AN INTERNSHIP REPORT

ON

SIMULATION STUDY ON BREAST CANCER DETECTION USING PHASE RETRIEVAL IN MICROWAVE IMAGING

Submitted

by

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Enrolment No. - 210583

Under the supervision of

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Candidate's Declaration

I hereby declare that the work which is being presented in the internship report entitled "**SIMULATION STUDY ON BREAST CANCER DETECTION USING PHASE RETRIEVAL IN MICROWAVE IMAGING**" is an authentic record of my own work, carried out under the guidance of **Prof. Dharmendra Singh**, Department of Electronics and Communication Engineering, Indian Institute of Technology Roorkee, Roorkee, Uttarakhand, India.

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CERTIFICATE

This is to verify that, to the best of my knowledge and belief, the candidate's statement is accurate. This is a declaration that the report, "**SIMULATION STUDY ON BREAST CANCER DETECTION USING PHASE RETRIEVAL IN MICROWAVE IMAGING**," is an accurate account of the candidate's own work, which he completed with my help and supervision.

Date:

Place: IIT Roorkee

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ABSTRACT

Breast cancer is a serious health issue that affects women everywhere, and early identification is essential for a successful course of treatment and better outcomes. Researchers and scientists have long worked to create methods that are affordable, simple to use, and quick to identify malignant tissues. Mammography is the most often used diagnostic method for finding breast cancer. However, this method has certain drawbacks, including pain, radiation exposure, and the potential for false-positive findings. As a result, scientists are looking at cutting-edge techniques for finding breast cancer, such as microwave imaging (MWI). In this work, a new MWI-based technique for early breast cancer detection is analyzed. To increase the sensitivity and precision of the MWI system, a uniplanar elliptical antenna is designed and analyzed with an operating frequency range of 1 GHz–5 GHz that provides a bandwidth of 1.46 GHz. This obtained frequency range and bandwidth provides better penetration depth and good resolution, which allow it to distinguish between normal and malignant tissue, make it suited for diagnosing breast cancer. In order to evaluate the MWI system's efficacy, a breast phantom with electrical characteristics that are equivalent to human body is designed and analyses. A rigorous testing of tumor detection using single and multiple antennas to assess the performance of the MWI system is performed. Since it is well known that comparing magnitudes does not provide us with a definitive answer, therefore, a detailed analysis of the variation in the phase retrieval in S parameters for tumors of various radii and positions. Later, comparing the outcomes with and without the tumor made it obvious that the MWI method might identify breast cancer at an early stage. Overall, our findings imply that MWI could be a useful technique for early breast cancer detection. The MWI system may be further enhanced to increase its sensitivity and accuracy for the diagnosis of breast cancer using the optimized antenna design and breast phantom. By employing phase retrieval, these findings have an important implication for enhancing breast cancer detection and therapy efficacy, which will eventually improve outcomes and survival rates of the patient.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

1.INTRODUCTION

1.1 Background

Breast cancer is a common disease in women which is very hard to detect in early stages and is hazardous in nature. Scientists over the years have tried to develop methods to detect cancerous tissues at an early stage. Advancement in technology has encouraged researchers to investigate a screening method that can identify tumors in early stages, assisting surgeons in a more thorough diagnosis [1]. There are many methods which are already in practice and are used to detect cancer cells, X-Ray Mammography being the most common one. Nowadays, scientists are trying to develop non-invasive and non-ionizing screening methods to reduce the pain, cost and time consumed by traditional methods [2].

Although X-ray technology is a well-known technique for finding breast cancer, it has been noted to have negative effects on the patient's breast tissue and overall health. Ultra-wideband radar has been effectively used by researchers in recent years to perform microwave imaging techniques for the early identification of breast tumors. This modality has the following benefits [2,8]:

Compared to the already practiced X-ray mammography, this method has the following advantages:

- Low cost
- Exposure to safe radiation
- High accuracy
- Improved patient comfort.

An ideal breast screening device

- Should pose few health hazards
- Capable of early cancer diagnosis
- Susceptible to tumor detection
- Non-invasive and simple to use

To detect small tumors, it is important to establish a consistent contrast between the dielectric properties of the tumor and normal tissues. The effectiveness of microwave imaging methods for the identification of breast tumors varies [7]. While ultrasound is widely used to differentiate between liquid cysts and solid tumors, magnetic resonance imaging is frequently used to examine embedded tumors but may be expensive as a screening method [7]. The warmth, tenderness, and electrical or optical characteristics of the tissue can all be used to detect malignant tissues. We concentrate on methods that make use of electrical property contrasts. Approaches using the microwave frequency range are now being investigated for the identification of active breast tumors.

One such techniques that makes use of the variance in dielectric strengths between cancerous and healthy breast tissue at microwave frequencies and is known as ultra-wideband radar (UWB) imaging [9]. UWB imaging algorithms typically light the breast with a pulse before measuring the backscattered signals. These signals are then processed using imaging techniques to provide a rough representation of the breast tissue being studied. This report presents the experimental results of a microwave imaging system for radar-based breast cancer detection.

1.2 Motivation

Breast cancer is the commonest malignancy among women globally. From being fourth in the list of most common cancers in India during the 1990s, it has now become the first. There can be many reasons for the exponential rise of the patients, however, it is also known that if the cancerous tissues are detected early then the probability of effective treatment becomes very high. Early diagnosis of malignant tissue is essential, and sensitivity and specificity may be used to assess how well breast cancer imaging techniques work. Sensitivity describes the proportion of patients with an illness who receive a timely diagnosis, whereas specificity shows the proportion of healthy patients who do not receive a diagnosis. The sensitivity and specificity of screening procedures must be high in order to prevent false-negative and false-positive results.

However, there are many drawbacks of the currently used imaging techniques which can have a negative lasting effect on the patients. Nowadays, there are many technologies which uses microwave imaging techniques for non-invasive and non-ionizing diagnostics of breast cancer to get around these restrictions. By contrasting the dielectric characteristics of breast tissues from malignant and healthy breasts, these methods detect the existence of tumor.

CHAPTER 2

2.LITERATURE REVIEW

Since the human body and water have comparable impedances, scientists created an array of water-immersed antenna in the early stages of developing microwave imaging in the biomedical field to allow microwaves to flow through biological materials [3]. These early discoveries have made microwave imaging for biological applications quite popular. Due to the ionizing nature of X-rays, mammography is indeed controversial in terms of its safety. It also has a high probability of missed detection and false alarms, as well as a treatment that may be unpleasant or even painful for the patient [1]. The hybrid microwave-induced acoustic imaging approach was created in the 1980s and uses ultrasonic transducers to detect pressure waves caused by the expansion of warmed tissues while microwaves are used to target-heat tumors. When high-conductivity cancerous tissues were heated instead of the nearby healthy tissues, the generated acoustic waves were recorded by ultrasonic sensors to create pictures [13]. Meaney et al. made substantial contributions to the development of breast cancer diagnosis utilizing microwave imaging, which is a new and important application [4,5].

Low frequencies (around 1 GHz) offer deep penetration and enable an approximate scan of the entire tissue volume. The size of the radiating element of the system, however, restricts the ability of system to operate at low frequencies. Higher frequencies, on the other hand, increase imaging resolution but are attenuated inside the breast [14]. In microwave tomography, receiving antennas are used to collect the scattering fields and transmitting antennas are used to illuminate the breast [15]. Then, by resolving the non-linear inverse scattering problem using a variety of reconstruction techniques proposed by various researchers, an image of the dielectric profile in the breast is produced. Prior to collecting data in the form of scatters, microwave imaging defines the permittivity distribution as a function of location [1].

An array of antennas is used in a microwave breast imaging (MBI) system to light the tissue and quantify the scattered energy in order to localize the tissue's conductivity and dielectric permittivity. MBI provides a non-ionizing diagnostic technique for identifying cancers surrounded by healthy tissues and benign tumors in comparison with X-ray mammography [11,12]. Microwave imaging determines the spatial dielectric profile of the tissue by applying the proper techniques to solve the inverse EM scattering problem. So, microwave tomography has potential as an imaging technique that provides detectable contrast between tumor and healthy tissues [10,2].

Over time, many electromagnetic techniques for locating breast cancers have been created, each with benefits and drawbacks of their own. A few of these modalities include electromagnetic impedance tomography (EIT), diffuse optical tomography (DOT), magnetic resonance imaging (MRI), ultrasound, microwave radiometry, bio-potential, and bio-magnetic methods [6]. Before using any screening techniques, it is essential to get familiar with the fundamentals of breast anatomy.

Table 1: Summary of relevant phantom and simulation microwave imaging studies for breast cancer detection

Ref.	**MWI Method**	**Frequency range**	**Antenna used**	**Findings**
[4]	Active, radar based.	1.5-3.3 GHz	Microstrip Patch	A real-time breast tumor detection system based on UWB antennas was proposed. Breast tumor cells have been found using the uniplanar elliptical antenna.
[5]	Active, radar based.	1.53-3.3 GHz	Microstrip Patch	A circular array of 6 uniplanar elliptical antennas arranged around a breast phantom was proposed. Breast tumor cells have been detected by analyzing the phase difference of phantom with or without tumor.
[11]	Active, radar based	2.8-7 GHz	Slot	On the basis of UWB antennas, a real-time breast tumor detection system was suggested. Breast tumor cells enable a significant fluctuation of the backscattered signal. The side-slotted Vivaldi has been used to discover breast tumor cells.

[12]	Active, CMI	3.1-14 GHz	Microstrip Patch	Findings indicated that the CMI algorithm is reliable for locating and detecting tumors, and that monostatic UWB radar systems with CMI may be used to detect breast cancer. When compared to other screening techniques, the procedure is less expensive and is regarded as non-invasive radiation.
[13]	Active, radar based	2-5 GHz	Vivaldi	Extremely accurate tumor detection in various locations (maximum positioning error was 10.8 mm) and practical setup for operation in actual examinations were obtained by using lower contrast in fibro glandular tissue.

CHAPTER 3

3.RESULTS AND DISCUSSION

3.1 What is Breast Cancer?

This is a form of cancer that stems from the cells of breast tissue. It is a malignant tumor which means it consists of a collection of cancer cells that rapidly travel to other regions of the body as they develop and divide. According to statistics breast cancer is more prevalent in women over the age of 65 and have a low chance of happening in a young person. Although males can also get breast cancer women are the ones who are most likely to get it.

However, the definition of breast cancer is different when seen from a microwave standpoint. According to studies, normal tissues, and malignant cells have different dielectric constants, and when the disease spreads, the dielectric constant rises even more. The goal is to identify the existence of cancer in its early stage so that prompt therapeutic care may be given. However, the breast anatomy is complex and comprises a variety of tissues, such as

- fat (adipose),
- glandular, and
- fibrous connective tissue (Cooper's ligaments).

Each type of tissue interacts with electromagnetic waves differently because of its unique electrical properties. Therefore, prior knowledge of the electrical properties of various breast tissues is crucial before beginning a diagnostic using electromagnetic techniques.

3.2 Antenna Design:

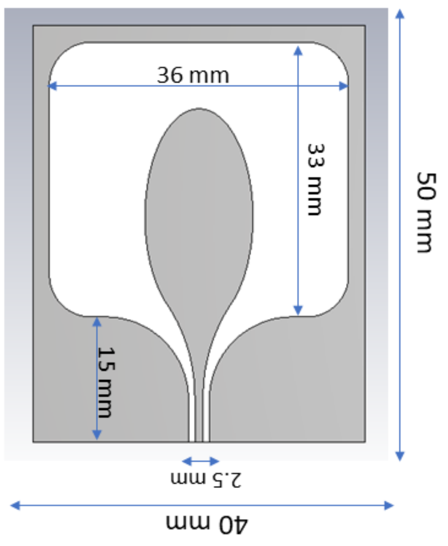

Figure 1 – Uniplanar Elliptical Antenna

A Uniplanar Elliptical Patch Antenna is a usual kind of antenna due to its small size and focused emission pattern. A Uniplanar Elliptical Patch Antenna with a 1.46 GHz bandwidth that resonates between 0 and 5 GHz has been made using CST software. The antenna consists of a ground plane printed on one side of a Rogers RO3210 (lossy) substrate with an elliptical shape with a major axis of 26 mm and a minor axis of 13 mm. The elliptical shape of the patch allows for a wide bandwidth in the antenna, and the Rogers RO3210 substrate's high permittivity and low loss properties also contribute to the improved performance of the antenna.

3.2.1 Design Parameters of Antenna:

A series of parameter assignments must be followed in order to design an antenna with the best performance. To ensure that the antenna meets the necessary requirements, it is crucial to adhere to these guidelines and carefully plan the antenna. To boost performance even more, the antenna may also be improved and adjusted. These are the requirements set forth for the developed antenna.

Table 2 - Design Parameters of the Antenna

Parameter	**Value (in mm)**	**Description**
subs_w	40	Substrate Width
subs_L	50	Substrate length
subs_h	1.27	Substrate Thickness
g	0.035	Ground Thickness
mp_w	36	Metal Plate Width
mp_L	46	Metal Plate Length
Xc	0	Ellipse Centre X
Yc	2	Ellipse Centre Y
ms1_w	2.5	Microstrip 1 Width
ms1_L	15	Microstrip 1 Length
ms2_w	1	Microstrip 2 Width
minor_rad	6.5	Elliptical Minor Radius
major_rad	13	Elliptical Major Radius
subs_w	40	Ground Width
subs_L	50	Ground Length

3.2.2 Radiation Pattern of the Antenna:

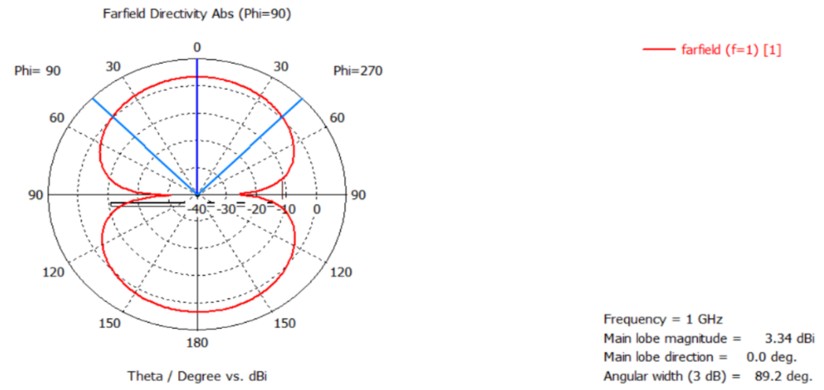

Figure 2 - Far-field at f = 1 GHz

For the above Antenna, At Frequency 1 GHz & Phi = 90 we have the following

- Main Lobe Magnitude = 3.34 dB
- Main lobe Direction = 0.0 deg.
- Angular Width (3 dB) = 89.2 deg.

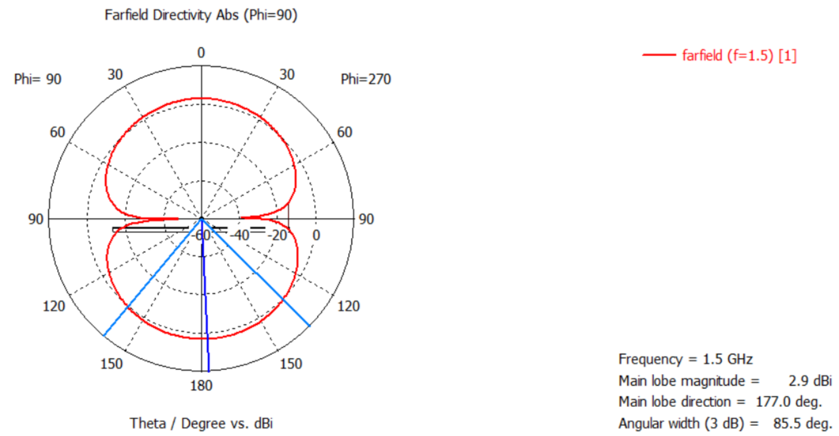

Figure 3 - Far-field at 1.5 GHz

For the above Antenna, At Frequency 1.5 GHz & Phi = 90 we have the following

- Main Lobe Magnitude = 2.9 dB
- Main lobe Direction = 177 deg.
- Angular Width (3 dB) = 85.5 deg.

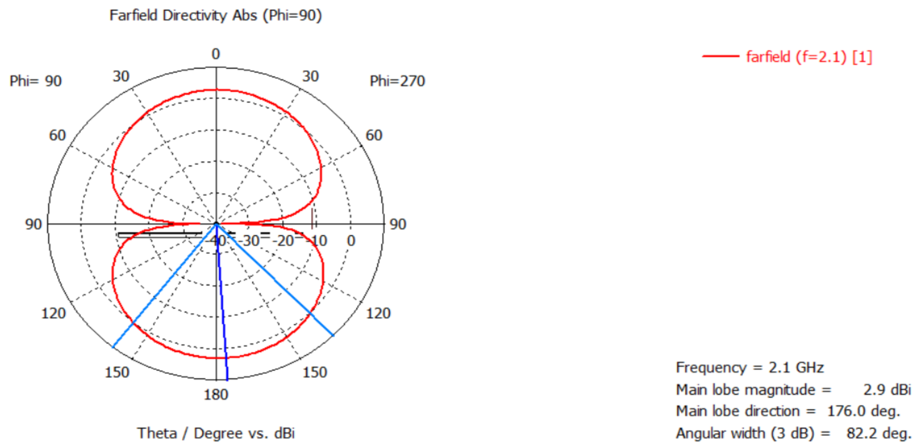

Figure 4 - Far-field at 2.1 GHz

For the above Antenna, At Frequency 2.1 GHz & Phi = 90 we have the following

- Main Lobe Magnitude = 2.9 dB
- Main lobe Direction = 176 deg.
- Angular Width (3 dB) = 82.2 deg.

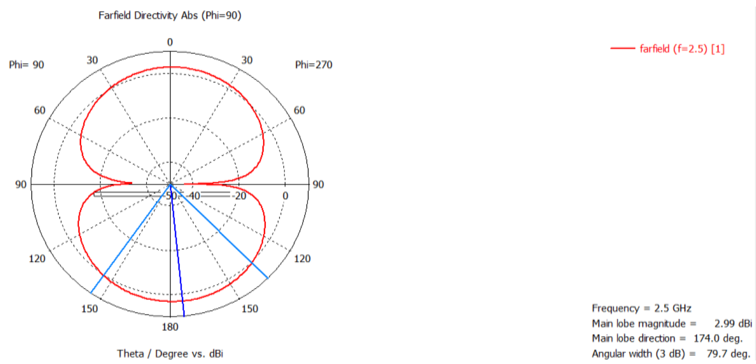

Figure 5 - Far-field at 2.5 GHz

For the above Antenna, At Frequency 2.5 GHz & Phi = 90 we have the following

- Main Lobe Magnitude = 2.99 dB
- Main lobe Direction = 174 deg.
- Angular Width (3 dB) = 79.7 deg.

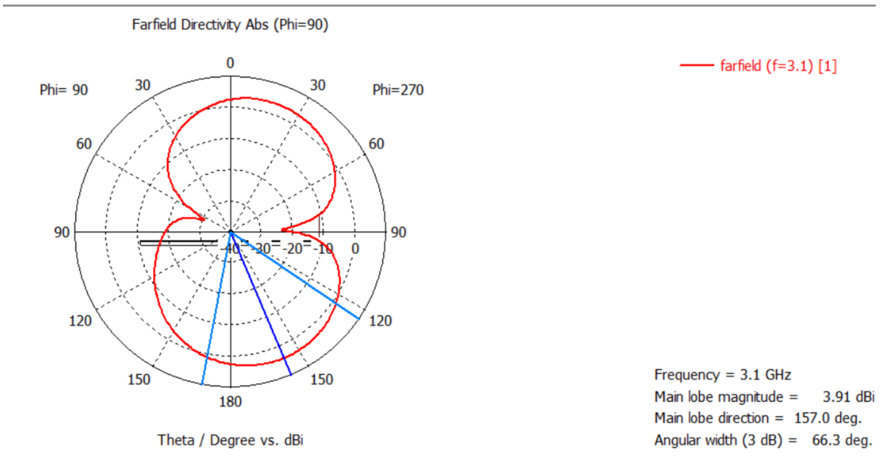

Figure 6 - Far-field at 3.1 GHz

For the above antenna, at frequency 3.1 GHz & phi = 90 we have the following

- Main lobe Magnitude = 3.91 dB
- Main lobe direction = 157 deg.
- Angular Width (3 dB) = 66.3 deg.

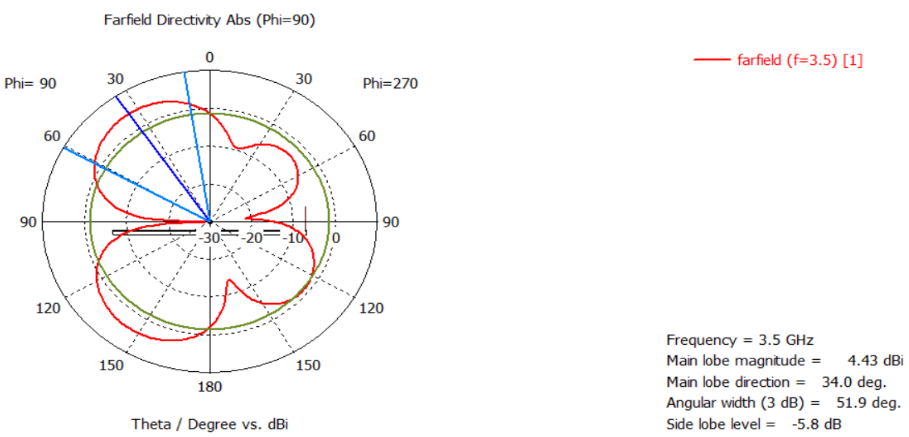

Figure 7 - Far-field at 3.5 GHz

For the above antenna, at frequency 3.5 GHz & phi = 90 we have the following

- Main lobe Magnitude = 4.43 dB
- Main lobe direction = 34 deg.
- Angular Width (3 dB) = 51.9 deg.

3.2.3 Swath Calculation:

Antenna Swath Calculation is the process of determining the coverage area of an antenna. The Swath is the width of the area covered by the antenna beam, and it is usually measured in degrees.

Swath (in degrees) = 2 * arctan ($\frac{Antenna\ Length}{2*height\ above\ ground}$)

Where:

- Antenna Length is the length of the Antenna in meters
- Height above ground is the height of the antenna above the ground in meters.

In our case, Antenna Length = 50mm & Height above ground = 5mm

Swath (in degrees) = 2 * arc tan ($\frac{50}{2*5}$) = **157.38 degrees**

Table 3 - Swath in degrees at different target distances

Target distance (d) (in mm)	**Swath in Degrees**
0.5	177.7
1	175.4
1.5	173.1
2	170.8
2.5	168.5
3	166.3
3.5	164.0
4	161.8
4.5	159.5
5	157.3
5.5	155.1
6	153.0
6.5	150.8
7	148.7
7.5	146.6

8	144.5
8.5	142.4
9	140.4
9.5	138.3
10	136.3

3.2.4 Simulated results of antenna:

The antenna's performance has been simulated, and a plot of the S11 graph has been generated.

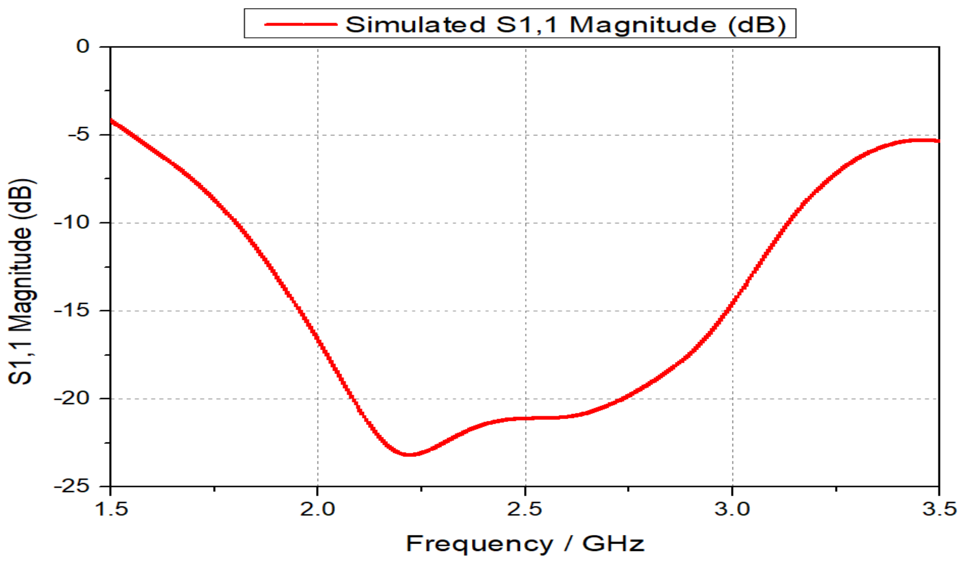

Figure 8 - Simulated S1,1 plot

The -10 dB line was observed to touch at 1.77 GHz and 3.23 GHz, indicating that the antenna's bandwidth is 1.46 GHz.

3.2.5 Antenna Gain:

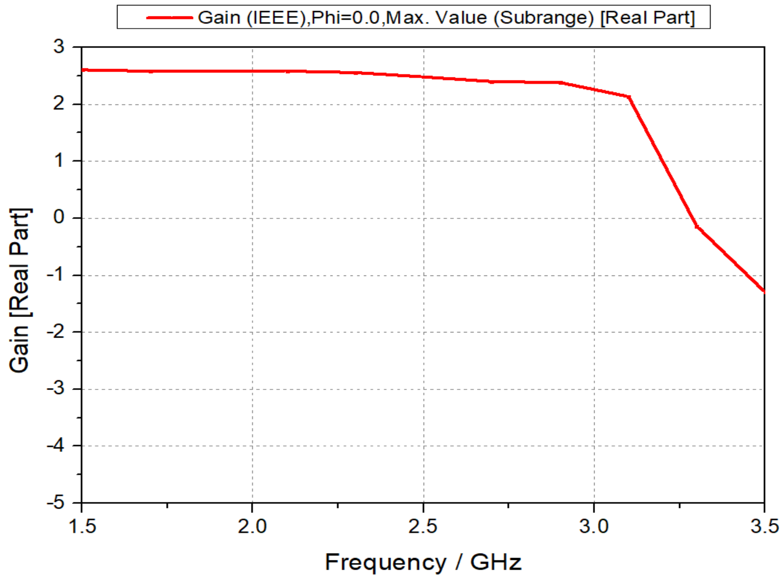

Figure 9 - Gain plot of antenna

Observation:

The antenna gives a gain of 2.6.

3.3 Phantom Design:

In CST, the Breast Phantom is simulated using a variety of layers with various dielectric properties, including fat, skin, and adipose tissue. Relevant parameters are established to allow for proper parametric analysis. In order to account for position changes, additional parameters like Tx, Ty, and Tz are inserted inside the phantom along with a tumor. For parametric analysis of the tumor inside the phantom, another parameter called tumor_rad is used.

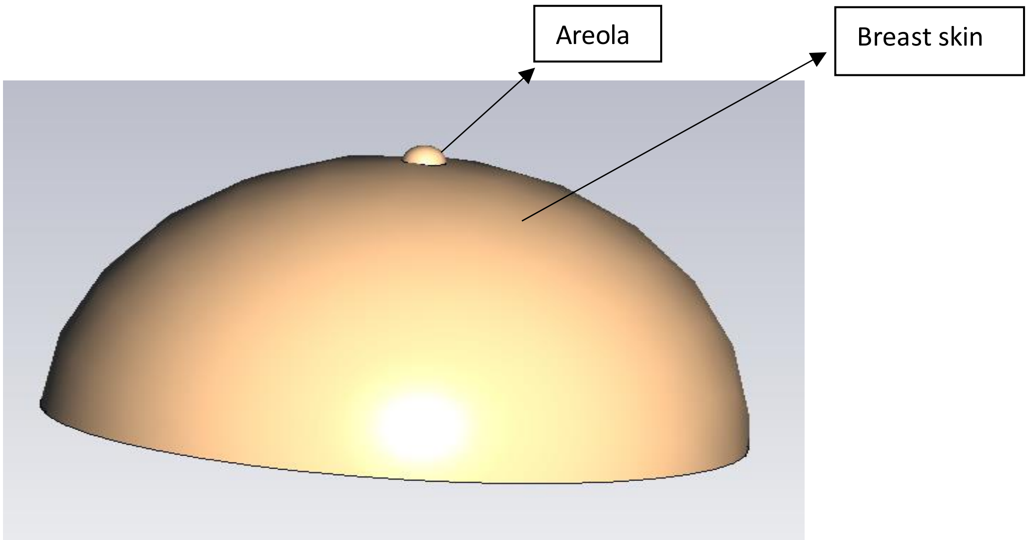

Figure 10 - Breast phantom designed in CST

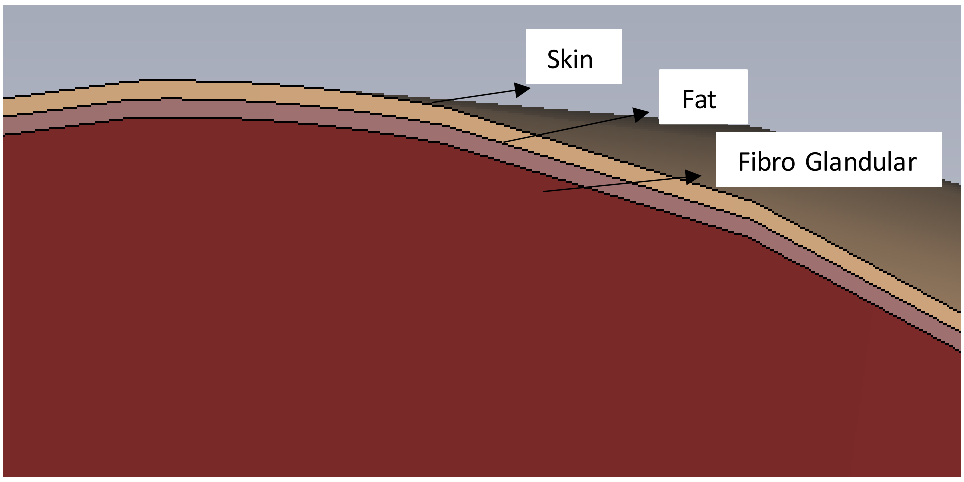

Figure 11 - Layers of breast phantom

Breast Skin   Breast Fat   Fibro Glandular

Table 4 - Design Parameters of Breast Phantom

Parameters	Value (in mm)
Breast Radius	80
Areola Distance	79.5
Areola radius	5

Tx	0
Ty	0
Tz	0
Tx1	0
Ty1	10
Tz1	10
Tumor radius	5

The parameters Tx, Ty, and Tz are used in the microwave imaging system to change the location of tumor 1. These variables represent possible translations to the coordinates of tumor 1 in the imaging program along the x, y, and z axes. By changing these parameters, the system may simulate different locations of tumor 1 with respect to the imaging device, allowing one to assess the effects of various treatment approaches.

These parameters are used in the same imaging system along with Tx1, Ty1, and Tz1 to modify the location of tumor 2. Depending on the tumor's characteristics and location, Tx, Ty, and Tz may have different values. The system is capable of replicating two tumors in distinct sites and analyze how they interact or react to various therapies by manipulating both set of characteristics.

The breast phantom shown below is an illustration of a model used to test and evaluate medical imaging and treatment systems. It can be examined or treated using a variety of tools and techniques because it is made of synthetic breast tissue that mimics the optical and mechanical characteristics of actual breast tissue. Both a single tumor and multiple tumors present in the breast phantom are represented by small spherical objects buried in the breast tissue. The phantom can replicate various clinical settings and circumstances by manipulating the size, shape, and location of the tumor.

The phantom also provides a way to investigate the effects of tumor distance, which can be changed by rearranging the locations of the tumor objects in relation to one another. This trait is useful for evaluating how well imaging or treatment systems distinguish between multiple tumors that are close to or far from one another.

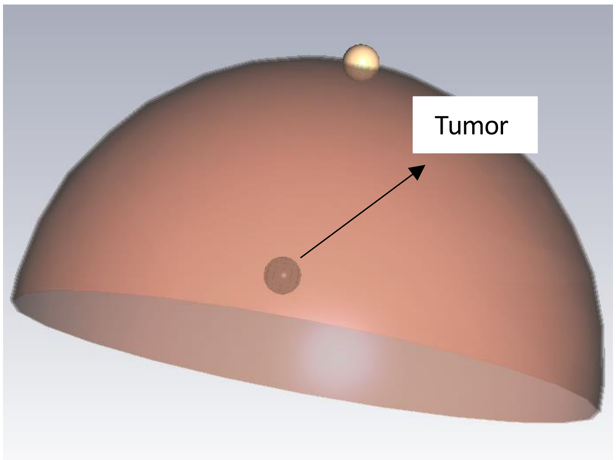

Figure 12 - Breast phantom with single tumor

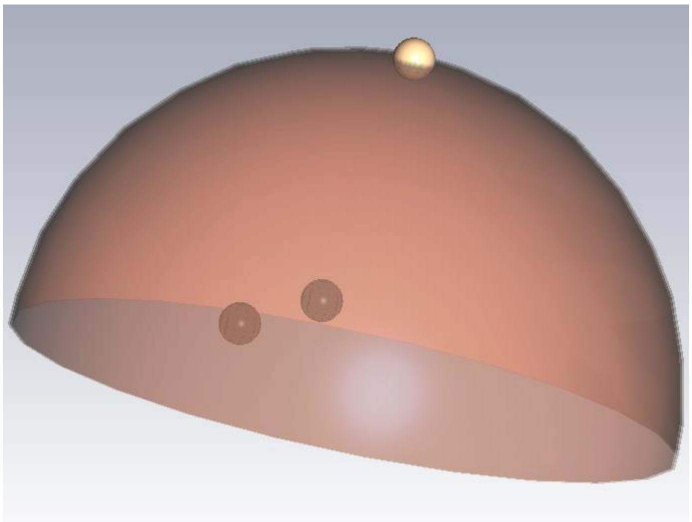

Figure 13 - Breast phantom with multiple tumor

3.3.1 Dielectric Properties of Breast:

- How a substance reacts to an electromagnetic field depends on its electrical and dielectric properties. The dielectric properties of a breast phantom are essential for simulating the behavior of real breast tissue in these applications.
- Individual variations in breast tissue's ability to conduct electricity depend on the frequency of the electromagnetic field being used, and they can have a significant effect. The two most significant dielectric properties of breast tissue are permittivity and conductivity. Permittivity, a measurement of how well the material is able to store electrical energy in an electric field, is correlated with the lipid and water content of the tissue. Conductivity, a metric of how well a substance is able to conduct electrical current, is linked to the ionic concentration and cell membrane properties of the tissue.

- By altering the structure and content of the phantom materials, such as by varying the proportions of water, fat, or other ingredients, it is possible to modify the dielectric characteristics of a breast phantom.
- Accurate modelling of dielectric characteristics of breast phantom is crucial for assuring the precision and dependability of medical imaging and treatment simulations, as well as for enhancing the detection and management of breast cancer.

Table 5 - Dielectric Properties of Breast Phantom

Tissue Type	**Relative Permittivity**	$\tan\delta$
Adipose	3.19	0.00864
Fibro Granular	16	0.3689
Skin	15.3	0.1006
Tumor	18.79	0.273

3.3.2 Simulation Study of Phantom with and without Tumor using Proposed Antenna:

A breast phantom was placed in the centre of a testing arrangement to increase the identification of breast cancer. The phantom was then tested using a variety of antenna configurations, starting with just one antenna and working our way up to many. Using CST software, the results of each test were meticulously documented, and the phantom was examined both with and without a tumor.

Analysing the information gathered from the various antenna designs will help researchers better understand the effectiveness of the various breast cancer screening methods. In the end, earlier identification and better patient outcomes will result from using this information to improve screening processes.

3.3.3 Phantom modelling: With and Without Tumor

In CST, phantom modelling with multiple levels can be simulated by allocating ports on both sides. The S31 plot can be used to visualize the structure's electromagnetic response. Comparing the S31 plot with and without a tumor is necessary to comprehend how the tumor affects the phantom's electromagnetic characteristics. With the help of this technique, tumor effects can be examined, and it helps develop diagnostic tools for identifying and monitoring tumors.

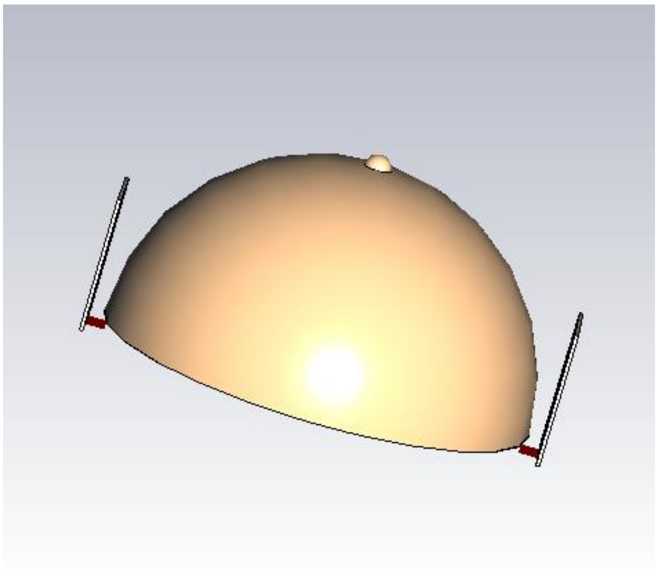

Figure 14 - Breast phantom simulation along with port (without tumor)

Between two antennas with ports is a breast phantom with layers of skin, fat, and glands. This configuration makes it possible to simulate electromagnetic interactions inside the phantom. The phantom properly depicts the dielectric characteristics of breast tissue by giving the layers and ports the necessary qualities. This modelling strategy promotes the creation of non-invasive methods for the analysis and diagnosis of breast cancer.

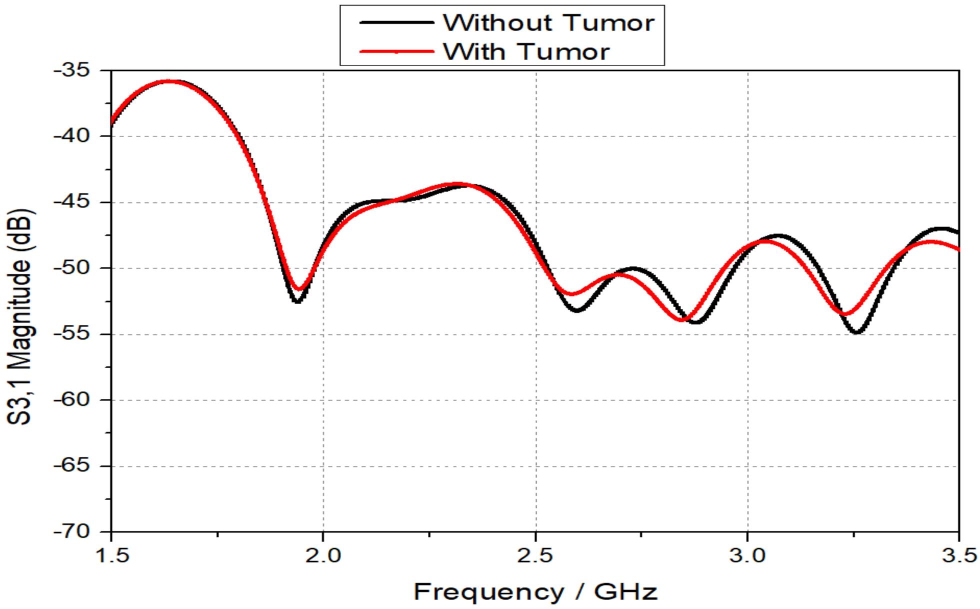

Figure 15 - Comparison between S3,1 with and without tumor

Observation:

By comparing the S3,1 magnitude parameters of the antenna array with and without tumor it can be observed that there is a significant difference in the plot and the difference gets wider at higher frequencies.

3.3.4 Phantom with Single Antenna & Tumor:

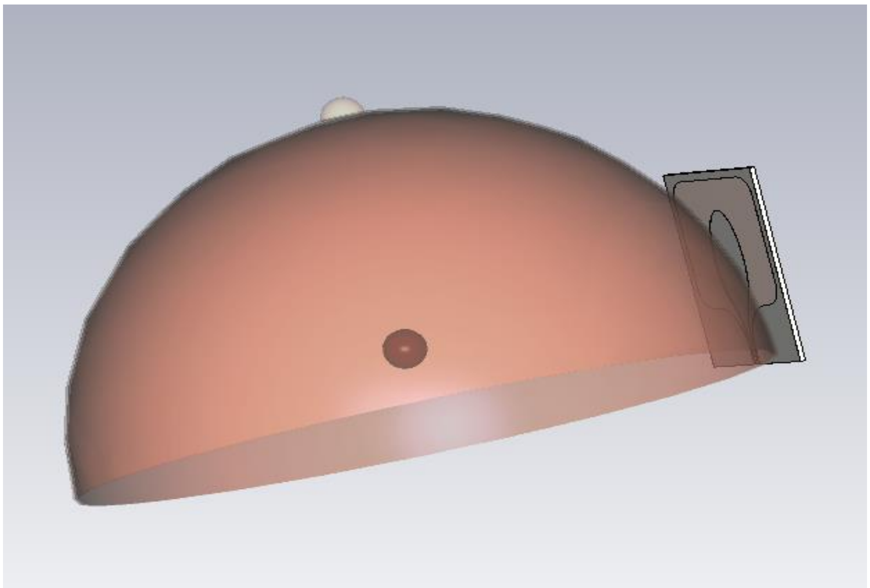

Figure 16 - Breast phantom with single antenna & tumor

3.3.5 S1,1 plot of single antenna & Tumor:

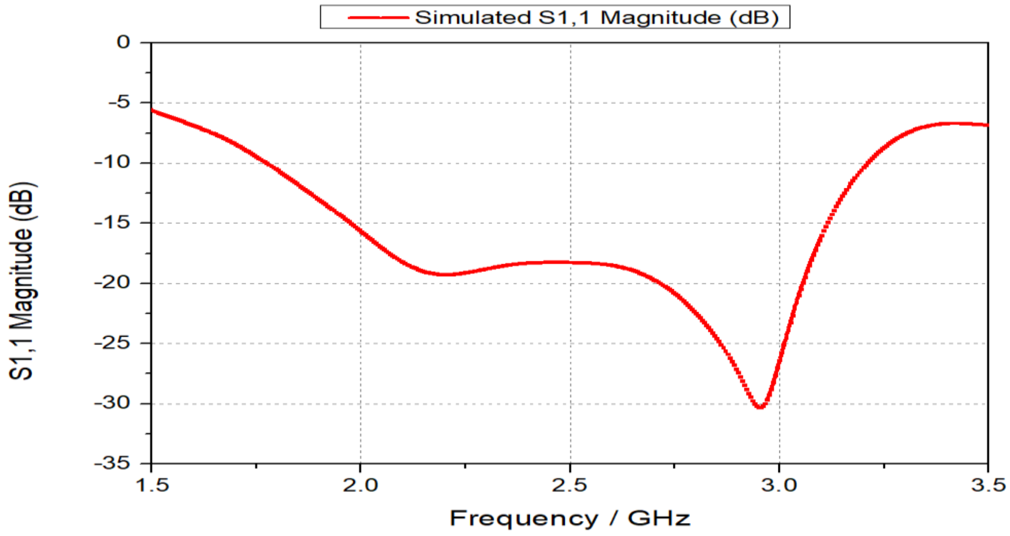

Figure 17 - S1,1 plot of single antenna & tumor

Observation:

In this S1,1 plot of single antenna and tumor it can be observed that there is a significant down slope of nearly 30dB near frequency 2.5 GHz which goes up to 2.8 GHz which mean that the antenna is radiating well.

3.3.6 Phantom with single antenna and multiple tumor:

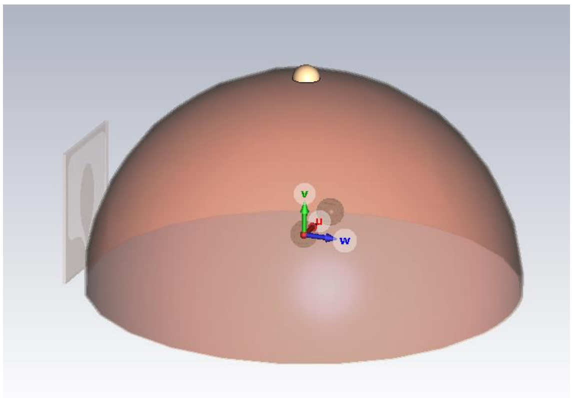

Figure 18 - Breast phantom with single antenna & multiple tumor

We can learn a lot about how electromagnetic waves behave in complex breast tissue structures by simulating a breast phantom made up of many tumors by placing a single uniplanar elliptical antenna along it in CST. An elliptical antenna can be used to focus the microwave radiation more effectively, which can lead to higher spatial resolution and more accurate tumor identification.

Several tumors in the breast phantom may be modelled in this simulation with different sizes, forms, and placements to replicate the variety in breast cancer cases. The simulated outcomes can shed light on the antenna's ability to recognize and localize multiple tumors simultaneously, which is crucial for developing a dependable and efficient method for detecting breast cancer. The simulation can also be used to investigate the effects of different antenna properties on detection accuracy, including antenna size, shape, and direction. The antenna's performance for detecting breast cancer can be enhanced by using this information to improve the design of the antenna.

3.3.7 Parametric Analysis plot of a single antenna with Tumor:

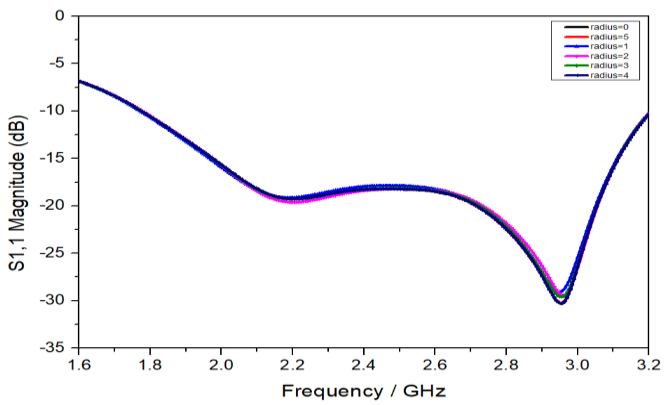

Figure 19 - S1,1 plot with size variation of tumor

Observation:

In this parametric S1,1 plot of single antenna and tumor it can be observed that there is a significant down slope of nearly 30dB near frequency 2.5 GHz which goes up to 2.9 GHz which mean that the antenna is radiating well.

3.3.8 Phantom with Single Antenna and without tumor:

The simulation produced by a single antenna without a tumor in CST (Computer Simulation Technology) can provide important details regarding the behaviour of electromagnetic waves in pathologically unaffected breast tissue. The simulation can be used to study the performance of antenna in detecting and imaging healthy breast tissue.

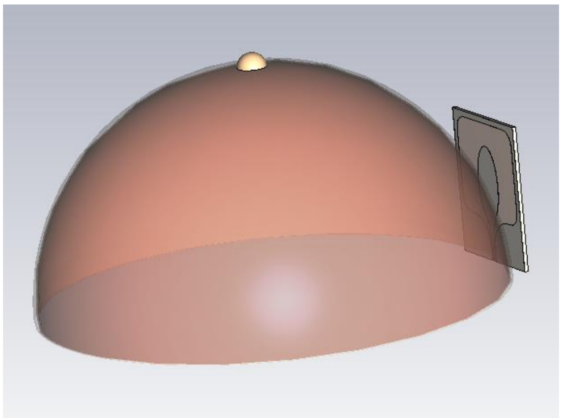

Figure 20 - Single antenna with no tumor

The simulation may also be used to examine how various antenna characteristics, such as the size, shape, and direction of antenna affect detection accuracy. This data may be utilised to enhance the design of antenna and boost its functionality for breast imaging applications.

By simulating the performance of a single antenna without a tumor in CST, we can examine the effects of various tissue qualities, such as the dielectric properties of healthy breast tissue, on the antenna's performance. By better comprehending the variables affecting breast imaging systems' accuracy, more precise and dependable systems may be developed.

3.3.9 S1,1 plot without Tumor:

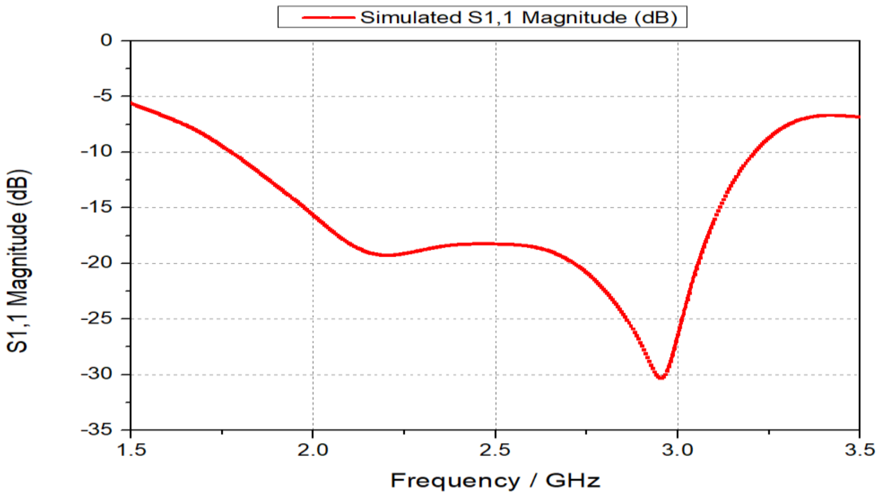

Figure 21 - S1,1 plot with no tumor

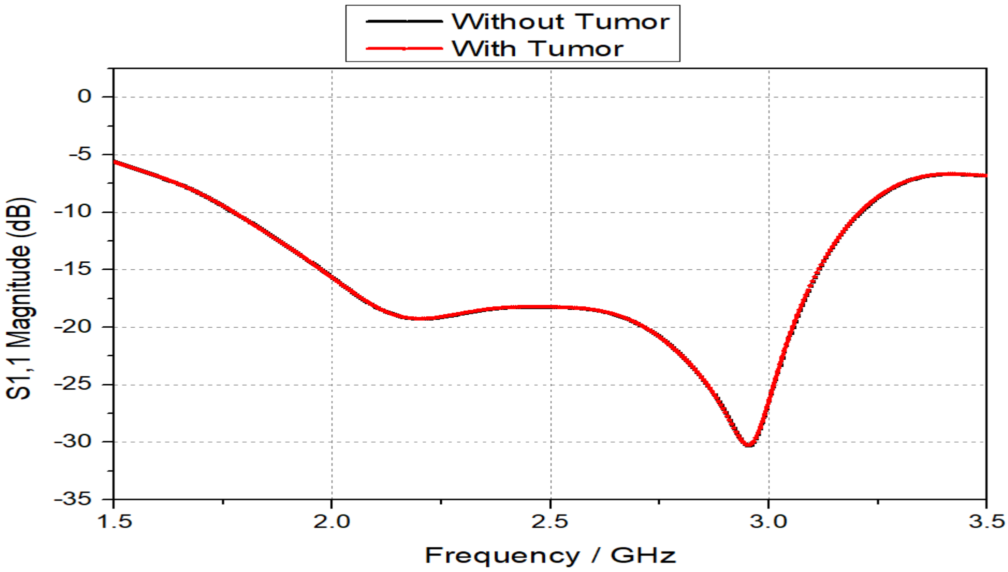

Figure 22 - S1,1 plot with and without tumor

Observation:

In this S1,1 plot the phantom with and without tumor against a single tumor have been observed and it can be seen that there is a very minute change in the plot which means that a single antenna is able to detect the tumor inside the phantom.

3.3.10 Phantom with single tumor antenna array:

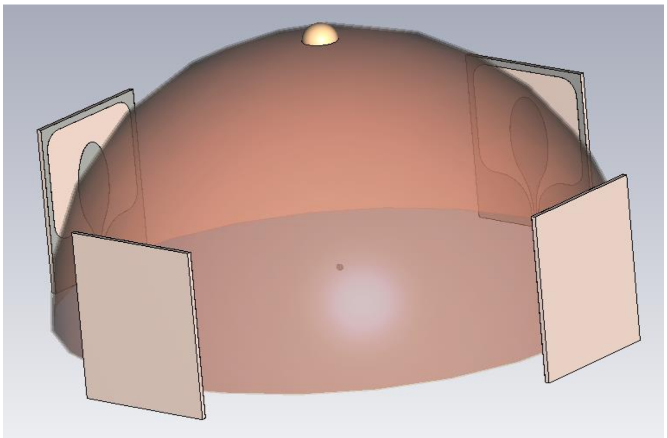

Figure 23 - Breast phantom with single tumor

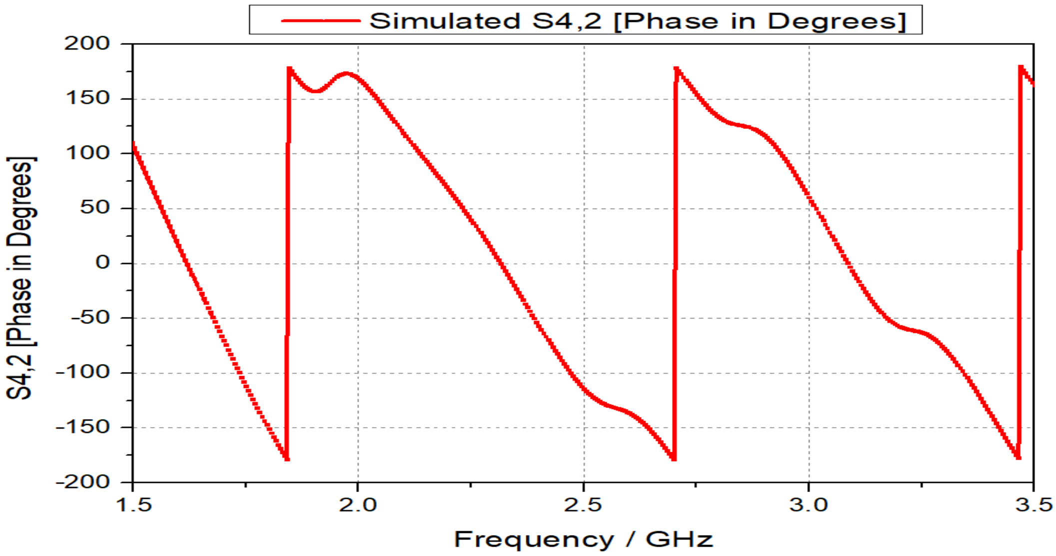

Figure 24 - S4,2 phase plot with tumor

Observation:

We have arranged 4 antennas in an array to increase the sensitivity of the system and it can be observed that the is significant change in the phase plot of S4,2 parameter and a difference of approximately 20 degrees near 1.8 GHz.

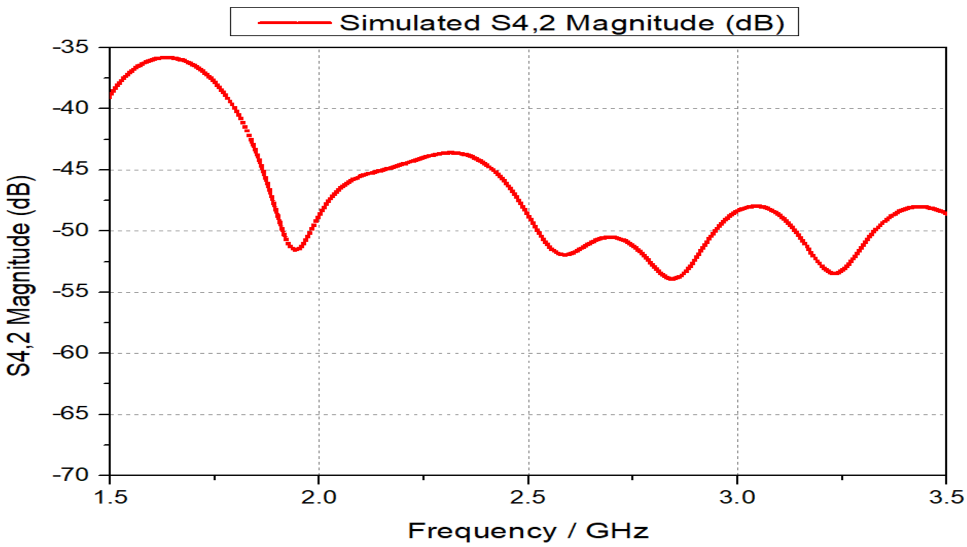

Figure 25 - S4,2 magnitude plot with tumor

Observation:

We have arranged 4 antennas in an array to increase the sensitivity of the system and it can be observed that there is significant change in the magnitude plot of S4,2 parameter when tumor is inserted.

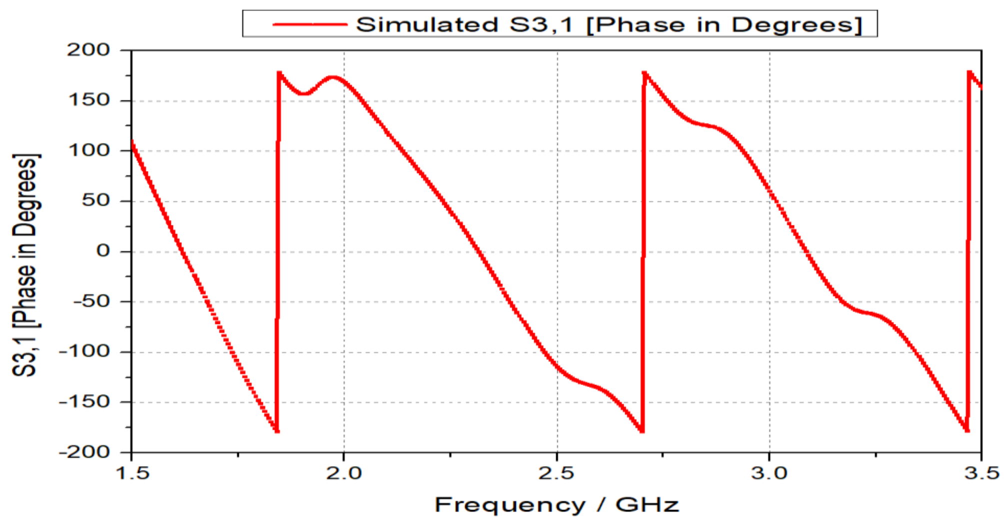

Figure 26 - S3,1 phase plot with tumor

Observation:

We have arranged 4 antennas in an array to increase the sensitivity of the system and it can be observed that the is significant change in the phase plot of S3,1 parameter and a difference of approximately 20 degrees near 1.8 GHz.

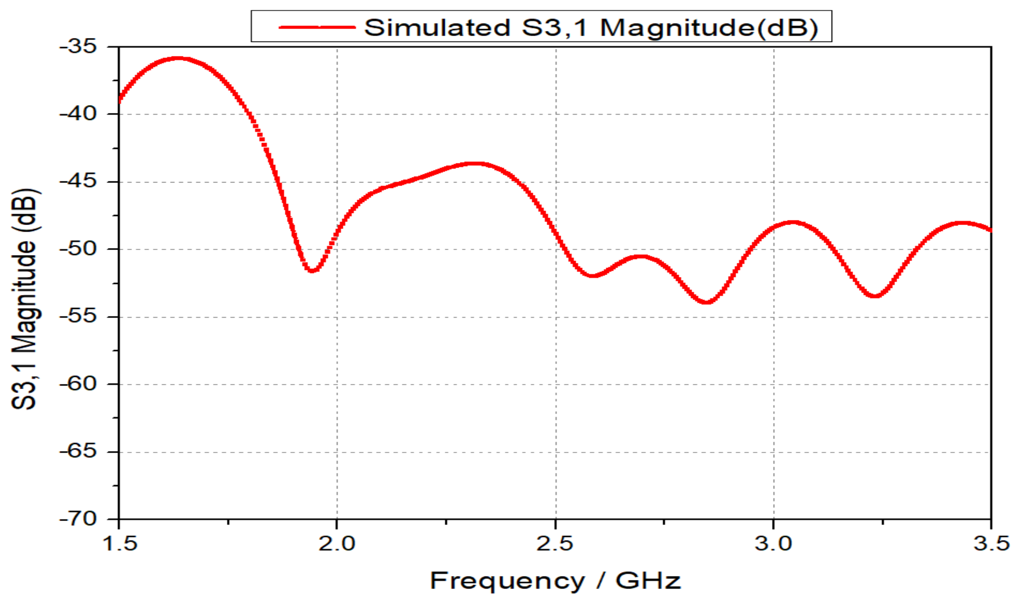

Figure 27 - S3,1 magnitude plot with tumor

Observation:

We have arranged 4 antennas in an array to increase the sensitivity of the system and it can be observed that the is significant change in the magnitude plot of S3,1 parameter when tumor is inserted.

3.3.11 Plot comparison of S3,1 and S4,2 parameters of antenna array with tumor:

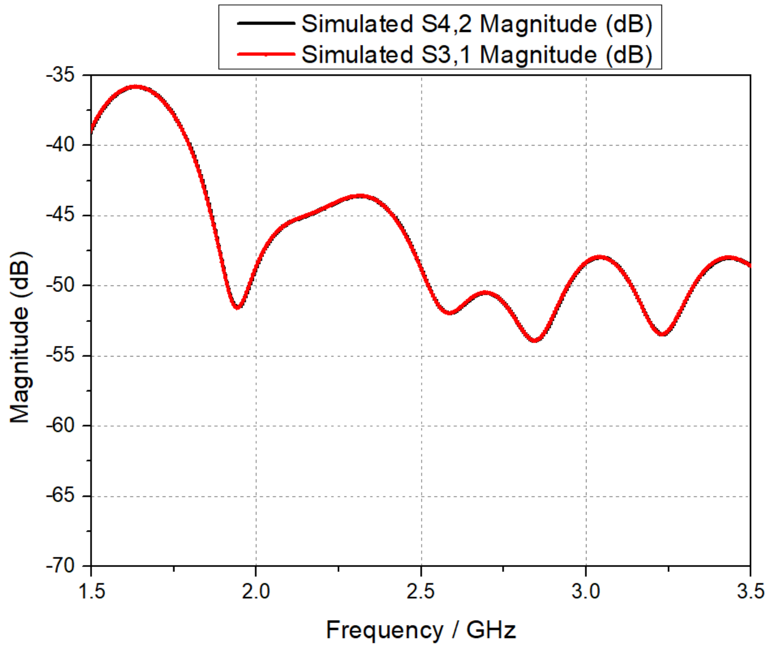

Figure 28 - Magnitude comparison between S3,1 and S4,2

Observation:

In this magnitude plot comparison of S3,1 and S4,2 parameters of antenna array with tumor there is less to no significant difference in the plot which means that radiation pattern of all the antenna involved are approximately same.

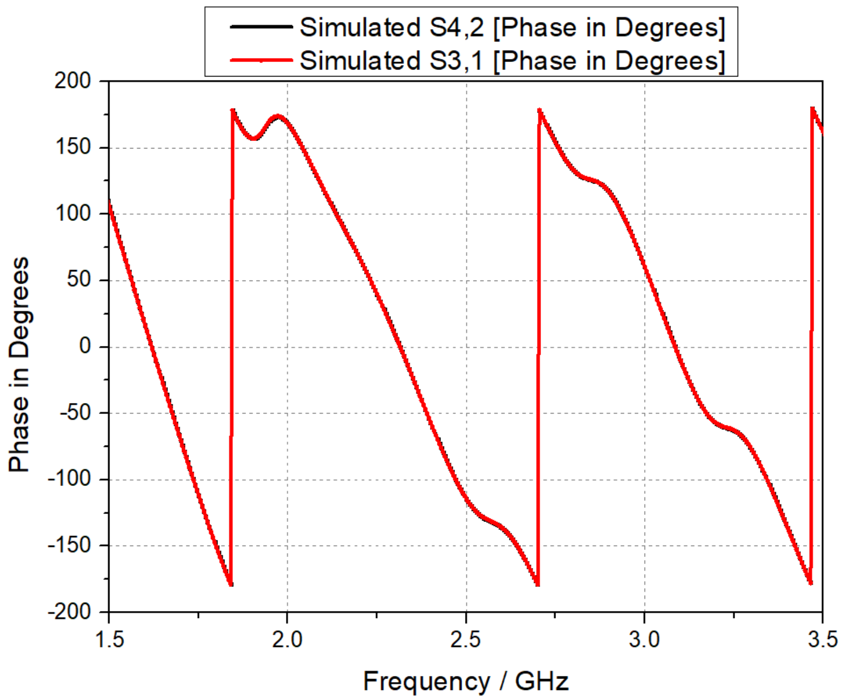

Figure 29 - Phase comparison between S3,1 and S4,2

Observation:

In this phase plot comparison of S3,1 and S4,2 parameters of antenna array with tumor there is less to no significant difference in the plot which means that radiation pattern of all the antenna involved are approximately same.

3.3.12 Phantom with antenna array without tumor:

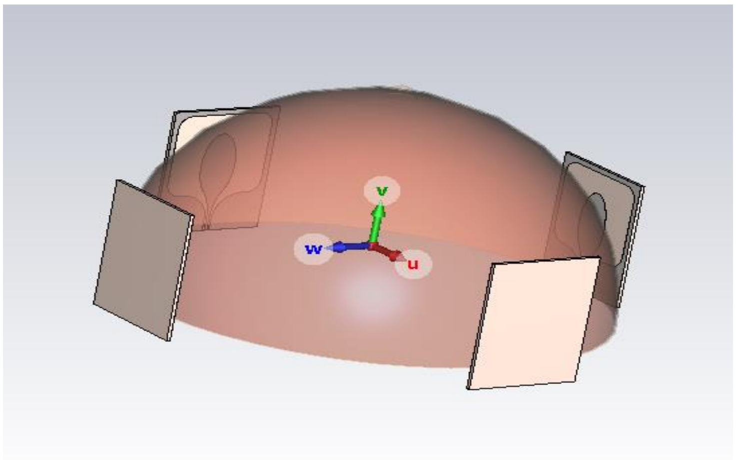

Figure 30 - Breast phantom without tumor

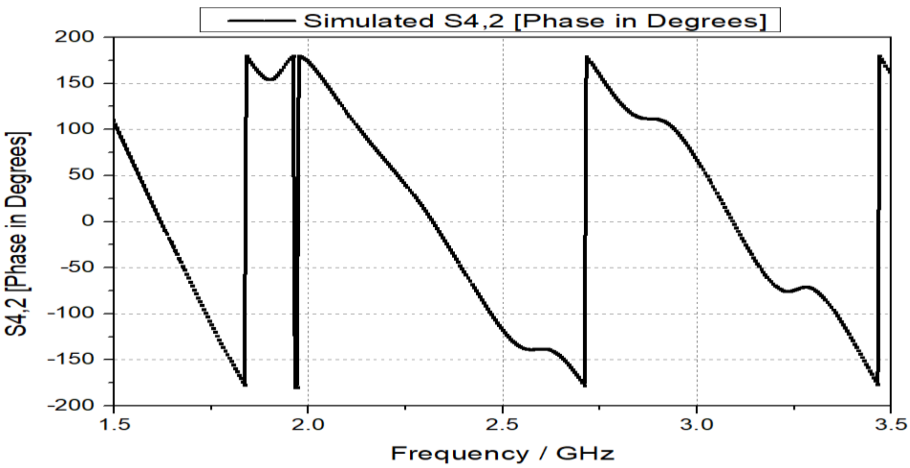

Figure 31 - S4,2 phase plot without tumor

Observation:

We have arranged 4 antennas in an array to increase the sensitivity of the system and it can be observed that the is significant change in the phase plot of S4,2 parameter and a difference of approximately 20 degrees near 1.8 GHz.

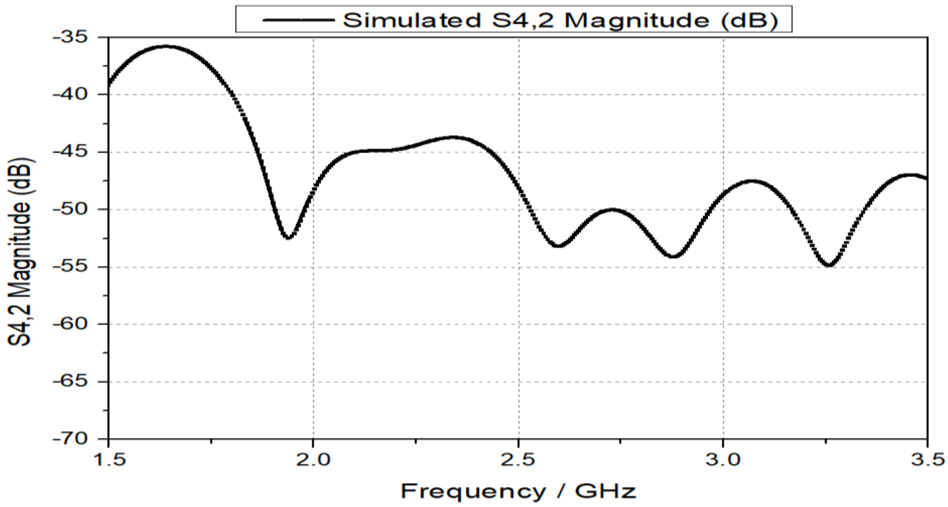

Figure 32 - S4,2 magnitude plot without tumor

Observation:

We have arranged 4 antennas in an array to increase the sensitivity of the system and it can be observed that the is significant change in the magnitude plot of S4,2 parameter.

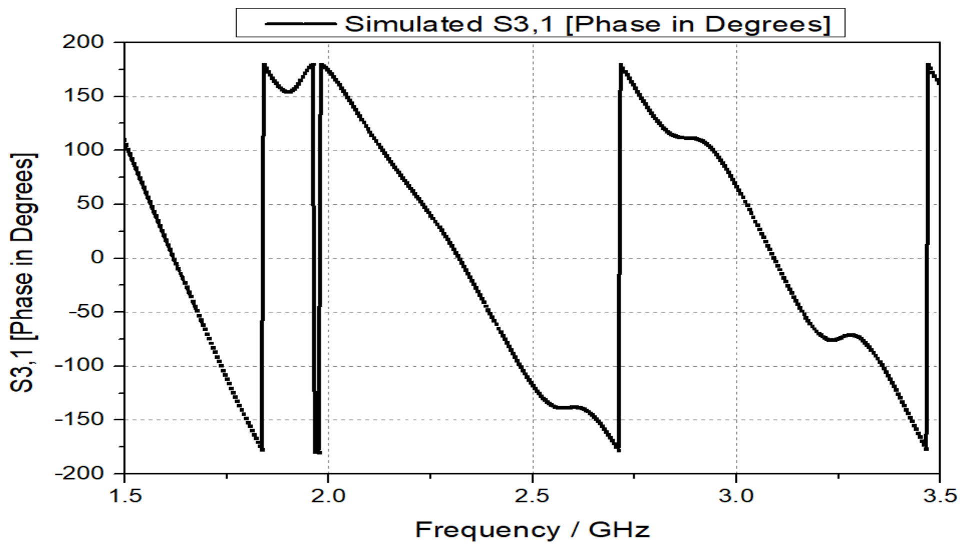

Figure 33 - S3,1 phase plot without tumor

Observation:

We have arranged 4 antennas in an array to increase the sensitivity of the system and it can be observed that the is significant change in the phase plot of S3,1 parameter and a difference of approximately 20 degrees near 1.8 GHz.

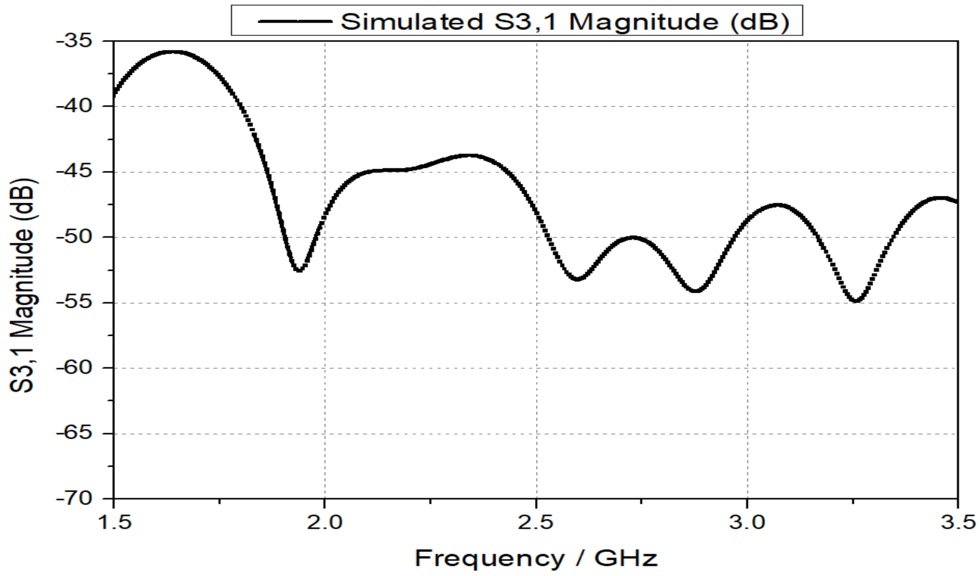

Figure 34 - S3,1 magnitude plot without tumor

3.3.13 Plot comparison of S3,1 and S4,2 parameters of antenna array without tumor:

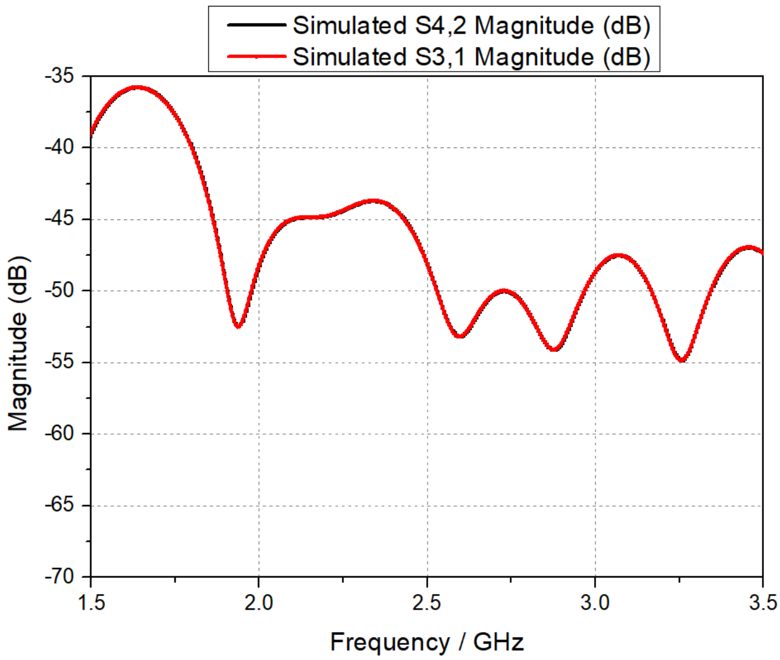

Figure 35 - Magnitude comparison between S3,1 and S4,2

Observation:

In this magnitude plot comparison of S3,1 and S4,2 parameters of antenna array without tumor there is less to no significant difference in the plot which means that radiation pattern of all the antenna involved are approximately same.

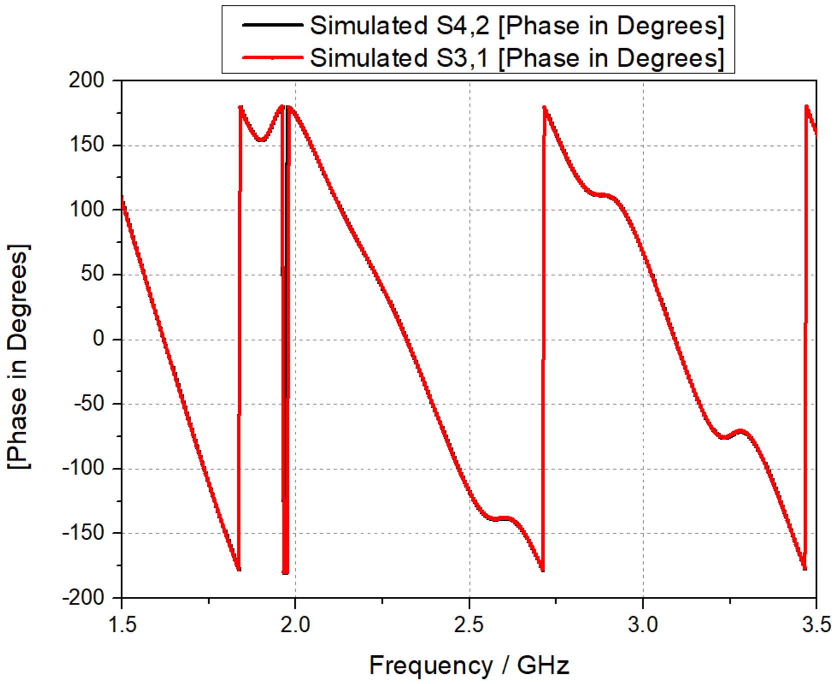

Figure 36 - Phase comparison between S3,1 and S4,2

Observation:

In this phase plot comparison of S3,1 and S4,2 parameters of antenna array with tumor there is less to no significant difference in the plot which means that radiation pattern of all the antenna involved are approximately same.

3.3.14 Phantom with multiple tumor antenna array:

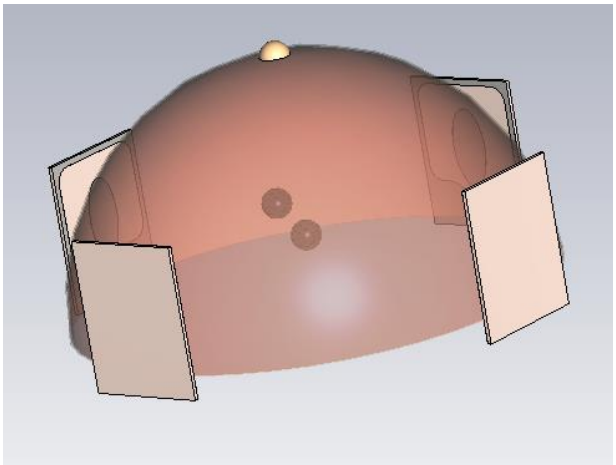

Figure 37 - Breast phantom with multiple tumors

3.3.15 Magnitude plot of antenna array with and without tumor:

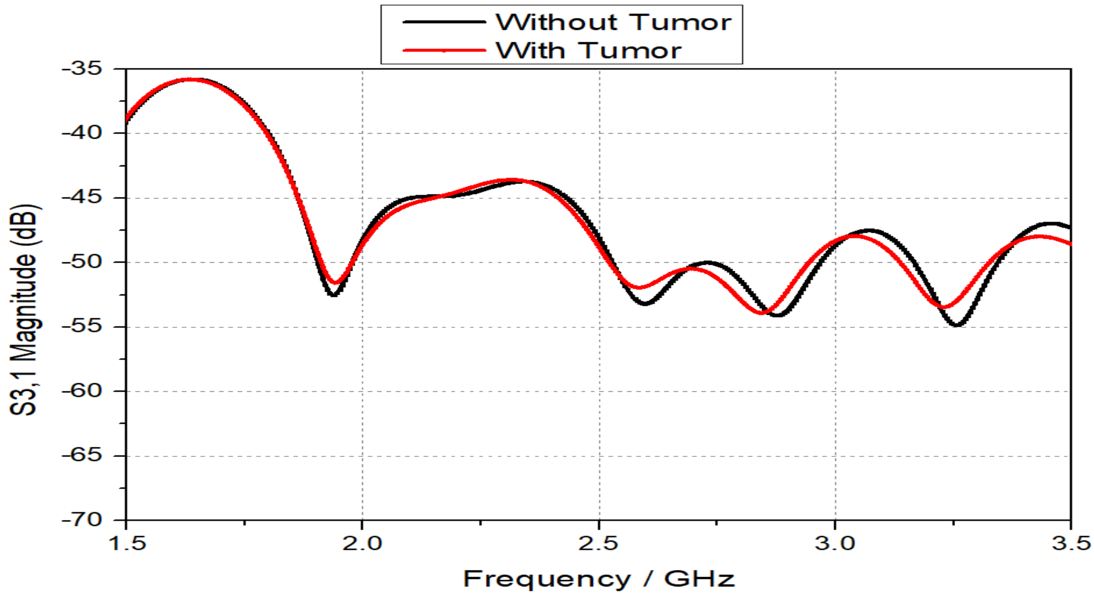

Figure 38 - Compared S3,1 magnitude of antenna array with and without tumor

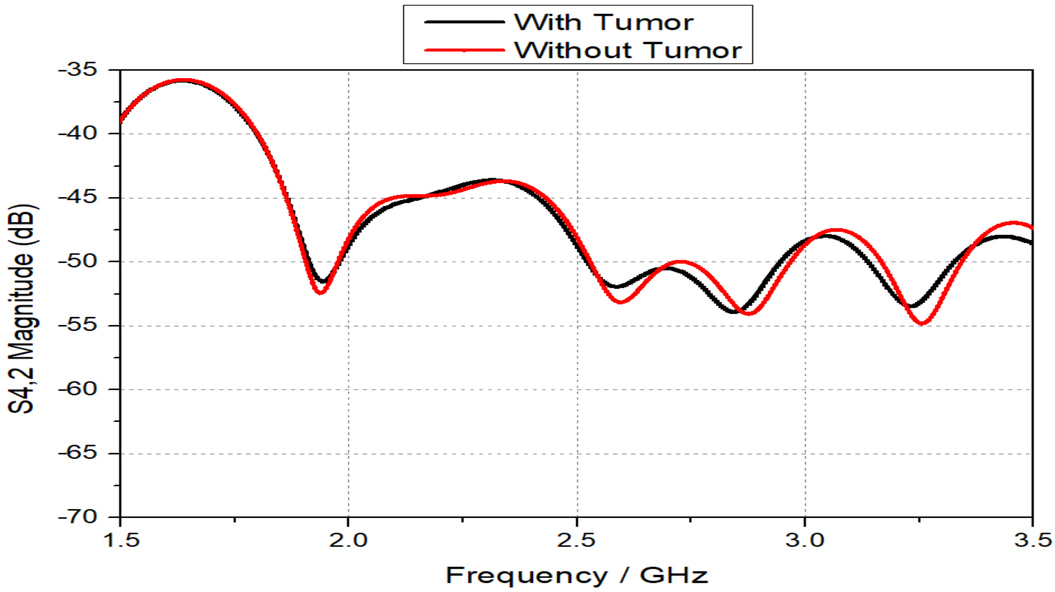

Figure 39 - Compared S4,2 magnitude of antenna array with and without tumor

3.3.16 Phase Retrieval of Single antenna with tumors of different radiuses:

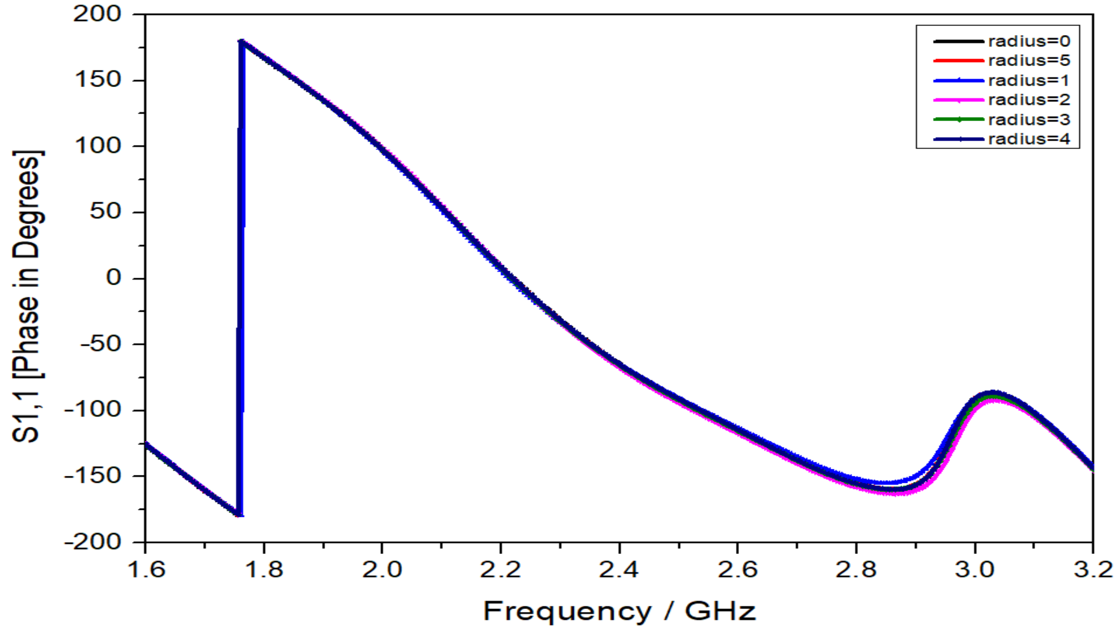

Figure 40 - Parametric phase plot of single antenna with different radiuses

Observation:

When tumors of different radiuses are inserted in the breast phantom with only a single antenna it can be observed that there is change in the phase plot near 2.8 GHz.

3.3.17 Phase Retrieval of single antenna with and without tumor:

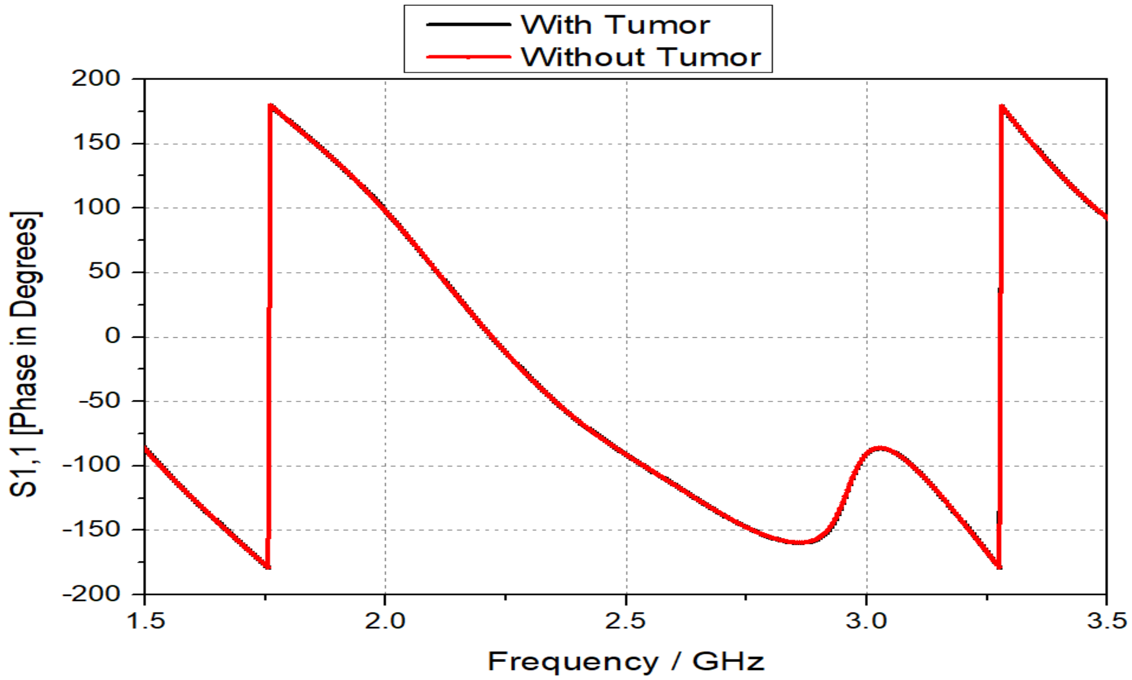

Figure 41 - Compared phase of single antenna with and without tumor

3.3.18 Phase Retrieval of Antenna Array with and without tumor:

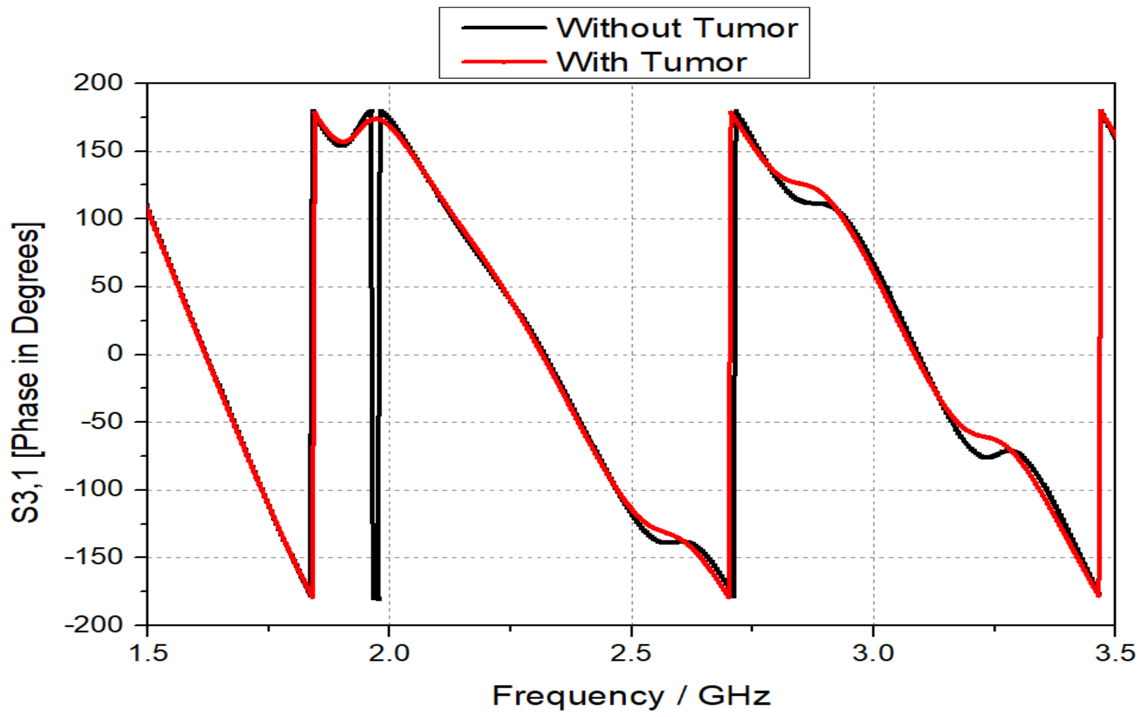

Figure 42 - Compared S3,1 phase plot of array with and without tumor

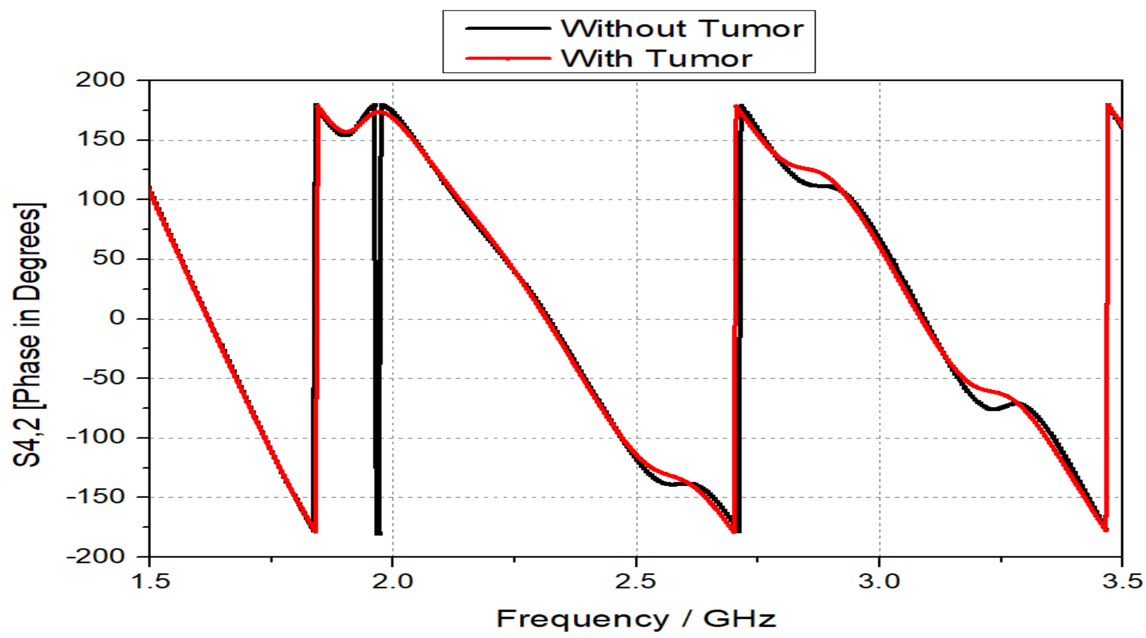

Figure 43 - Compared S4,2 phase plot of array with and without tumor

Observation:

When phase of antenna array is compared with and without tumor the difference in the plot can be observed clearly. It indicate that the designed system is able to detect tumor in the phantom.

CHAPTER 4

4.CONCLUSION AND FUTURE WORK

The proposed work in this report has fulfilled the following tasks:

- Designed a uniplanar elliptical antenna and studied its gain, bandwidth and reflection parameters using magnitude and phase retrieval.
- Designed a multilayered breast phantom having properties similar to that of a real breast.
- Designed an antenna array of four antennas around the breast phantom.
- Further studied about the reflection parameters of a single antenna on the breast phantom with and without tumor.
- Studied about the reflection parameters of antenna array on the breast phantom with and without tumor.

The experimental findings of microwave imaging systems for early breast tumor identification and radar-based breast cancer detection are presented in this study. Although microwave imaging techniques may make it easier to detect breast cancer, they also have considerable limitations and challenges that need to be overcome before they are regularly utilized in clinics. Once some of these obstacles are removed, we will have solid proof that microwave breast cancer detection will replace standard mammography in the clinical setting.

Current techniques in measurements of the electrical properties of normal breast tissue and common anomalies provide a sound foundation for the enhanced design of microwave systems based on the technologies discussed here.

There is still need for improvement in hardware designs, coupling systems, antennas, signal processing methods, and other areas.

To achieve optimal performance, more work must be done on developing improved coupling systems, antennas, signal-processing methods, hardware designs, and other innovations. Effective treatment and better patient outcomes depend on early detection of breast cancer. Even though the present study shows a viable strategy for early breast cancer identification using microwave imaging (MWI), there is still more research to be done in this area.

Future study can focus on improving the sensitivity and specificity of the MWI system by upgrading the antenna arrangement, frequency range, and imaging techniques. Additionally, more rigorous testing on human subjects is necessary to determine the MWI system's effectiveness for therapeutic applications.

Machine learning techniques are being developed to help in the interpretation of MWI images. The creation of machine learning algorithms to aid in the interpretation of MWI pictures is another area for future study. These algorithms might lessen the possibility of false positives or negatives while assisting in the diagnosis and categorization of breast tumors. Combining MWI with additional imaging techniques like mammography, ultrasound, or magnetic resonance imaging (MRI) may improve the precision of finding and diagnosing breast cancer. Additionally, the combination of these modalities could make it possible to characterize breast tumors more accurately and aid in making treatment choices.

A scan:

A scan is a one-dimensional scanning technique in which a frequency-domain signal is acquired while an antenna is in in place. The received data is then translated into the time domain using a Fast Fourier Transform (FFT), and the result is shown as a signal strength or intensity value against time delay. This can also be converted into distance, spatial domain, or downrange in order to locate the target. The analyser collects information in the form of data points, which are precise frequency points in the frequency domain The data is then converted into the time domain using an inverse fast Fourier transform (IFFT). After being collected in the frequency domain, the data is translated into the time domain using the IFFT algorithm.

B scan slicing:

In the context of antenna design, a B-scan is a technique used to visualize the radiation pattern of an antenna. The B-scan is a two-dimensional representation of radiation pattern of the antenna in a plane perpendicular to the direction of propagation. It provides a cross-sectional view of the radiation pattern of antenna.

To perform a B-scan in antenna design, the antenna is placed in a fixed position, and measurements are taken at various points in a plane perpendicular to the axis of antenna. These measurements capture the field strength or power density of antenna at each point, forming a "slice" of the radiation pattern.

By combining multiple B-scans taken at different angles, a three-dimensional visualization of the radiation pattern can be created. This helps antenna designers understand and analyse a performance characteristic of antenna such as beamwidth, sidelobes, and polarization.

B-scans are particularly useful for designing and optimizing antenna arrays, where multiple antenna elements are used together to achieve desired radiation patterns and performance. By examining the B-scans of individual array elements and their combination, engineers can fine-tune the characteristics for specific applications, such as maximizing gain in a certain direction or achieving beam steering capabilities.

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