# ANALYSIS OF BREAST PHANTOM IMAGING USING MICROWAVE PATCH ARRAY SENSOR ANTENNA


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in partial fulfillment for the requirements of B.E Degree in Electrical (Telecom) Engineering.

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In the name of ALLAH, the Most benevolent, the Most Courteous

# CERTIFICATE OF CORRECTNESS AND APPROVAL

*This is to officially state that the thesis work contained in this report "***Analysis of breast phantom imaging using microwave patch array sensor antenna"**

*is carried out by:*

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*under my supervision and that in my judgement, it is fully ample, in scope and excellence, for the degree of Bachelor of Electrical (Telecom.) Engineering in Military College of Signals, National University of Sciences and Technology (NUST), Islamabad.*

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**Department of EE, MCS**

Date: ___________

# DECLARATION OF ORIGINALITY

We hereby declare that no portion of work presented in this thesis has been submitted in support of another award or qualification in either this institute or anywhere else.

# ACKNOWLEDGEMENTS

Allah Subhan'Wa'Tala is the sole guidance in all domains.

Our parents, colleagues and our supervisor Dr Farooq Ahmed Bhatti, Dr Hussain and all other faculty members who supported us.

The group members, who through all adversities worked steadfastly.

## Plagiarism Certificate (Turnitin Report)

This thesis has 10% similarity index. Turnitin report endorsed by Supervisor is attached.

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# ABSTRACT

Breast cancer is the most common cancer in women and is a major killer of women around the world. Early detection of breast cancer is essential for patients to receive the most effective clinical treatment possible. Using the proposed information normalization method, this paper develops a multi-level function selection technique to extract statistically significant features for detecting the size of breast cancers. Most phantom models do not have cancerous and healthy tissue delineated. In order to test the efficacy of microwave hyperthermia in the treatment of breast cancer. This presented report gives solution of the early detection of cancerous tissue. Dielectric constant of phantom and tumor are determined using S parameters and are presented in this report. Phantom experiments were conducted in accordance with the reported dielectric properties of tissue. Electrical conductivity and dielectric consistency were evaluated on phantoms of both normal and malignant breast tissue S parameter properties and dielectric probe package. The operating frequency of microwave is 3 GHz. The value of dielectric constant was measured in frequency of 3GHz which are found to be 6.725 for phantom and 52.566 for tumor respectively. As a result, this phantom can be used for antenna overall performance analysis and optimization and microwave hyperthermia in the treatment of breast cancer.

# Table of Contents

# List of Figures

# Chapter 1: Introduction

In-depth research into using microwaves as an early-detection modality for breast cancer has been ongoing for over a decade. Microwave imaging may prove useful in such situations. Before being used in clinical practise, breast cancer treatments should undergo extensive evaluation for efficacy, side effects, and safety. The number of women diagnosed with breast cancer every year is rising. Breast cancer accounts for one out of every ten new cases of cancer in women each year, making it the most common cancer in women worldwide. In addition, it accounts for the vast majority of cancer-related deaths among females. Evidence from a number of studies shows that the number of cases of breast cancer among women worldwide is rising, especially in developing nations. Breast cancer is often diagnosed in its final stages, when symptoms such as breast changes become apparent. Because of this, most cases of breast cancer are discovered too late for effective treatment, increasing the likelihood of the disease's fatality. Metrics used to evaluate the success of microwave therapy for breast cancer include temperature, lesion size, time, and power to achieve lesion. It is helpful to evaluate treatments using tissue-equivalent phantoms. Human tissue phantoms are created by combining different materials to achieve the desired properties for a specific use case. Studies have shown that tumour tissue has a higher permittivity than healthy tissue by about 10% to 20%. Tissue phantom (TM) materials are available to simulate the high or low water content of actual biological tissues. Depending on the nature of their main component, these materials can be placed in a variety of different categories. However, the vast majority of phantom models do not distinguish between tumour and normal tissue definitions within a single TM. For this reason, we propose in this article a novel solid breast - tumour phantom for the application of microwave hyperthermia to the treatment of breast cancer. Obtaining dielectric properties similar to those of tissues for electromagnetic radiation TM is important for efficient energy coupling or for predicting the subsequent microwave absorption in the heated tissue region. The potential for microwave energy to cause adverse biological effects has prompted studies of the mechanisms by which microwaves might interact with tissues.

## 1.1 Overview

Breast cancer is the leading cause of cancer-related deaths in Malaysia, according to the National Cancer Registry (NCR) Report, which is published every 5 years. In addition, the report states that between 2012 and 2016, the Age- Standardized Incidence Rate (ASR) for women was 34.1% per 100,000 people. Incidence rates are higher in men than in women, with 0.5 cases per 100,000 men compared to 0.2 cases per 100,000 women. Clinical methods for diagnosing and detecting breast cancer have improved significantly in recent years. Common diagnostic procedures include mammography, magnetic resonance imaging, and ultrasound. However, studies have shown that these methods aren't sensitive enough to early-stage breast cancer, and that they're too invasive and time-consuming to be practical. These limitations significantly slow progress towards accurate early breast cancer detection. Early detection is crucial for successfully diagnosing and treating breast cancer. The patients' survival rate is indirectly impacted by the lengthy detection process. Breast cancer worldwide statistics are shown in fig 1 below.


**Figure 1: Breast cancer statistics**

## 1.2 Problem Statement

- One of the most widespread health issues affecting women globally is breast cancer.
- According to 2020 survey in Pakistan 28.7% women are suffering from this breast tumour.
- The existing technologies used for detection breast tumour are MRI, Mammography and Ultrasound. All these technologies have failed to give the early detection.

## 1.3 Proposed Solution

- To overcome this problem literature says Microwave imaging is only solution to the early detection.
- Researchers of this area are working all over the world to find microwave solution for early detection of breast tumour and same is our problem.
- So, the problem define for the FYP is early detection of Breast cancer of tumour.

## 1.4 Working Principle

The measurements were taken by using two array patch antenna, one act as a receiver and other act as a transmitter. The phantom was placed between the two-array patch antenna which were connected to the VNA. The values of scattering parameters S11 and S21 were examined by placing the phantom in between the transmitter and receiver. The distance of phantom from the transmitter and receiver was 10mm and 1mm.

The values of S11 and S21 of phantom taken by VNA were used to find the dielectric constant of phantom.

## 1.5 Objectives

### 1.5.1 General Objectives:

The purpose of creating a breast phantom, measuring its dielectric constant, and analyzing with a microwave patch array is to detect cancerous tumours at an early stage.

### 1.5.2 Academic Objectives:

- Development of breast phantom for the advancement in the Detection of breast cancer in medical sciences.
- To design a project that contributes to the welfare of biomedicines.

## 1.6 Scope

- Service to Humanity by having Early detection of breast tumor.
- Very useful in biomedical.
- useful for microwave imaging.

## 1.7 Relevant Sustainable Development Goals

### 1.7.1 Primary Goal:

Make sure people are healthy and happy no matter what their age is.

### 1.7.2 Secondary Goal:

Advancement in medical technology.

## 1.8 Structure of Thesis

The literature review and background/analysis study are included in this Chapter 2. The planning and execution of the project are described in detail in Chapter 3. Evaluation and analysis of the code are introduced in great depth in Chapter 4. The project's final results are presented in

Chapter 5. The remaining tasks necessary for this project's commercialization are outlined in Chapter 6.

# Chapter 2: Literature Review

A new product is launched by modifying and enhancing the features of previously launched similar products. Literature review is an important step for development of an idea to a new product. Likewise, for the development of a product, and for its replacement, related to breast tumor a detailed study regarding all similar projects is compulsory. Our research is divided into the following points.

- Basics about phantom
- Material for development of phantom
- Analysis of phantom
- Simulated results

## 2.1 Basic about phantom

When it comes to diagnosing and treating breast cancer, breast imaging technology is indispensable. The field of medical phantom construction has recently seen a surge in interest in 3D printing technology due to its versatility and relatively low cost. However, no established protocol exists for implementing multi-modality breast phantoms for quality assurance testing at this time (QC). In this study, we sought to create a 3D-printed breast phantom that would be a physiologically and anatomically accurate surrogate for real breast tissue, and that could be used for a wide range of breast imaging quality control purposes.

Using an anthropomorphic breast phantom is crucial for assessing and enhancing imaging equipment's effectiveness. These models are often manufactured with such exacting attention to anatomical detail that the resulting images are virtually indistinguishable from those of real animals at those locations. Therefore, these phantoms can stand in for a "standard patient," providing reliable clinical data that can be applied to a wide range of scenarios. For instance, they can be used as instructional tools for image-guided diagnostic and interventional procedures. Furthermore, they can be utilized as a quality assessment and image optimization device during the initial implementation of an imaging protocol, as well as for routine quality control of the same image modality to guarantee the scanning system is operating properly. Human performance under stress needs to be evaluated with anthropomorphic phantoms that are as close to the real thing as possible in terms of anatomy, physiology, and pathology.

The phantom replicates the female breast and all of its imaged structures, down to the smallest detail, including fiber injuries and tumours of varying sizes. The phantom was used to test a variety of imaging modalities for injury detection sensitivity, spatial resolution, and thresholds of detect ability. Phantoms, or fabricated replicas of real objects, are used to test and compare the capabilities of imaging equipment. By eliminating the need to conduct tests on living subjects, these inanimate objects also prevent any harm from coming to those subjects.

## 2.2 Methods for development of phantom

### 2.2.1 Tissues Mimicking Materials (TMM):

Each phantom breast was made using a breast mould, skin mould, and an internal fibro glandular mould, and was assembled in five separate steps [8]. External breast mould replicated the shape of a prone human breast, while internal fibro glandular mould provided a structurally complex interface between the fat and fibro glandular regions of Phantom B. Initial construction of the phantom involved placing the tumor in a simple hemispherical mould. The next step involved casting a very thin layer of skin (about 1-2 mm) using the external breast mould and the skin mould. It took about five hours for the skin layer to harden before we could proceed. In the third phase, the skin served as an external mould for the subcutaneous fat, while the internal fibro glandular mould served as an opposing internal mould. The subcutaneous fat layer was left to harden for the next five hours. The fourth step was to suspend the tumor inside the fibro glandular cavity, after which the tissue mimic was poured into the cavity and allowed to congeal for five hours. The final step involved pouring a tissue mimic for the pectoral muscles into a fat tray and allowing it to partially solidify before inserting the main breast phantom into the tray.

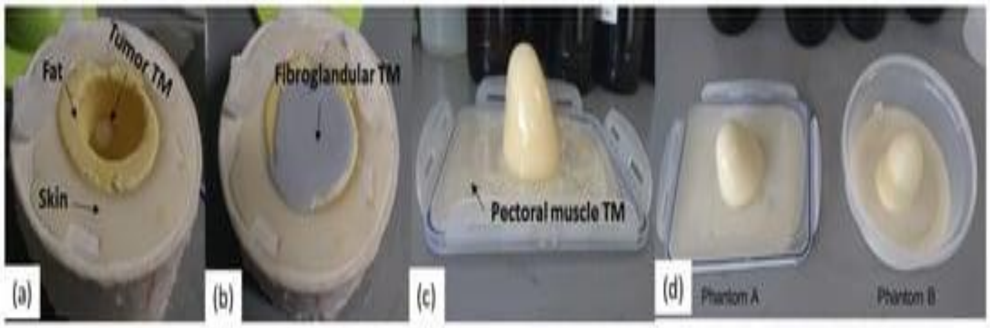



**Figure 2: Tissues Mimicking Materials (TMM) [8]**

### 2.2.2 3D Printed Phantom:

In order to create a breast phantom, we used a 3D printing technique and PVC-based materials [10]. Incorporating structures like microcalcifications, fiber lesions, and tumors of varying sizes that have been imaged in female breasts, the phantom can simulate a wide range of breast imaging scenarios. Different imaging modalities were tested on the phantom to determine the sensitivity, depth resolution, and detectability thresholds for lesion detection. The phantom tissues were characterized by their attenuation [Hounsfield unit (HU)] on CT scans and their relaxation times on MRI scans.

### 2.2.3 Oil-In-Gelatin-Based Mixtures:

Breast phantoms have been made from a variety of substances, including oil and gelatin. A hemispherical phantom (called the "OG phantom") was created using oil-in-gelatin mixtures of varying percentages. This phantom was used to simulate the aforementioned four types of tissue. At 2.45 GHz, the operating frequency of a laboratory-developed experimental imaging system Agilent 85070E open-ended coaxial probe was used to take the dielectric measurements, with help from a network analyzer. Multi-point measurements on the phantom show the varying dielectric constants and conductivities of each mixture. Group averages predicted by Debye models for different tissues are used for comparison as shown in fig 3.

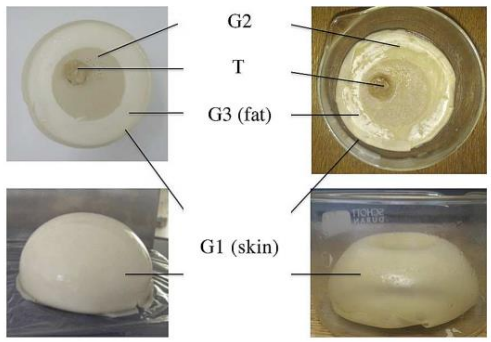



**Figure 3: Oil gelatin phantom [9]**

Oil and gelatin mixtures can be used to make materials with dielectric properties similar to different breast tissues. Dispersions of oil in gelatin maintain their dielectric properties for at least 8 weeks when prepared properly. Conversely, oil-in-gelatin phantoms are highly susceptible to environmental factors and will dry out if not properly protected. Because of the fragility of these apparitions in relation to their environments, long-term storage is problematic. Fig. 3 shows images of the OG phantom taken on the day it was made and again three months later to illustrate this point, [9] reports a significant change in the dielectric properties of such mixtures.

## 2.2.4 Vaseline Phantom:

Last but not the least is Vaseline method phantom and this is the one that we are working on. This phantom is last longing and it gives result near to the real breast tissue. Breast phantoms are used in the data collection process. Different types of materials have been used in the creation of the breast phantoms [1]. Construction of the breast phantom involved the following components:

- Use of Vaseline (Petroleum jelly)
- Oil from olives Flour from wheat Water

## 2.3 Analysis of phantom

Different literatures have their own methods for the development of breast phantom but there are some issues in developing the breast phantom. The breast phantom was designed after a real breast with a tumor embedded in its fatty tissue, as stated in Dr. Tariq ul Islam's research paper [6]. Sodium chloride (NaCl), polyethylene powder, agar powder, xanthan gum, sodium dehydroacetate monohydrate, and distilled water are mixed together in the right amounts to create the phantom and tumor. However, the greatest difficulty in fabricating the ghost was the scarcity of suitable materials. Breast phantoms have been constructed from a variety of materials, including oil and gelatin, as detailed in another of Dr. Nadine Jachimowicz's published studies [2]. We have created a hemispherical phantom (nicknamed the "OG phantom") out of oil-in-gelatin mixtures of varying percentages to simulate the four different tissue types. The main problem, however, was that the phantom was not solidifying into anything concrete. But Dr. Vijayasarveswari's research paper [1] claims that breast phantoms are used in the data collection process. The breast phantoms are made from a variety of materials. For accurate results, it is important that the dielectric properties of the breast phantoms mimic those of real breast tissue in terms of permittivity and conductivity. Inexpensive and non-chemical ingredients like Vaseline (petroleum jelly), wheat-flour, water, and olive oil are used to create heterogeneous breast phantoms in most laboratories, according to reviews of the scientific literature. This kind of phantom do not have any issues and also adopt the proper shape and takes a hard form.

# Chapter 3: Phantom Development

## 3.1 Simulated result

### 3.1.1 Simulated result of breast phantom:

Before fabricating the Phantom we first did simulation of breast phantom and tumor in HFSS software. The model of Breast phantom for simulation is shown below in fig 4-a and simulated result of breast phantom is shown below fig 4-b.

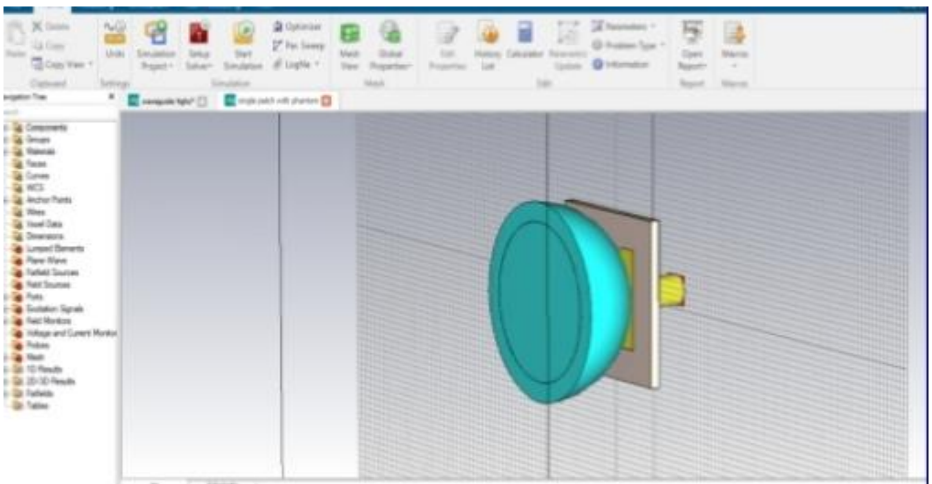


**Figure 4-a: Breast Phantom model in HFSS**

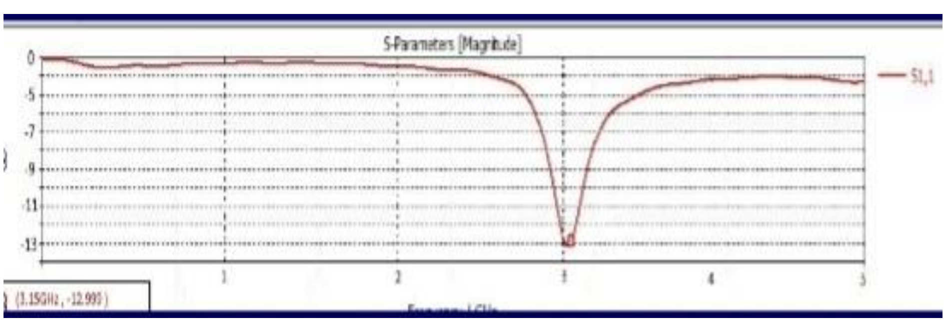



**Figure 4-b: Result HFSS**

### 3.1.2 Simulated result of breast phantom with tumor:

Before fabricating the tumor we first did simulation of breast phantom with tumor in it in HFSS software. The model of Breast phantom with tumor is shown below in fig 5-a and simulated result of breast phantom tumor is shown below fig 5-b.

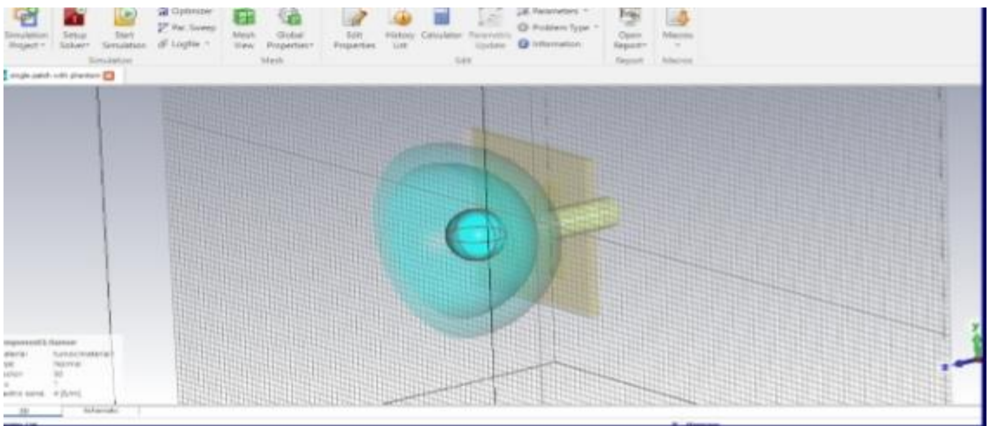
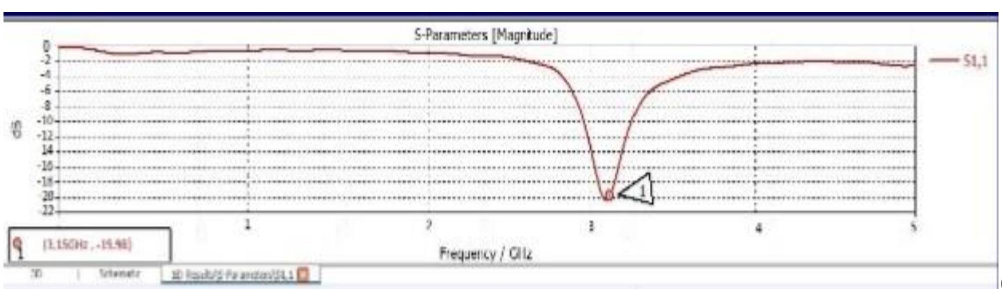


**Figure 5-a: Breast cancer tumor model**




6

**Figure 5-b: Breast cancer tumor result**

## 3.2 Fabrication of breast phantom

The breast phantoms are made from a variety of materials. For accurate results, it is important that the dielectric properties of the breast phantoms mimic those of real breast tissue in terms of permittivity and conductivity. Inexpensive and non-chemical ingredients like wheat flour, water, soy oil, or Vaseline are commonly used to create heterogeneous breast phantoms, according to reviews of the relevant literature (petroleum jelly). In this study, the breast phantoms used were constructed similarly to those used in previous studies as given in [1]. Wine glasses measure 75 mm in diameter, 60 mm in height, and 1.9 mm in thickness; these are the dimensions of the breast phantom skin. Mixing equal parts of petroleum jelly, soy oil, and wheat flour yields a heterogeneous breast phantom. It is also diluted to a 25% concentration with water as shown in fig 6. Tumor growth medium contains 10 times as much water as wheat flour, at a ratio of 5.5:1. A method for producing test tumors of varying sizes (2 mm, 3 mm, 4 mm, 5 mm, and 6 mm). Petroleum jelly, olive oil, wheat flour, and water are the materials chosen for the development of the breast phantom, as reported in the aforementioned literature. Breast phantoms can be made with a mixture of petroleum jelly, olive oil, and wheat flour (in that order) and 75% water.

**Figure 6: Breast Phantom**

## 3.3 Method to determine the dielectric constant of phantom

The breast phantom is positioned between an antenna pair that is placed facing each other. The measurements as shown in fig 7 were taken by using two array patch antenna, one act as a receiver and other act as a transmitter. The phantom was placed between the two-array patch antenna which were connected to the VNA. The values of scattering parameters S11 and S21 were examined by placing the phantom in between the transmitter and receiver. The distance of phantom from the transmitter and receiver was 10mm and 1mm.

The values of S11 and S21 of phantom taken by VNA were used to find the dielectric constant of phantom. The present work implements the Nicholson ross weir method [7] to find the permittivity and permeability through algorithm in MATLAB.

**Figure 7: Measurement image**

### 3.4 Development of tumor

Tumors are used in the data collection process. The following have been used in the creation of the tumors:

- Water
- Wheat flour

When a 10:9 ratio of water to wheat flour is used to grow tumours, the flour becomes malignant. The percentage of water to wheat flour is 90%. We made tumor at different percentages like 55%,75%,80% and 90% and got the results at 90% we got near real results.

### 3.5 Method to determine the dielectric constant of tumor

The tumors is situated between two antennae that are set at right angles to one another. The measurements were taken by using two array patch antenna, one act as a receiver and other act as a transmitter. The tumor was placed between the two-array patch antenna which were connected to the VNA. The values of scattering parameters S11 and S21 were examined by placing the tumor in between the transmitter and receiver.

The values of S11 and S21 of phantom taken by VNA were used to find the dielectric constant of phantom. The present work implements the Nicholson ross weir method [7] to find the permittivity and permeability through algorithm in MATLAB.

# Chapter 4: Code for Analysis of breast phantom and Its dielectric values Evaluation

## 4.1 Introduction

Nicholson ross weir method [7] is used to determine the phantom's dielectric constant. By utilizing the Nicholson-Ross-Weir method, permittivity and permeability can be calculated straight from the s-parameter values. It's how most people go about making changes like this. Two measurements of the S parameters of the material under study are required to calculate the reflection and transmission coefficients, respectively (S11 and S21).

## 4.2 Measurement of s parameters of phantom

The values of scattering parameters S11 and S21 were examined by placing the phantom in between the transmitter and receiver. The distance of phantom from the transmitter and receiver was 10mm and 1mm. The values of S11 and S21 of phantom taken by VNA were used to find the dielectric constant of phantom.

## 4.3 Code for dielectric constant of phantom

```
clear all; clc;

close all;

S21_amp = [ -15.59, -15.59];

S21_phase = [ -125.05, -125.05];

S11_amp = [ -36.79, -36.79];

S11_phase = [ -56.79, -56.79];

C = 3e10;  % Velocity of light in free space in m/s

Freq_vec =2e9:0.5e9:6e9;  % Frequency zone of Operation
```

```
for k = 1: length (Freq_vec)
  Freq = Freq_vec(k)
    lamda0 = C./Freq;  % Free Space Wavelength
%lamda0 = C./Freq;                % Free Space Wavelength
lamdaC =30 ;
    L = 0.4e-3;   % Sample length in centimeter
% Starting of the calculation...
% Stage - 1 : Calculation of S11 & S21
    S11 = -15.59*exp(1j*-125.50*pi/180);
    S21 = -36.79*exp(-1j*56.79*pi/180);
% Stage - 2 : Calculation of various relevant parameters
    X = ((S11.^2)-(S21.^2)+1.0)./(2.*S11);
    Y1 = X + sqrt((X.^2)-1.0);
    Y2 = X - sqrt((X.^2)-1.0);
for ii = 1:length(Y1)
if abs(Y1(ii)) >= 1
            Y(ii) = Y2(ii);
else
            Y(ii) = Y1(ii);
end
    T = (S11+S21-Y.')./(1.0-((S11+S21).*Y.'));
    Z=  log(1./T)
```

```
   Q =-(((Z)./(2*pi*0.5)).^2);

   R = sqrt(Q);

   O=((1+Y.')/(1-Y.'))

   I = sqrt((1./lamda0.^2)-(1./lamdaC.^2));

Mu_eff(k) = (R.*O)./(I)

Eps_eff(k) = (((Q+(1./(lamdaC).^2))).*((lamda0).^2))./(Mu_eff(k))

end

plot(Freq_vec, real(Mu_eff))

xlabel('Frequency');

ylabel('real. Mu');

figure

plot(Freq_vec,imag(Mu_eff))

xlabel('Frequency');

ylabel('Imag. Mu');

figure

plot(Freq_vec,real(Eps_eff))

xlabel('Frequency');

ylabel('real. Eps');

figure

plot(Freq_vec,imag(Eps_eff))

xlabel('Frequency');

ylabel('Imag. Eps');
```

## RESULTS

Results for frequency vs permtitivty and frequency vs permeability are shown in fig 8-a and 8-b.

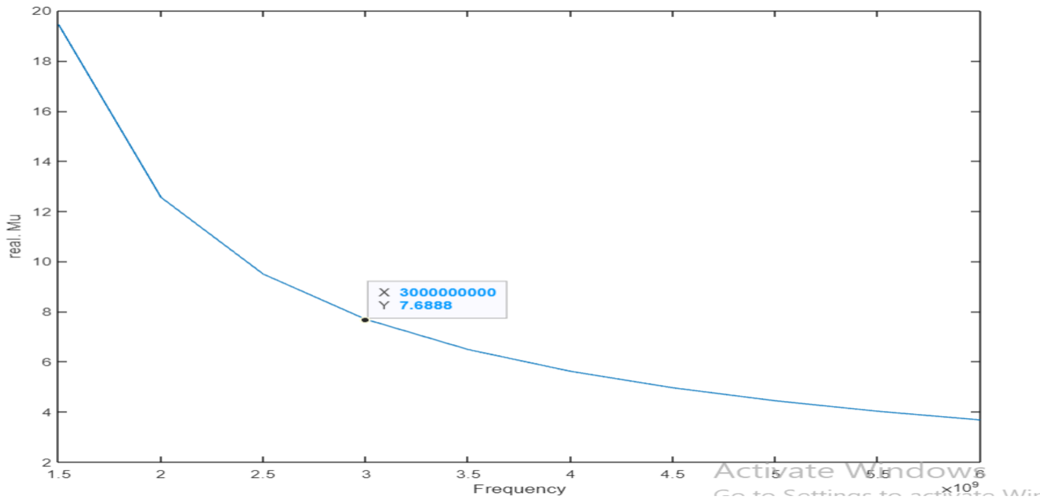



**Figure 8-a: Permittivity VS Frequency**

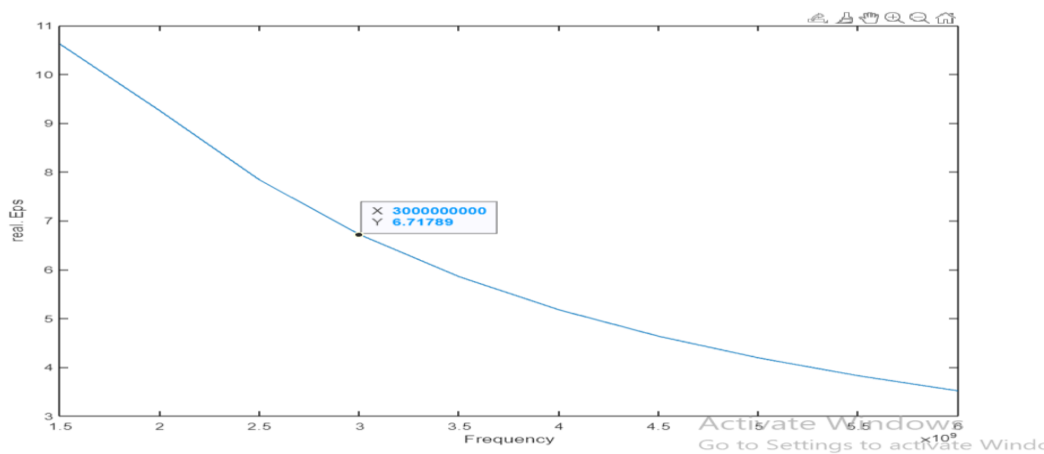



**Figure 8-b: Permeability VS Frequency**

## 4.4 Measurment of S parameter of tumor

The values of s parameter (S11, S21) of tumor was determined by placing the tumor in between the two array patch antenna. The two array patch antenna were connected to the VNA. The VNA showed the calculated results of s parameters.

## 4.5 Measurment of dielectric constant of tumor

```
%% Calculation of Mu & Epsilon from Data file

% Development Date : 18.04.2020

clear all; clc;

close all;

S21_amp = [ -21.64,-21.64];

S21_phase = [ 158.05,158.05];

S11_amp = [ -19.36, -19.36];

S11_phase = [ -151.64, -151.64];

C = 3e10;   % Velocity of light in free space in m/s

Freq_vec =2e9:0.5e9:6e9;   % Frequency zone of Operation

for k = 1:length(Freq_vec)

    Freq = Freq_vec(k)

    lamda0 = C./Freq;   % Free Space Wavelength

%lamda0 = C./Freq;               % Free Space Wavelength

lamdaC =30 ;

    L = 0.4e-3;   % Sample length in centimeter
```

```
% Starting of the calculation...

% Stage - 1 : Calculation of S11 & S21

   S11 = -21.64*exp(1j*158.05*pi/180);

   S21 = -19.36*exp(-1j*151.64*pi/180);

% Stage - 2 : Calculation of various relevant parameters

   X = ((S11.^2)-(S21.^2)+1.0)./(2.*S11);

   Y1 = X + sqrt((X.^2)-1.0);

   Y2 = X - sqrt((X.^2)-1.0);

for ii = 1:length(Y1)

if abs(Y1(ii)) >= 1

         Y(ii) = Y2(ii);

%        disp(ii)

else

         Y(ii) = Y1(ii);

end

end

   T = (S11+S21-Y.')./(1.0-((S11+S21).*Y.'));

   Z=  log(1./T)

   Q =-(((Z)./(2*pi*0.5)).^2);

   R = sqrt(Q);

   O=((1+Y.')/(1-Y.'))

   I = sqrt((1./lamda0.^2)-(1./lamdaC.^2));

Mu_eff(k) = (R.*O)./(I)
```

```
Eps_eff(k) = (((Q+(1./(lamdaC).^2))).*((lamda0).^2))./(Mu_eff(k))

end

plot(Freq_vec,real(Mu_eff))

xlabel('Frequency');

ylabel('real. Mu');

figure

plot(Freq_vec,imag(Mu_eff))

xlabel('Frequency');

ylabel('Imag. Mu');

figure

plot(Freq_vec,real(Eps_eff))

xlabel('Frequency');

ylabel('real. Eps');

figure

plot(Freq_vec,imag(Eps_eff))

xlabel('Frequency');

ylabel('Imag. Eps');
```

# RESULTS

Results for frequency vs permtitivty and frequency vs permeability are shown in fig 9-a and 9-b.

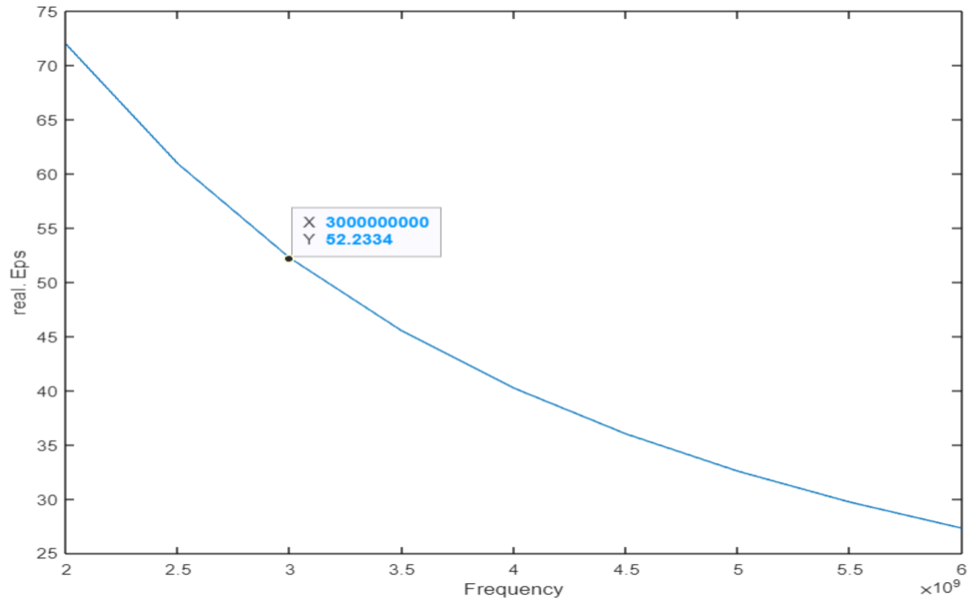



**Figure 9-a: Frequency vs permitivity**

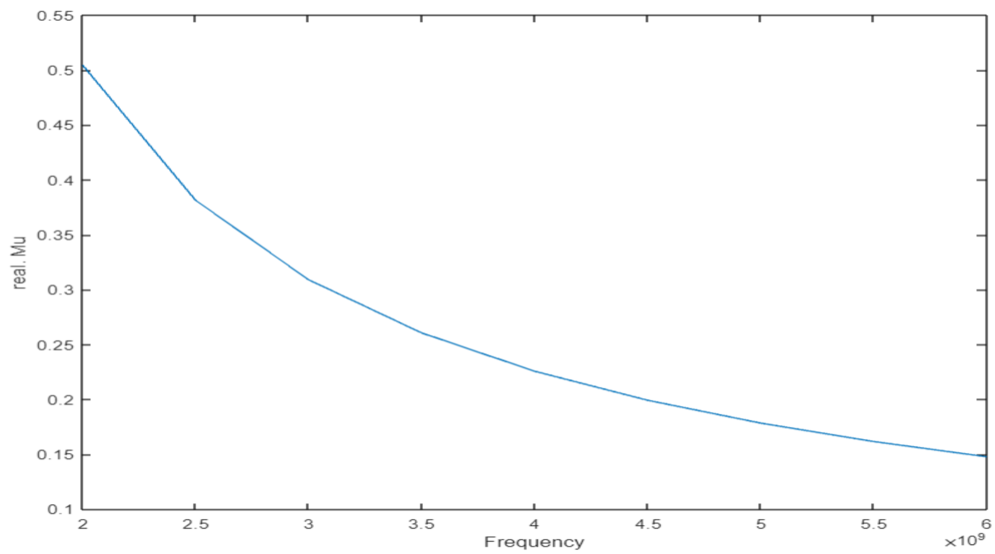



**Figure 9-b: Frequency vs Permeability**

# Chapter 5: Conclusion

The Breast phantom was made using a pair of array patch antennas for use in diagnostic and experimental work.. The experiment was conducted in a regular, noisy laboratory. If a tumour is discovered, it must first be classified as benign or malignant. Both the breast and tumour phantoms were made to look realistic and were cast in solid silicone. Since the amount of energy absorbed by normal and tumour tissues in response to electromagnetic radiation can be predicted using measurements of dielectric constant and electrical conductivity, these tests were performed. Dielectric property behaviour of the phantom breasts is similar to that of real breast tissue in both the normal and tumour states. An assortment of dielectric constants and conductivities are useful for use in breast tumour phantoms. The presented findings are in excellent agreement with those predicted. This phantom can be used in research and practise related to the use of microwave hyperthermia in the treatment of breast cancer. We have studied two types of mixtures whose dielectric properties are comparable to those of different breast tissues between 2.5 and 6 GHz, making them suitable for use in the development of reference breast phantoms for the assessment of microwave imaging systems [14].While oil and gelatin mixtures don't hold up well over time, a mixture of water, Vaseline, olive oil, and wheat flour has been shown to be a good candidate for the realisation of such phantoms due to its ease of preparation and relatively stable electromagnetic parameters. Permittivity of these mixtures can be predicted as a function of the Vaseline concentration and salinity using a binary fluid mixture model such as Böttcher's. Lastly, the liquid nature of the latter mixture is advantageous because it ensures the complete filling of phantoms with complex structures made of thin, slightly disturbing, rigid films that can mimic the actual breast structure.

# Chapter 6: Future Work

Further work in this direction can be for the devolpment of image location in 3D direction and specifically in sphereical coordinate system. Because the phantom is semi-sphere so, to do the analysis and to find the proper position of the tumor with the breast phantom we suggest that somebody can work in this direction and can find the location of the tumor in 3D dimension. In future it can be integrated with robot for automatic functioning. It includes the simulation of entire DCE-Breast CT imaging chain also includes the capability of coded aperture. Future work will incorporate this design into most improved phantom.

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