVIEW

In this chapter we choose the software for the design, and design of a circular microstrip patch antenna and evaluate the results of the Returns loss, VSWR, Gain, Directivity, Power loss density, a breast phantom model with a tumor will be designed to be simulated for the purpose of cancer detection. The SAR analysis approach will be tested for the detection of the tumor location.

4.2 SOFTWARE SELECTION

Two software found in this field one of them is the high frequency structure simulator (HFSS) is a 3D electromagnetic simulation software for the purpose of designing and simulating antennas or any other high frequency electronic. Researchers and engineering use the HFSS to design and simulate those electronics to build various communication systems, internet of things (IoT) products, digital devices, and other high-speed RF systems.

This software can give unparalleled performance and deep insight to all the 3D electromagnetic problems, providing a complete analysis of the electronics products with accuracy and reliability challenges by its automatic adaptive meshing technique and precise solvers.

A set of solvers to tackle electromagnetic problems starting from passive components to analyses with large-scale. The automatic adaptive mesh designed withing the software is reliable and make the design process easier by focusing only on the design rather than spending time finding the best mesh.

Another software used for antenna design is the CST Studio Suite. Which is a high-performance 3D EM analysis software package for designing, analyzing, and optimizing electromagnetic (EM) components and systems.

This software gives the engineers more flexibility in order to be able to analyze multiple components in an efficient and direct way. Because it can do multiple simulations, analyzation of performance and efficiency of antennas and other electromagnetics structures can be made software also the exposure of human body to the electromagnetic fields can be analyzed, which a great technology to be used to for easy simulation.

The CST MWS is based on FIT which finite integration technique. It gives the user the choice of using frequency domain approach, and the time domain approach. Hexahedral mesh type is used to have a transient analysis of the proposed structured antenna; the user has a full control over the mesh size in CST, which make it a good competitor for the HFSS. In this work, the CST Microwave studio will be used for designing and simulating the antenna.

4.3 METHODOLOGY

4.3.1 Microstrip Antenna

The microstrip patch antenna have a simple design that can be adjusted as the designer want to achieve a desired outcome. The design has basically a thin metallic strip, which is going to be replaced over a ground plane having a material with a specific dielectric property in between. The thin metallic strip, which is also called a patch, can have many shapes such as rectangular, circular or square. Different materials are used in the design and specific dimensions assigned to have the antenna operate on a specific frequency. Usually, the length of the metal patch is $\lambda/2$. The radiation pattern of it is broad with low power and the bandwidth have a narrow frequency. Additionally, the directivity of the microstrip patch antenna is low. Figure 4.1 is a real microstrip patch antenna example, it shows main antenna components.

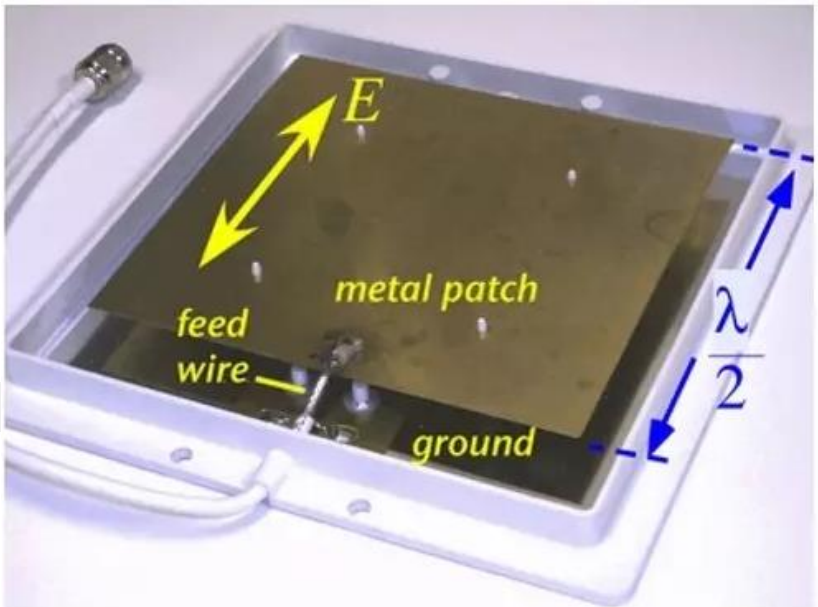

Figure 4.1: Microstrip Patch Antenna

4.3.2 Circular Patch Antenna Basic Design

At first, we started by a basic design of a microstrip patch antenna with a specific dimension to attack the size issue of an antenna which can be placed over the breast and start a detection process. Using the design formula to trace back the frequency, which those dimensions of the antenna will make the antenna operate on.

At first, a basic design of a circular micro strip patch has been designed with a substrate of 60×70, a thickness of 1.6 having a circular patch with radius of 18. A full ground plane placed on the back of the substrate which is a FR-4 having a dielectric property of Er= 4.3, the feedline used has a width of 3mm and length of 25mm the patch height is 0.1mm. The design can be seen in Figure 4.2. Those dimensions are shown in Table 4.1.

Table 4.1: Circular Design Dimensions

Symbol	Dimension(mm)	Description
SW	60	The width of the substrate
SL	70	The length of the substrate
FW	5	The width of the feedline
FL	25	The length of the feedline
PD	36	The diameter of the patch
SH	1.6	The height of the substrate
PH	0.1	The height of the patch

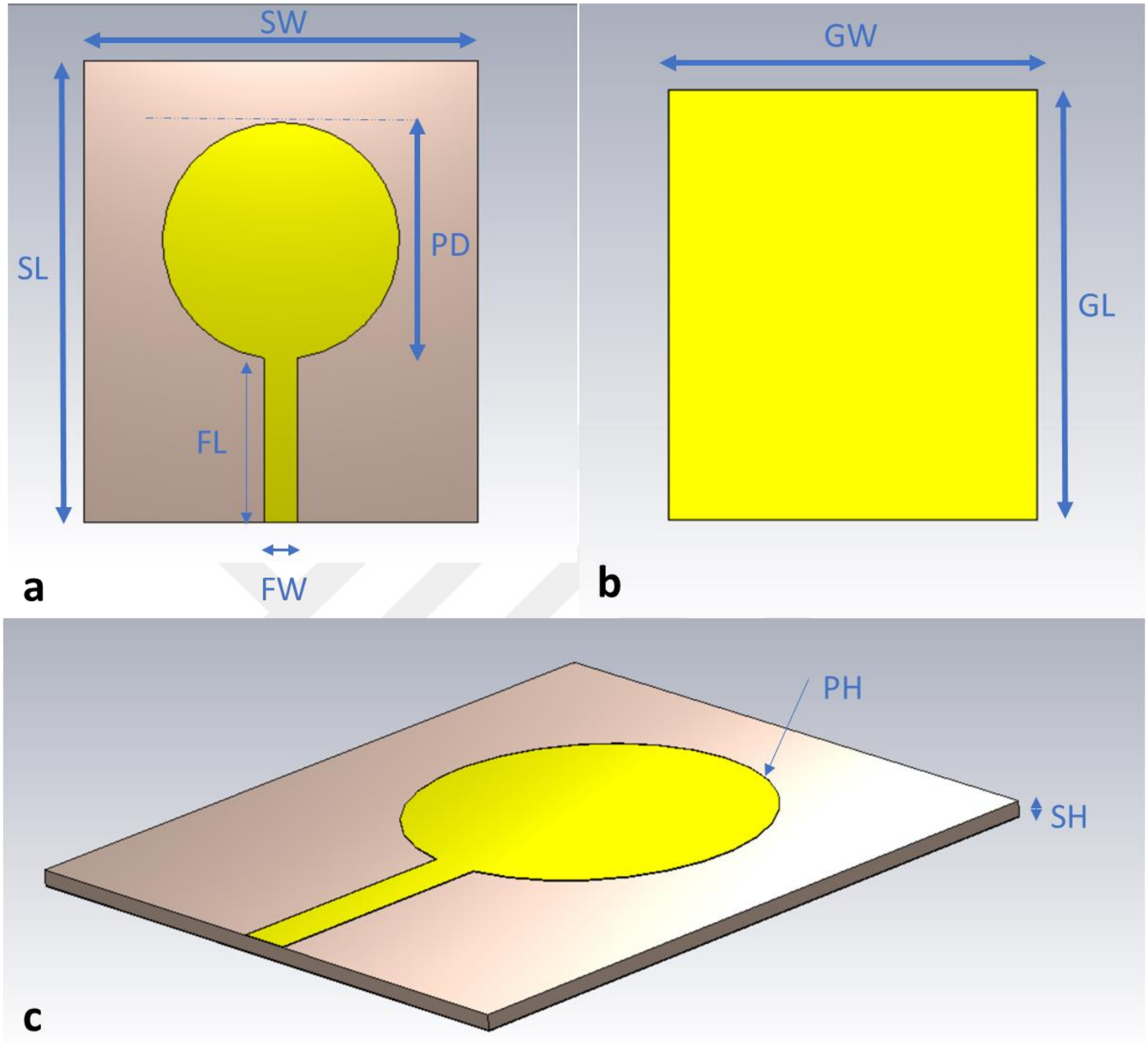

Figure 4.2: a) Top View of Circular Antenna Design, b) Bottom View of Circular Antenna Design , c) Side View of Circular Antenna Design

4.3.3 Results of the Basic Antenna Design

The basic design shows a good return loss as seen in Figure 4.4 but the VSWR is more than 2 as shown in Figure 4.5, which indicates a mismatching that will cause a major reflection of the power and high reflection efficiency. So, this problem must be solved, and better bandwidth should be obtained which make us think of approaching the design in a different way as seen in the next sections with detailed results.

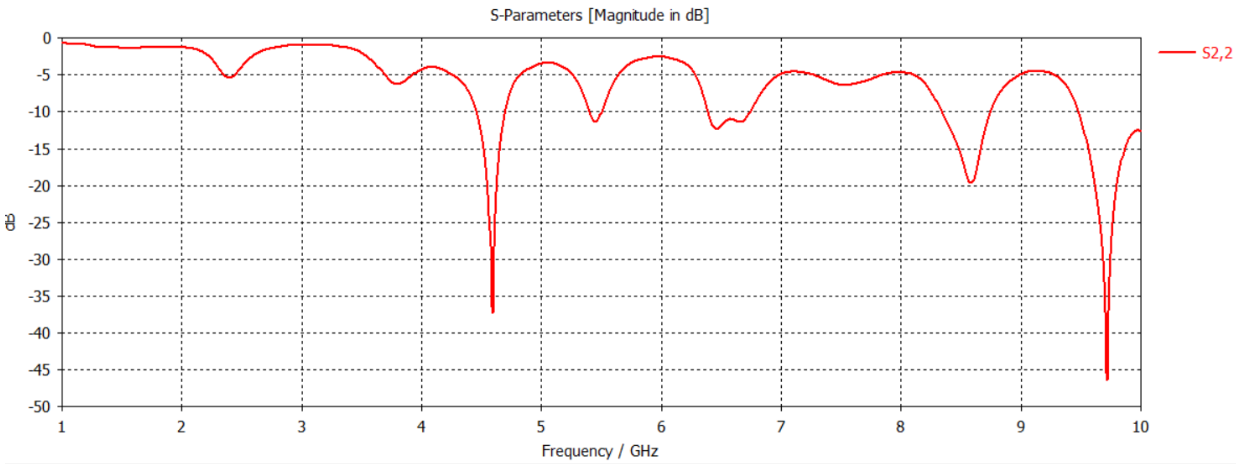

Figure 4.3: Return Loss Results of Basic Design

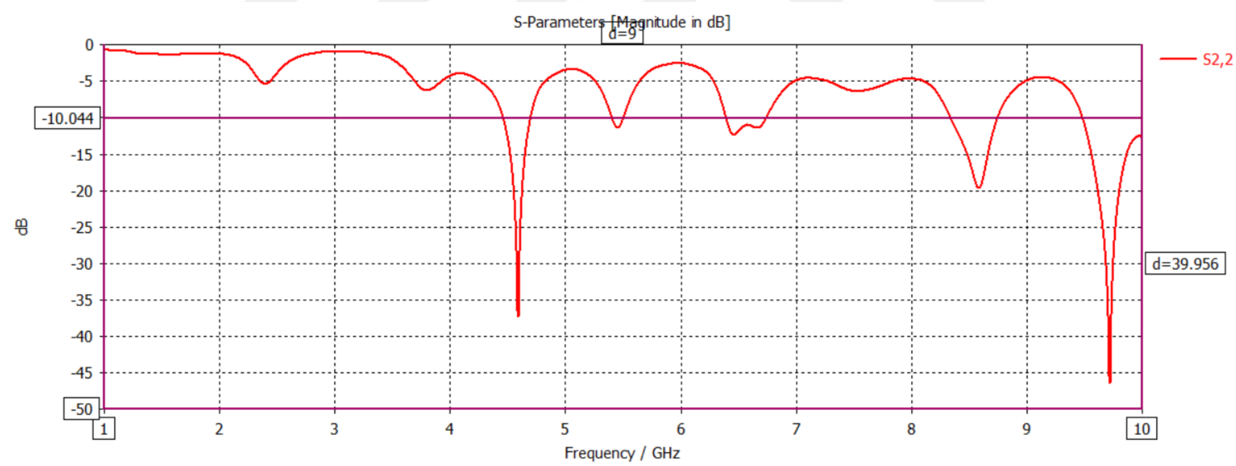

Figure 4.4: Detailed Return Loss Results of Basic Design

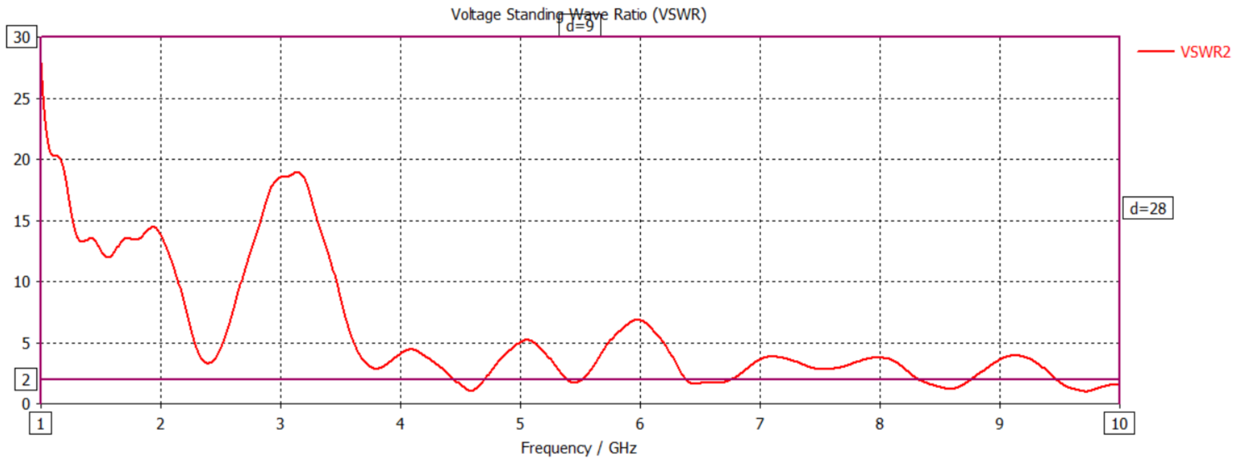

Figure 4.5: VSWR Results of Basic Design

4.3.4 Proposed Antenna Design

UWB have great properties such as low power consumption, low cost, and high data rate that will be very valuable in breast cancer detection. In order to achieve the UWB a few adjustments are needed to be done to the basic design.

First, a partial ground plane should be used to increase the capacitance between the radiating surface and ground to achieve UWB. The ground plane width is 58.5mm to it have two side slots of 2.25mm with a rectangular slot with 1mm length and 10mm width. In addition, the feedline has been adjusted to 3.1 to ensure impedance matching with 50 ohms. The substrate dimensions of the proposed design are 63×72 keeping the FR-4 as the substrate with thickness of 1.6, copper as the radiated surface with thickness of 0.1. The circular patch having the same radius of 18mm. But patch antennas have its own limitations such as small bandwidth and bad gain, in order to achieve better results different techniques is used, in out design a slot of 14mm width and 0.5 length has been made in the center of the patch which gave better performance and better outcomes for this design. The design can be seen in Figure 4.6. Table of dimensions shown in Table 4.2.

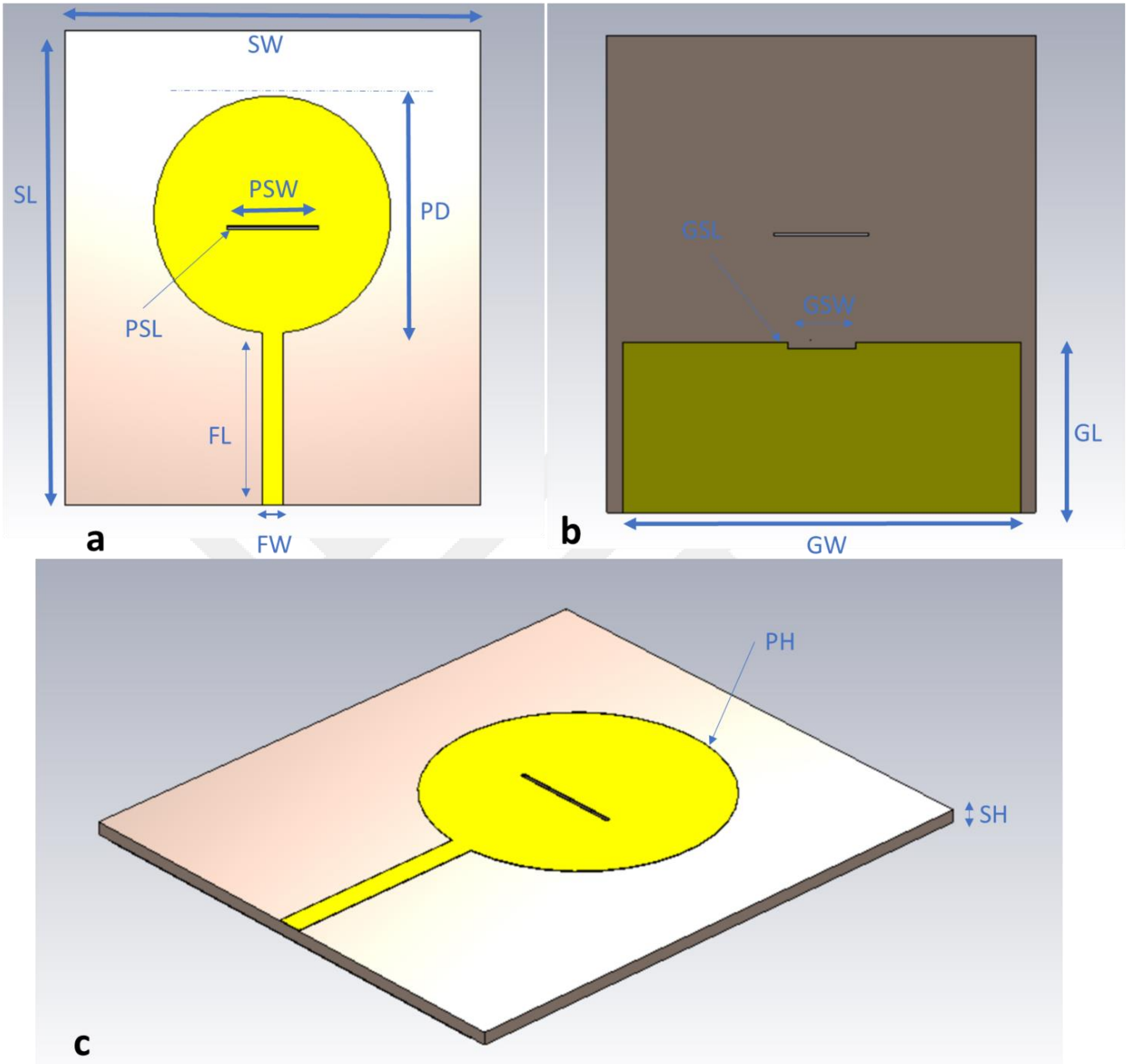

Figure 4.6: a) Top View of Proposed Antenna Design, b) Bottom View of The Proposed Antenna, c) Side View of The Proposed Antenna Design

Table 4.2: Proposed Antenna Dimensions

Symbol	Dimension (mm)	Description
SW	63	The width of the substrate
SL	72	The length of the substrate
FW	3.1	The width of the feedline
FL	26.5	The length of the feedline
PD	36	The diameter of the patch
SH	1.6	The height of the substrate
PH	0.1	The height of the patch
GW	58.5	The width of the ground
GL	25.7	The length of the ground
GSW	10	The width of the slot of the ground
GSL	1	The length of the slot of the ground
PSW	14	The width of the slot of the patch
PSL	0.5	The length of the slot of the patch

4.3.5 Results of the Proposed Design

The return loss S11 can be seen in Figure 4.8, which shows an ultra-wideband that expands from 1.6 GHz to 10 GHz under the -10 dB. The VSWR is less than 2 for the whole range of the band as shown in Figure 4.9 which is acceptable. The antenna experience a gain and directivity of 4.431 dBi and 5.197 dBi as shown in Figures 4.10 and 4.11 respectively, which give an adequate efficiency to convert the electrical energy to a radiation energy. The radiation pattern at 3.664 GHz tends to be suitable for the design purpose as shown in Figure 4.13. the surface current in Figure 4.12.

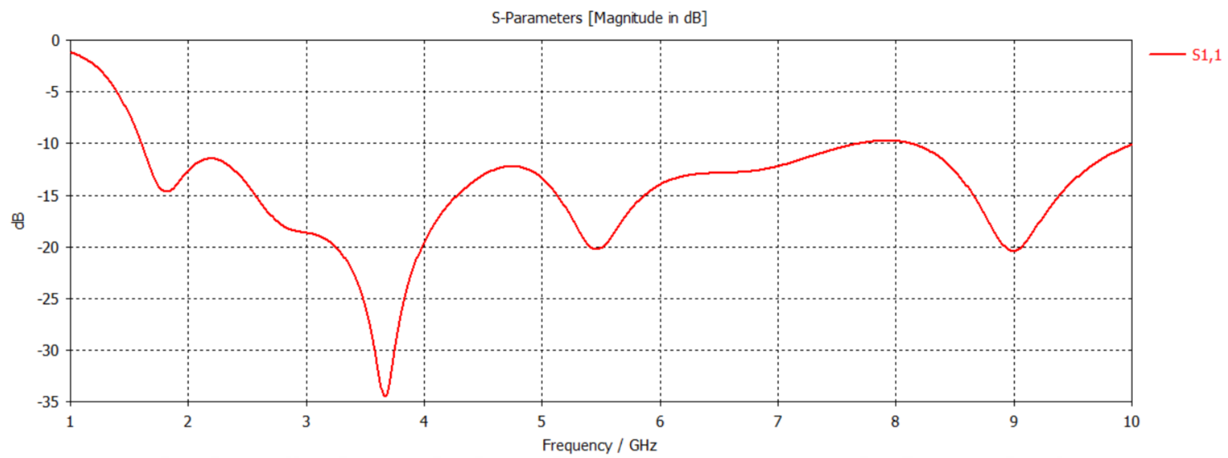

Figure 4.7: Proposed Antenna Return Loss

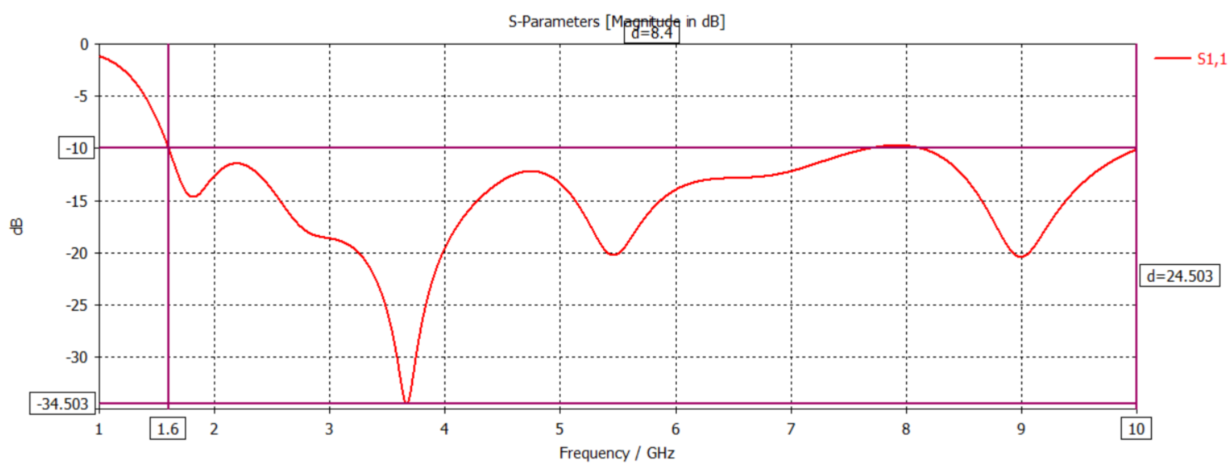

Figure 4.8: Detailed Return Loss of Proposed Antenna

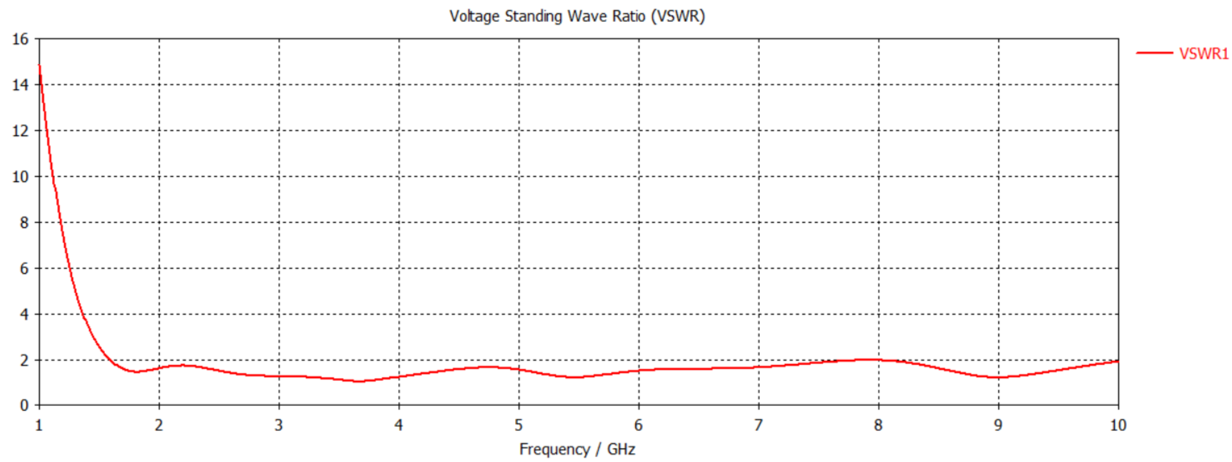

Figure 4.9: Proposed Antenna VSWR

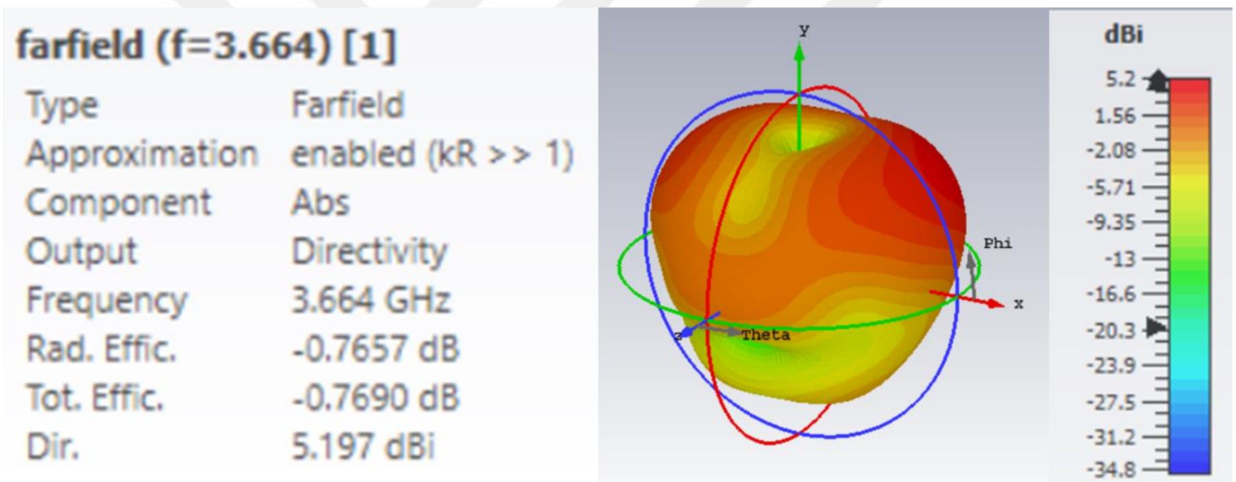

Figure 4.10: Fairfield Results

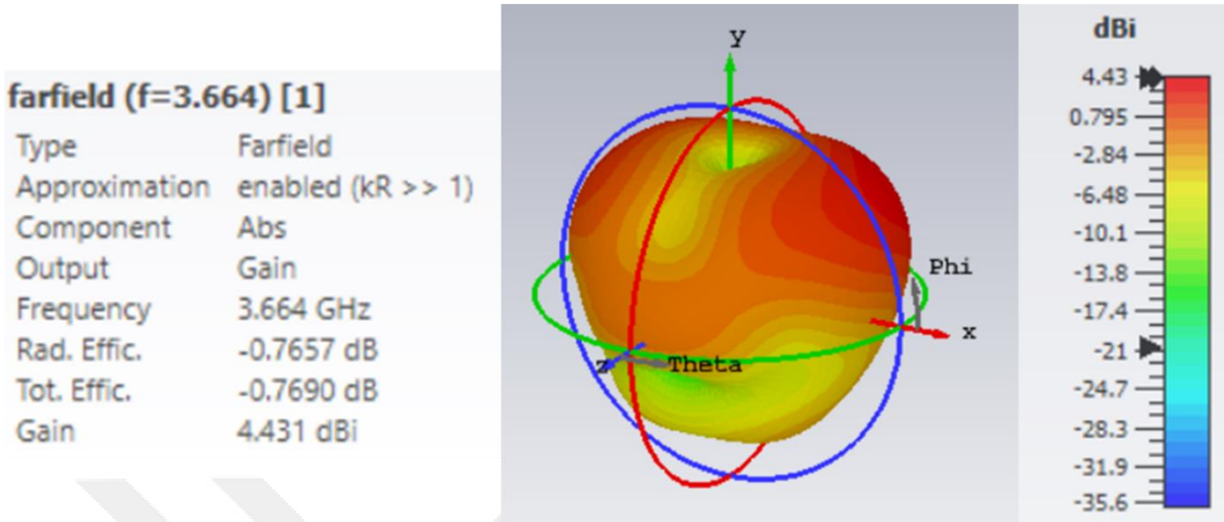

Figure 4.11: Fairfield Results (Gain)

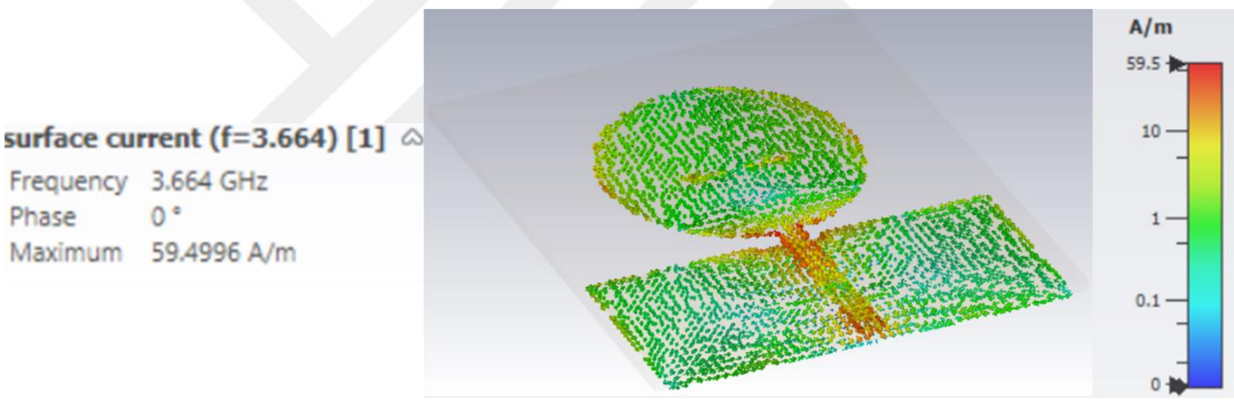

Figure 4.12: Surface Current

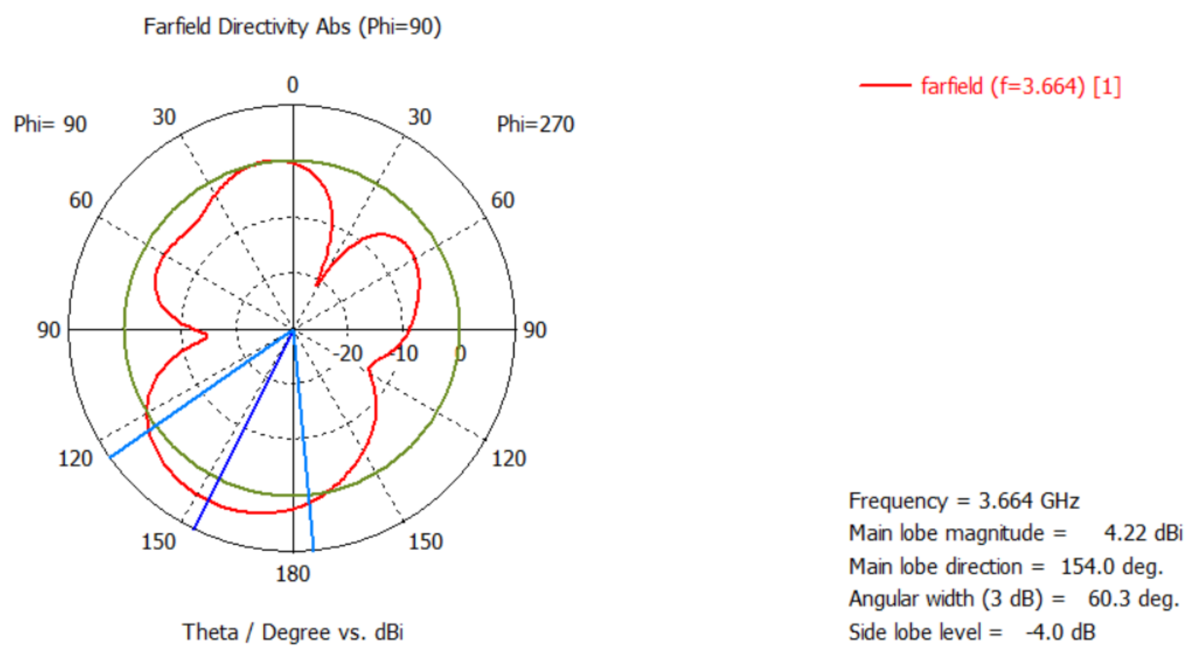

Figure 4.13: Radiation Pattern

4.4 BREAST PHANTOM MODEL

4.4.1 Breast Phantom

A breast was designed in CST to be simulated along with the antenna having (4mm) skin thickness. The breast phantom can be seen in Figure 4.14 to create the breast model proper material had to be chosen, since CST software didn't have those materials inside its libraries, so a material creation has been conducted having the parameters of permittivity, electrical conductance, density, heat capacity and thermal conductance listed in Table 4.3 for each layer. [49]

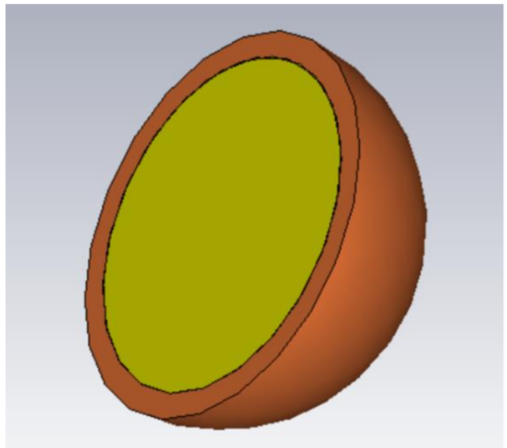

Figure 4.14: Breast Phantom Model

Table 4.3: Parameter of Breast Phantom

Tissue	Permittivity	Electrical conductance	Density	Heat capacity	Thermal conductance
Skin	36.7	2.34	1109	3391	0.37
Fat (adipose tissue)	4.84	0.262	911	2348	0.21
Tumor	54.9	4	1058	-	-

4.4.2 Breast Phantom with Tumor

A tumor is placed at a location having the coordinates of (0, 10, 40) to test our antenna. The tumor has the parameters listed in Table 4.3. Figures 4.15 and 4.16 shows the breast phantom along with the tumor.

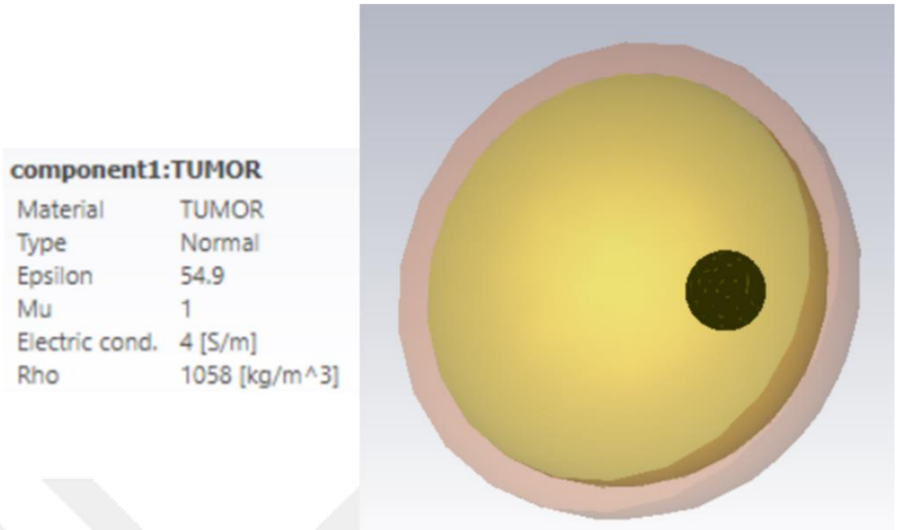

Figure 4.15: Breast Phantom with Tumor

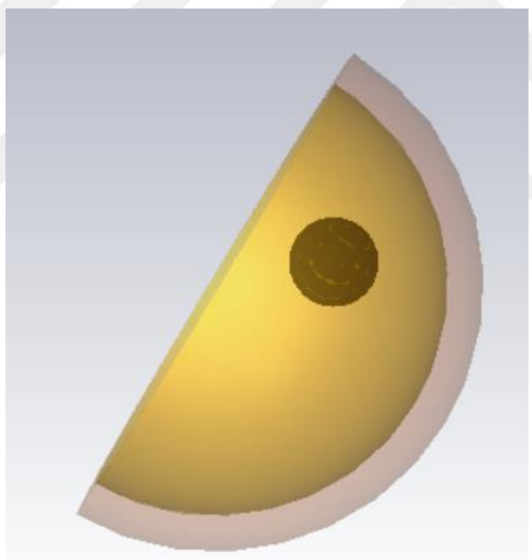

Figure 4.16: Side View of The Breast Phantom

4.5 CANCER DETECTION

4.5.1 Specific Absorption Rate

The SAR is a measurement of the absorption of the electromagnetic energy by the human tissues when it is exposed. It is defined as the power absorbed by tissues per mass, its unit of measure is

Watts for each Kilogram. The SAR value can be used for 10g mass of tissue, the values will be calculated in W/kg at each point in the tissue [50].

Calculation of the local SAR value can be made using Eq. (**4.1**).

$$SAR_{local}(r,\omega) = \frac{\sigma(r,\omega) \mid E(r,\omega)|^2}{2\rho(r)} \tag{4.1}$$

First, a cube having specific mass is found for each point, then over the cube, the power loss density will be integrated and the value in total will be divided over the mass of the cube. Calculation of the average SAR value can be made using Eq. (**4.2**)(4.**1**).

$$SAR_{average}\ (r,\omega) = \frac{1}{v}\int \frac{\sigma\ (r,\omega)|E(r,\omega)|_2}{2\rho(r)}\ dr \tag{4.2}$$

Having the σ(r,ω) material conductivity [S/m], dielectric material density at r in [Kg/m^3] as ρÏ'(r)-mass, E(r,ω) the electric field within the tissue [V/m], and the volume is V [m^3]

4.5.2 Tumor Detection with SAR Analysis

The breast phantom model is placed (20mm) away from the antenna, which will radiate towards the phantom and the response reflection will go back so the antenna could receive it as seen in Figure 4.17.

The simulation is made for 10g of mass tissue at 3.664 GHz having the tumor located at the coordinated (0, 10, 40).

The results of the simulation show a maximum SAR value of 0.69, which satisfies the SAR limitation of 1.6 W/kg, which considered dangerous to the human body, so the antenna can be used for biomedical application because the maximum SAR value is less than 1.6 W/kg. The coordinates were the maximum SAR value at is (1.085, 9.47273, 32.25) [mm] where x= 1.085, y=9.47273, and z=32.25 as shown in Table 4.4.

The tumor was located manually at (0, 10, 40) [mm], where x= 0, y=10, and z =40. When designing the breast phantom model which is considered the real tumor location. After the SAR analysis the prediction of the tumor location is at (1.085, 9.47273, 32.25) [mm], where x= 1.085, y=9.47273, and z=32.25, which is the predicted tumor location. That gives a rough idea over the tumor location compared with the actual location of the tumor so we can say that it can easily identify the tumor location. The real tumor and the predicted tumor location can be seen in Figure 4.19.

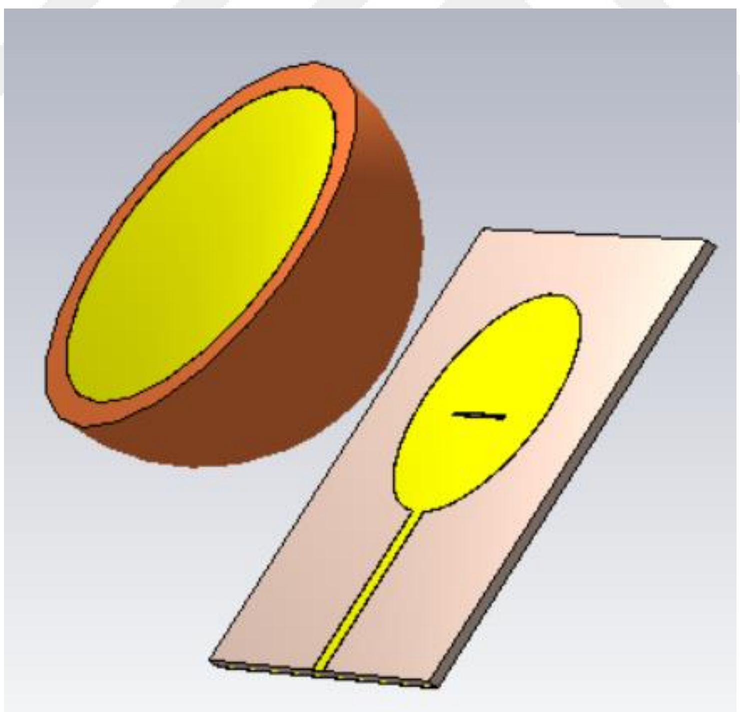

Figure 4.17: Proposed Antenna with Breast Phantom

Table 4.4: SAR Results

SAR Calculation Results	
Powerloss density monitor used	loss (f=3.664) [1] at 3.664 GHz
Power scaling [W]	None
Stimulated Power [W]	0.5
Accepted Power [W]	0.499823
Average cell mass [g]	2.53793e-05
Averaging method	IEEE/IEC 62704-1
Averaging mass [g]	10
Entire Volume	
Min (x,y,z) [mm]	-45.1269, -49.6269, -13.7269
Max (x,y,z) [mm]	45.1269, 49.6269, 63.6269
Volume [mm^3]	692939
Absorbed power [W]	0.07612
Tissue volume [mm^3]	56547.9
Tissue mass [kg]	0.0555005
Tissue power [W]	0.0187236
Average power [W/mm^3]	3.3111e-07
Total SAR [W/kg]	0.337359
Max. point SAR [W/kg]	9.67361
Maximum SAR (10g) [W/kg]	0.694738
Maximum at (x,y,z) [mm]	1.085, 9.47273, 32.25
Avg.vol.min (x,y,z) [mm]	-10.2492, -1.86151, 20.9158
Avg.vol.max (x,y,z) [mm]	12.4192, 20.807, 43.5842
Largest valid cube [mm]	22.7176
Smallest valid cube [mm]	21.9791
Avg.Vol.Accuracy [%]	0.0001
Calculation time [s]	38457

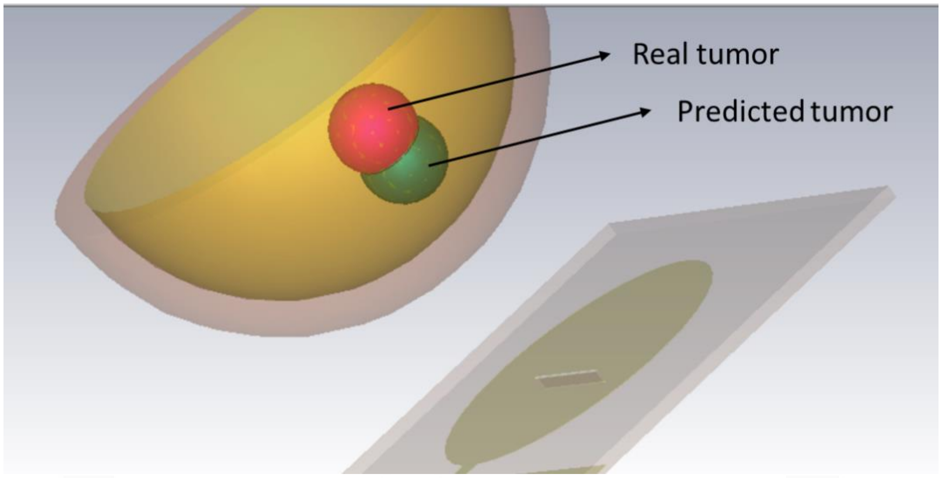

Figure 4.18: Real and Predicted Tumor

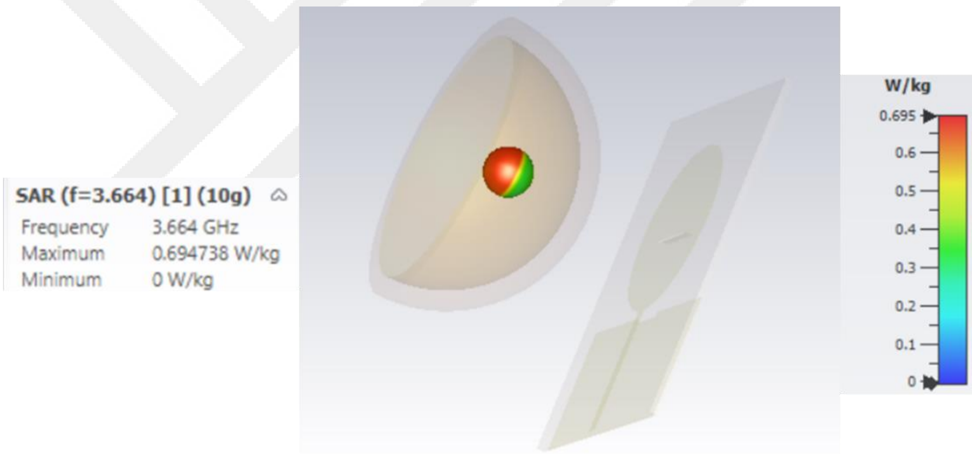

Figure 4.19: SAR at 3.664GHZ

4.6 CONCLUSION

In this chapter a design of a basic circular microstrip patch antenna has been made. Results were not suitable for the purpose of breast cancer detection, that is what arise the need of adjustments to be made over the antenna design dimensions which will have an effect over the entire results. So, a new antenna has been proposed with different parameters to be simulated along with the phantom which has been created to evaluate the return loss, gain, radiation pattern, directivity and power loss density, a tumor was placed inside the breast phantom for detection purposes. The detection is made by using the SAR analysis for locating the tumor location in the breast.

5. CONCLUSION

In this report the first step was specifying the problem and objective of the work which was the detection of breast cancer using wearable antenna with low cost and high efficiency.

The second step was doing a conceptual research that covers all of the essential information that we will needed in our work such as the work concept of the antenna itself, cancer in general, breast cancer, using antenna for cancer detection, wearable antenna and its challenges and ultra-wideband microstrip patch antenna in cancer detection.

The third step included the similar work of other researchers interested in this field and their results and a study of their approach of cancer detection using antenna.

After that our design have been proposed which is a circular microstrip patch with defected ground, a FR-4 substrate has been used with er=4.3, copper has been used as the radiated surface and the ground. A Return loss shows a bandwidth expands from 1.6 GHz to 10 GHz under -10 dB the VSWR is below 2 for the entire band which ensures a good reflection efficiency. A breast phantom with tumor has been created, the tumor location was manually assigned to be at the coordinates (0, 10, 40) for the detection SAR analysis is used. The maximum SAR value was 0.69 W/kg which is less than 1.6 W/kg which makes it suitable to be used in biomedical applications the SAR maximum is at (1.085, 9.47273, 32.25) which indicates that the SAR value is higher at the location of the tumor cells which make the cancer cells can be differentiated easily.

For the future work, more calculations can be made with SAR analysis approach using different mass of tissues, different tumor locations, different size of breast and different distance from the antenna.

A bending test could be conducted to see if the proposed antenna can work efficiently when it is bended, after that a prototype of the antenna can be printed to be tested on a similar tissue outside the human body then it could be tested on the human body.

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APPENDIX A

CURRICULUM VITAE

Paragraph.