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UNIVERSIDAD POLITECNICA DE VALENCIA

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"Una antena microstrip para aplicaciones médicas: Detección de tejidos"

TRABAJO FINAL DE GRADO

Autor/a:
Xie ZhenYun

Tutor/a:
José Chilo (PhD)

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Resumen:

El propósito de esta tesis es diseñar una antena microstrip que pueda detectar los diferentes tejidos, según esta pista, suponemos que puede ser utilizada en aplicaciones médicas, por ejemplo, para detectar el tumor de mama. Nuestra investigación y la conjetura se basan en las diferentes propiedades eléctricas del tejido.

Siga la conductividad y la permitividad de los diferentes tejidos, se va a modelar una estructura simple de mama en 3D, y se definirá también un tejido tumoral. Se han diseñado y simulado cuatro tipos de antenas en HFSS.

La antena con el mejor rendimiento se fabricará, que es la antena microstrip rectangular con la brecha, que funciona con frecuencia de resonancia de 2.45GHz, y con la dimensión 37.26mm × 28.83mm.

Prueba S21 de antena en Vector Network Analyzer con diferentes tejidos biológicos, con el fin de hacer una prueba simple de que la antena puede detectar los diferentes tejidos. El resultado muestra que el S21 se cambia cuando usamos diferente el tamaño y la cantidad de los tejidos.

Palabras clave:

Antena microstrip; HFSS; Detección de tejidos

Abstract

The purpose of this thesis is going to design a microstrip antenna that can detect the different tissue, according to this clue, we suppose that it can be used in medical application, for example to detect the breast tumor. Our research and guess are based on the different electrical properties of the tissue.

Follow the conductivity and permittivity of different tissue, a simple 3D breast structure is going to be modelled, and a tumor tissue will be defined too. Four types of antenna have been designed and simulated in HFSS.

The antenna with best performance will be manufactured, which is the rectangular microstrip antenna with gap, it works under 2.45Ghz resonate frequency, and with dimension 37.26mm×28.83mm.

Test S21 of antenna in Vector Network Analyser with different biological tissue, in order to make a simple prove that the antenna can detect the different tissue. The result shows when we use the different tissue's size and quantity, the S21 changes.

Preface

This work has been done at the university University of Gävle, Gävle, Sweden. It was two and half months' project, from simulation to manufacture, and goal of this project has been realized at the end of May, 2017.

The work is done under the instruct in the Mahmoud Alizadeh Department of Electronics/Telecommunication University of Gävle, Gävle, Sweden.

From the preliminary stage to the final draft of my thesis that I have, because of strong support of University of Gävle.

The basis for this thesis stemmed from my passion for developing methods of detect tumor, and make people far away from the breast cancer, this thesis also for memories my best friend's mother who left us 10 years ago because of the breast cancer.

Furthermore, I am thankful to all of my friends and teachers for always encouraging and guiding me during my project working period.

Acknowledgement

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I am grateful to University of Gävle which support me a lots of equipment and the laboratories to help me to do my thesis.

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Personally I want to thanks my friends Iñaki Abrego Peris, Lander Lejarza and Jairo Lafuerza Novellón, they really gave me support and help when I feel helpless, especially we study outside they make me not feel lonely.

Finally, I really would like to thanks to my parents, without them I can't overcome so many difficulty, they are my light in my life. Wherever I am, whatever I do, they always give me the best support.

List of Elaborations

HFSS	High Frequency Electromagnetic Field Simulation
VNA	Vector Network Analyzer
LPKF	PCB Prototype Technology & Laser Material Processing
SAR	Specific Absorption Rate
ISM	Industrial, scientific and medical (ISM) radio bands
IEC	International Electrotechnical Commission
SMA	Subminiature Version A
StDev	Standard deviation
EC	Electric conductivity
DC	Relative permittivity
RF	Radio frequency
EMF	Electromagnetic field

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1. Introduction

Microwaves are kind of electromagnetic radiation with frequencies between 300 MHz and 300 GHz. The basic properties of microwave usually are penetration, reflection, absorption three characteristics. According to the microwave's properties, just as the high frequencies and short wavelengths of microwave energy, microwaves are applicated in many aspects in medical, like hyperemia, treatment in disease, non-contact diagnosis etc. When the microwave propagates in the living body, encounter the interface of different organizations or through different organizations, it will produce varying degrees of attenuation, phase shift, polarization, dispersion etc.

There are many work about the microwave non-contact diagnosis, most of work devoted to detect the tissue or some cancer disease, in the recent few years, the detection technique has made a big process, which is the microwave tomography, because of some limitation, it is difficulty to realize in the practical application. In this situation, our work is using the microwave knowledge and antenna theory to design a new simple method which can difference the tissue, in order to do spade work for the practical application in the future.

The microstrip antenna compared with other conventional microwave antennas, it is smaller than others, is lighter, and the electrical performance is diversified. Therefore, we suppose that the microstrip not only can be used in wireless communication but also can be used in medical area, such as different tissue detection, so in this thesis work has been done to investigate some models of the antenna and optimized those in order to get the best antenna with the best parameter. Then for prove our guess, we have done the simulation in program and experiment test.

1.1 Objective

The main objective of the thesis is that design four different microstrip antennas which can be used in detect the different tissue. Some objectives are summarized below:

I. The working frequency of antenna should around 2.45Ghz, it is means the reflection coefficient should be less than -5dB at least.

II. The evaluation of electromagnetic field and current density distribution values in the simulation should be different in the case of with tumor and without tumor.

III. Manufacture one antenna which has best performance in simulation.

IV. Test the S12 of antenna with two different tissue, the result should be downward trend.

1.2 Outline

In the chapter 2 we will talk about the microstrip antenna theory, and the electrical properties of different tissues in ISM frequency.

In the chapter 3 we are going to develop our research and experiment, in this chapter include:

- Part 3.1 four different antennas will be signed, and one simple breast model, it is working under the HFSS program.
- The simulation will be carried out in Part 3.2, the electrical field and current density will be showed as simulation result.
- Once obtained the simulation result, in Part 3.3 one of antennas with best simulation result will be manufactured in LPKF,
- Part 3.4 our microstrip antenna will be tested with different type of tissue.

In chapter 4 we are going to make conclusion about our work, and further work will be mentioned in chapter 5.

In the final, our work result, which include design, simulation and experiment will be attempted in appendix.

2. Theory

In this chapter, we are going to study 4 different microstrip antennas, and the bioelectrical properties of different tissue, the material for the thesis work will also be introduced in the last part, in order to make design and develop the experiment in chapter 3.

2.1 Theory of experiment

Microwaves use four frequencies in the technical field: 800 MHz, 2.45 GHz, 5.8 GHz and 13 GHz [21]. In this project, we are talking microwave which working under ISM: 27 MHz, 434 MHz, 915 MHz and 2450 MHz.

Because of the penetration of microwave properties, and the biologic tissue can absorb the microwave, when antenna transmit a quantity of microwave to the tissue, depending different tissue has different bioelectrical properties, the ability of microwave's absorption is different, the tissue with high water content will absorb more than low water content for example[16], and the rest of microwave through of the tissue will received by another antenna, compare the quantity of microwave in receiver, the different tissue will be determined, the next figure 2.1 will show the structure.

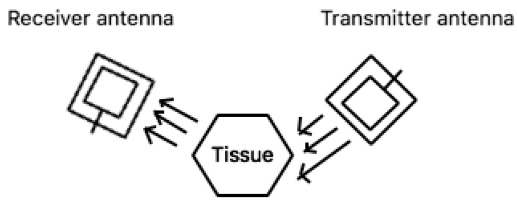


Figure 2.1 Structure of tissue detection

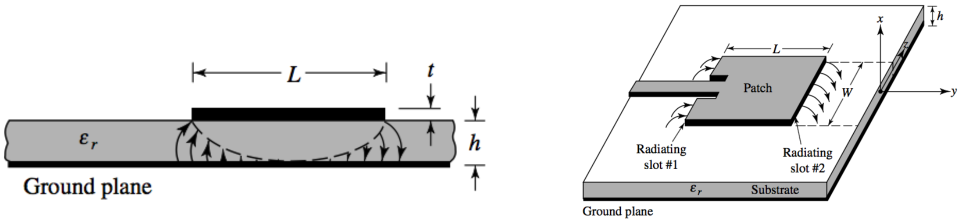
Also on account of the microwave can penetrate into the tissue, not only can detect the tissue individual but also can detect some different inner tissue, due to this clue, the microwave can be used to diagnose the breast tumor for example.

2.2 Theory of antenna

This thesis is going to investigate four microstrip antennas: circular patch antenna, rectangular patch antenna, U slot rectangular patch antenna, and rectangular patch antenna with gap.

Microstrip antenna is becoming useful due to their light weight and low cost, they are most use microwave frequencies, and can be printed directly onto a circuit board. The most microstrip patch antenna usually consists of a metal foil “patch” on surface on top of board, with a metal foil ground plane on the other side of the board, and the patch is generally made of any possible shape such as square, rectangular, circular and elliptical [14]. Normally we always use inset feed and coaxial feed methods, because it is easy to realize and obtain input match.

The patch antenna is a low profile antenna, because structure, it has good radiation ability, from the figure 2.2 a) we can see that the radiation of microstrip antenna is caused by the edge of the open side of the patch. Since the length of the radiation patch is about half of wavelength, the electric field is opposite in vertical component of open side, but the electric field is distributed in the same direction horizontal component, we can see from the figure 2.2 b).



a) Side view *b) Microstrip antenna*

Figure 2.2 Microstrip antenna structure [14]

I. Rectangular antenna:

This kind of microstrip antenna is easy to manufacture, because of the simple 2-dimensional physical geometry figure 2.3. Rectangular antenna is applied in Ultra High Frequency (300Mhz --- 3Ghz), because the size of antenna effects the wavelength at the resonant frequency.

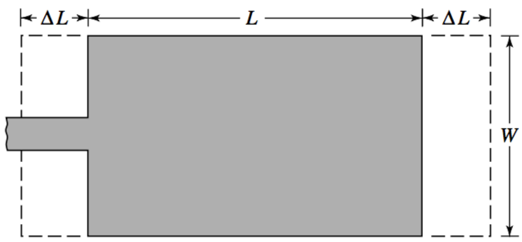


Figure 2.3 Rectangular antenna structure [14]

For the principal E-plane, the dimensions of the patch along its length have been extended on each end by a distance ΔL, which is function of the effective dielectric constant ε_e , where is [14]

$$\varepsilon_e = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}[1+12\frac{h}{W}]^{-\frac{1}{2}} \qquad 2.1$$

Where h is thickness of substrate, ε_r is dielectric constant of substrate and W is width of patch, which use formula 2.2 [14]

$$W = \frac{c}{2f_r} \cdot \sqrt{\frac{2}{\varepsilon_r+1}} \qquad 2.2$$

The c is the speed of light in free space = $3 \cdot 10^8$m/s.
For calculate the length extension ΔL, we have formula 2.3 [14]

$$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon_e+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_e-0.258)(\frac{W}{h}+0.8)} \qquad 2.3$$

once we have obtained the width W and extension ΔL, the length L we have [14]

$$L = \frac{c}{2f_r \cdot \sqrt{\varepsilon_r}} - 2\Delta L \qquad 2.4$$

II. Circular Patch antenna:

In this antenna, the radius of the patch is the only degree of freedom to control the modes of antenna figure 2.4.

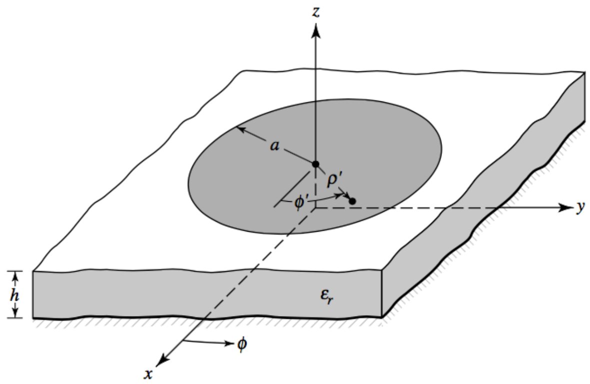


Figure 2.4 Circular Patch antenna [14]

For calculate the radius of the patch we use the next formula 2.5[14]

$$a = \frac{F}{(1+\frac{2h}{\pi\varepsilon_r F}[In(\frac{\pi F}{2h})+1.7726])^{\frac{1}{2}}} \qquad 2.5$$

Where the F we have:

$$F = \frac{8.791 \cdot 10^9}{f_r\sqrt{\varepsilon_r}} \qquad 2.6$$

The ε_r is dielectric constant of substrate, which we have mentioned in above part.

III. Rectangular patch antenna with gap:

This type of microstrip antenna is similar like the rectangular patch antenna, but there has a gap between patch and feed figure 2.5, we use formulas 2.2 and formula 2.4 to calculate the patch,

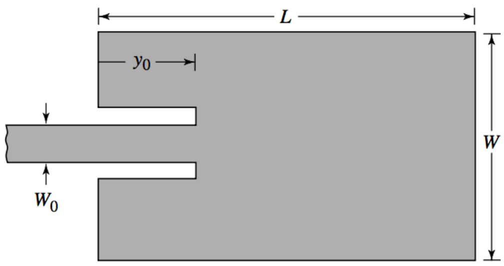


Figure 2.5 Rectangular patch antenna with gap [14]

and the gap we calculate from the formula 2.7[14]

$$R_{in}(y = y_0) = \frac{1}{2(G_1 \pm G_{12})} cos^2(\frac{\pi}{L} y_0) = R_{in}(y = 0) \cdot cos^2(\frac{\pi}{L} y_0) \qquad 2.7$$

Where the conductance G_1 and G_{12}

$$I_1 = \int_0^{\pi} \left[\frac{\sin(\frac{k_0 W}{2} \cos\theta)}{\cos\theta} \right]^2 sin^3\theta d\theta \qquad 2.8$$

$$G_1 = \frac{I_1}{120\pi^2}$$

$$G_{12} = \frac{I_1}{120\pi^2} \int_0^{\pi} \left[\frac{\sin\left(\frac{k_0 W}{2} \cos\theta\right)}{\cos\theta} \right]^2 J_0(k_0 L \sin\theta) sin^3\theta d\theta$$

Therefore, to archive 50Ω impedance, the gap y_0 we have:

$$50 = R_{in} \cdot cos^2(\frac{\pi}{L} y_0) \qquad 2.9$$

IV. U-Slot Rectangular Patch Antenna

Because of this antenna is also kind of rectangular, in order to calculate the patch dimension, we use the same formula 2.2 and formula 2.4. This type of antenna has U slot inside of patch we can see the next figure 2.6:

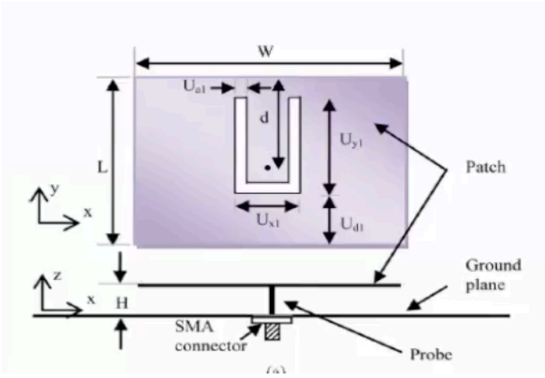


Figure 2.6 U-slot rectangular antenna structure

The slot thickness U_{al} is given by U_{al} = wavelength of light/60, and the deep of U slot we have [24]:

$$U_{dl} = \frac{L - U_{al} - 2\cdot \mathrm{d} - 1}{(\varepsilon_{eff})^{\frac{1}{2}} \cdot (\frac{c}{f} - (2\cdot U_{yl} + U_{xl}))} \qquad 2.10$$

Slot width U_{xl} is given by formula 2.11[24]

$$U_{xl} = \frac{C_0}{2 f_{low} \cdot \varepsilon_{reff}^{\frac{1}{2}}} - 2 \cdot (L + dL - U_{al}) \qquad 2.11$$

Where the C_0 is the speed of light, and slot height we have:

$$U_{yl} = U_{xl} \cdot 0.75 \qquad 2.12$$

2.3 Theory of proprieties of tissues

We apply the microwave microstrip antenna to detect and differentiate the tissues, according to this reason, we suppose it can be used to detect the breast tumor. For prove our conjecture, in this part, the electrical properties of different tissue will be researched.

Because the different tissue will absorb the different quantity microwaves, due to their electrical properties such as the electric conductivity (σ) and relative permittivity constant (ε), this parameter plays an important role to detect different tissue. The EC and DC can be calculated in the next two formulas 2.13 and 2.14 [17]:

$$\varepsilon_r = 1.71 \cdot f^{-1.13} + 4 + \frac{\varepsilon_s - 4}{1+(\frac{f}{25})^2} \quad 2.13$$

$$\sigma = 1.35 \cdot f^{0.13} \cdot \sigma_{0.1} + \frac{0.0222 \cdot (\varepsilon_s - 4) \cdot f^2}{1+(\frac{f}{25})^2} \quad 2.14$$

From the equations we can see that there has relation with frequency, in order to study the electrical properties of tissue influenced by frequency, we choice the skin, normal breast tissue, and tumor tissue for example.

The conductivity value in ISM frequency we obtain in the next table 2.1, the unit of conductivity is (S/m)

	Electric Conductivity (σ)			
	27Mhz	434Mhz	915Mhz	2450Mhz
Skin	0.4	0.84	0.97	1.46
Normal breast tissue	0.21	0.31	0.35	0.4
Tumor	0.76	1.12	1.45	2.1

Table 2.1 Conductivity in different frequency [1] [25]

From the next graphic, we can see the conductivity is increasing when get higher frequency.

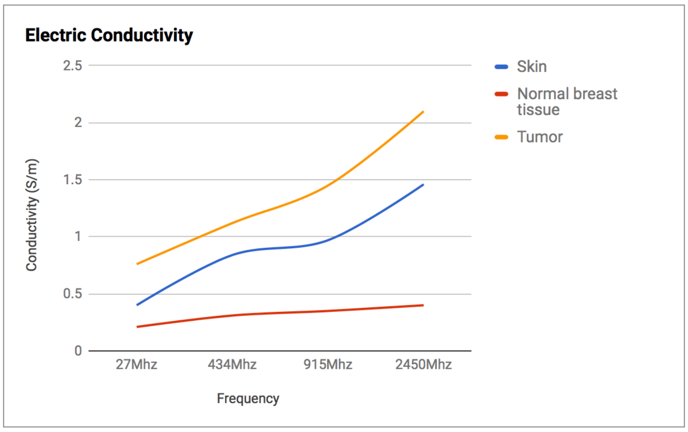


Figure 2.7 Comparison of conductivity

The permittivity of different tissue in ISM frequency we have in next table, the unit of permittivity is (F/m):

Relative Permittivity				
	27Mhz	434Mhz	915Mhz	2450Mhz
Skin	98	47	45	36
Normal breast tissue	22	19	15	9
Tumor	112	57	55.4	50

Table 2.2 Permittivity in different frequency [1] [25]

We obtain the next graphic figure 2.8, and we can see the permittivity get lower when increase the frequency.

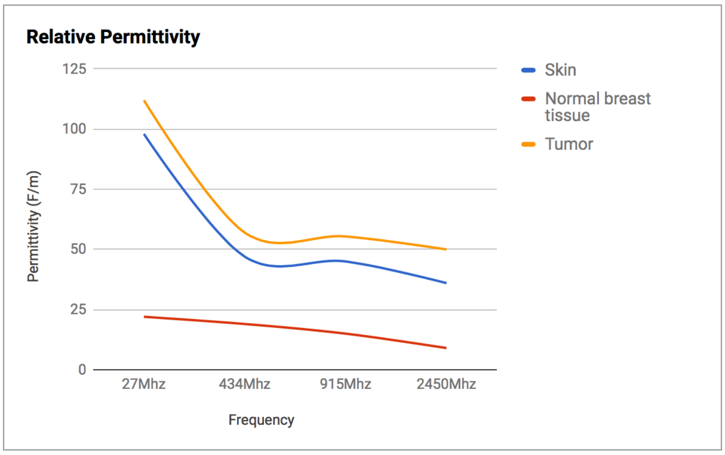


Figure 2.8 Comparison of permittivity

From the theory about antenna and proprieties of tissues, our ideal for this thesis is going to design the antenna model follow the theory, and make it as transmitter and receiver, use it to transmit the microwave to different tissues and receive the scattered waves at a receiving antenna, in this way to verify our guess.

2.4 Theory of SAR

The SAR is an index that quantifies the rate of energy absorption in biological tissue. It is the power absorbed per unit of volume, depends the tissues mass density, and it is proportional to the ratio between conductivity and density of the exposed tissue. It shows in the formula 2.15[21]:

$$SAR = \frac{P}{\rho} = \frac{\sigma |E|^2}{\rho} \qquad 2.15$$

Where the P is the power absorbed in the tissue [W], $|E|$ is the magnitude of the electric field strength vector [V/m], ρ is the mass density of the medium [kg $kg\ m^{-3}$] table 2.3, σ is the electrical conductivity [S/m].

Tissues	Density ρ $(kg\ m^{-3})$
Skin	1.10×10^3
Normal breast	0.92×10^3
Tumor breast	1.04×10^3

Table 2.3 Density of different tissues [25]

2.5 Program overview

For develop our thesis work successful, the next three materials will be introduced:

I. Antenna design and simulation softer ware:

Ansoft launched the three-dimensional electromagnetic simulation software; is the world's commercial three-dimensional structure of electromagnetic field simulation software, the industry recognized three-dimensional electromagnetic field design and analysis of electronic design software.

Ansoft HFSS can simulate the high frequency electromagnetic field of any three-dimensional passive structure, and can obtain the characteristic impedance, propagation constant, S parameter, electromagnetic field, radiation field, antenna pattern etc. The software is widely used in wireless and cable communications, computers, satellites, radar, semiconductor, microwave integrated circuits, aerospace and other fields to help customers design world-class products.

II. Manufacture machine:

LPKF Laser & Electronics is highly mechanical engineering company, it designs and manufactures laser systems, in this project, the LPKF ProtoMat E34 machine is used to make the antenna.

The E series LPKF ProtoMats are a low-cost printed circuit board prototyping. They will structure single- or double-sided circuit boards, drill holes for through-plating and cut individual boards from the base material.

The LPKF ProtoMat E34 has a 30 000 rpm spindle. The maximum travel speed is up to 100 mm per second. For manual tool change both possess a collet with a precise height adjustment by micrometer screw.

III. Test machine:

Vector Network Analyzer is an instrument to measure network parameters of electrical networks, it is used at high frequency from 5Hz – 60GHz

The network analyzer is a new type of instrument that can measure the parameters of the network. It can directly measure the complex scattering parameters of active or passive, reversible or irreversible dual-port and single-port networks, and give the amplitude of the scattering parameters in sweep mode.

It also can correct the measurement results point by point and convert dozens of other network parameters such as input reflection coefficient, output reflection coefficient, voltage standing wave ratio, impedance (or admittance), attenuation (or gain), phase shift and group delay and other transmission parameters and isolation and degree of orientation and so on.

3. Method and research

Our thesis work is following next process. Firstly, we are going to find and read references about our subject. Secondly, according to the knowledge, we design our microstrip antenna, once we finish the design, the simulation will be carried out, if simulation result gets not good, we back to study the theory, and make design again, otherwise one of antenna with best simulation performance will be manufactured and tested, in case of have bad test result, we need to manufacture the antenna again. Finally, according to the result of experiment, we can get conclusion. The next diagram shows our process:

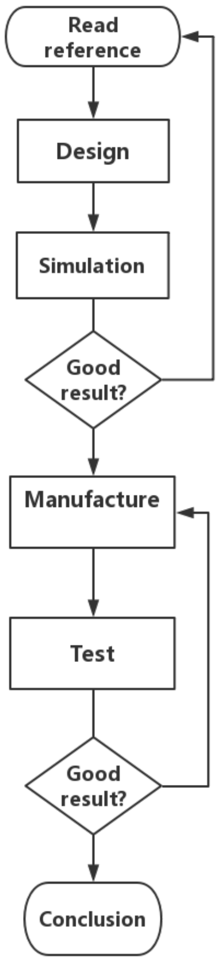


Figure 3.1 Diagram of process

3.1 Design

In this chapter, according to the theory from chapter 2, four different microstrip antennas will be designed, and a basic breast structure will be modelled.

3.1.1 Basic Breast Structure Design

For study the microstrip antenna can detect the different tissues, we are going to design a 3D breast model, with tumor model and without tumor model. The parameters we will take from the chapter 2 and configure in the HFSS program.

The structure breast is modelled by a cone, which lower radius of the cone is 0mm and the upper radius of the cone is 90mm, the height is 70mm. The electromagnetic space is also defined, with dimension $720mm \times 720mm \times 200mm$. The model shows in next figure 3.2:

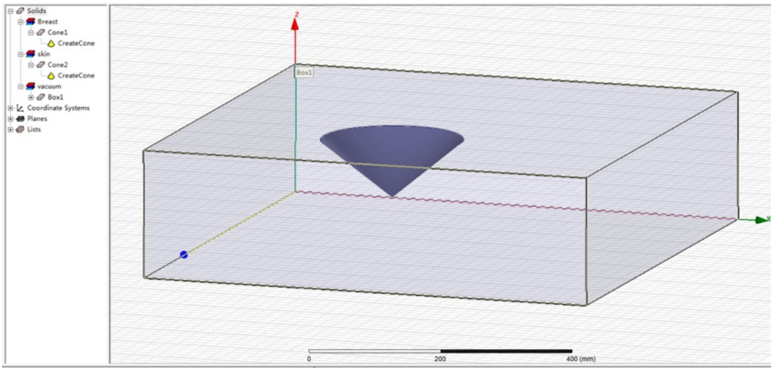


Figure 3.2 Breast tissue

On the other hand, a 2mm diameter sphere with parameter of tumor which from the chapter 2, it will be put inside of the cone model. It is supposed to have different simulation result. Figure 3.2 shows the structure.

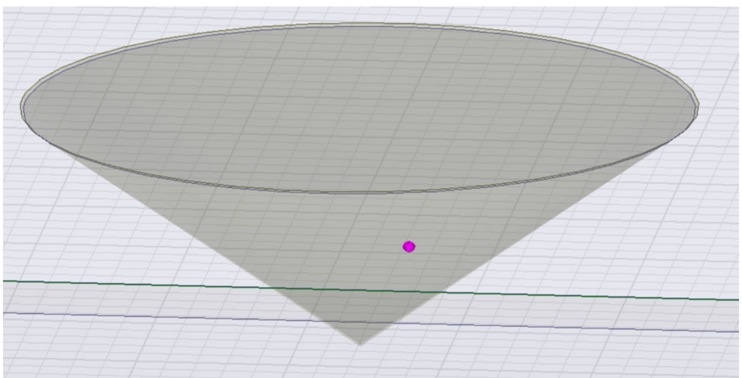


Figure 3.3 Tumor tissue

3.2.1 Antenna Design

Different antenna's patch shape probably causes the different result. In this part we are going to design four different patch shape follow the theory chapter 2, and use the substrate FR4 epoxy with dielectric constant $\varepsilon_r =$ 4.4, and thickness h is 1.588 mm.

I. Requirement of the microstrip antenna

In our project the antenna can works under ISM: 27 MHz, 434 MHz, 915 MHz and 2450 MHz, in order to design the antenna, we should choice the best operating frequency according to three aspects: precise location, antenna's size, specific absorption rate.

- Specific Absorption Rate:

Follow the theory of SAR, we are going to calculate and compare the value in ISM frequency. Assume that the $|E|$ is 1[V/m], and use the formula 2.15 we can calculate the SAR, the result shows in the next table:

	27Mhz	434Mhz	915Mhz	2450Mhz
Skin	3.64E-04	7.64E-04	8.82E-04	3.64E-03
Normal breast tissue	2.28E-04	4.46E-05	3.80E-04	4.35E-04
Tumor	7.31E-04	1.08E-03	1.39E-03	3.75E-03

Table 3.1 SAR of tissues in different frequency

From the table, it shows clear that when increase the frequency, the SAR value is higher. In this thesis work, only the tissue absorbs more microwaves, the antenna can detect easier, the result will be more obvious.

- Precise location:

On the other hand, the higher the frequency, the shorter the propagation range can be. The wavelength of high frequency is short, and its directivity angle is narrow, the location can be precise. At least the frequency 2450 MHz is chosen for the antenna frequency.

- Antenna size:

The next table 3.3 shows the dimension of antenna in different frequency:

Antenna	27Mhz	434Mhz	915Mhz	2415Mhz
Inset fed antenna	$3.4m \times 2.6m$	$210mm \times 165mm$	$100mm \times 78mm$	$37mm \times 28.8mm$
Circular antenna	$R = 1.5m$	$R = 95.7mm$	$R = 45mm$	$R = 16.6mm$
Rectangular antenna	$3.4m \times 2.6m$	$210mm \times 165mm$	$100mm \times 78mm$	$37mm \times 28.8mm$
U slot antenna	$2.9m \times 2.3m$	$208mm \times 153mm$	$95mm \times 74mm$	$35mm \times 26mm$

Table 3.2 Dimension of antenna

Because of low frequency will has large size of antenna, in this case the antenna should be design small, light and easy to use.

From all above 3 aspects, the frequency 2450 MHz will be used to design microstrip antenna.

II. Rectangular patch antenna:

We use the Matlab to calculate dimension of antenna, and design in HFSS where the Maltab code and detail of design we have attached in the appendix.

We obtained the result:

W(m)	L(m)	dL(m)	Eref(m)	Lef(m)	Wg(m)	Lg(m)	dif(m)
0.0367	0.0283	6.89E-04	4.2745	0.0297	0.0457	0.0373	0.009

Table 3.3 Parameters of rectangular patch antenna

The next figure 3.4 shows the rectangular patch antenna:

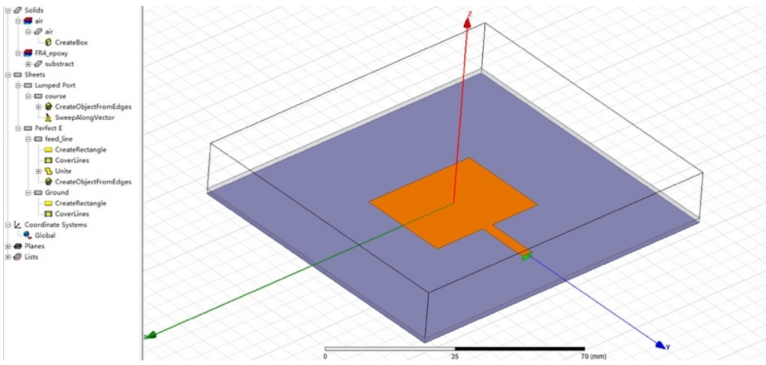


Figure 3.4 Rectangular patch antenna

III. Circular patch antenna:

We use the Matlab to calculate dimension of antenna, and design in HFSS where the Maltab code and detail of design we have attached in the appendix.

We obtained the result a = 16.6 mm, and the next figure 3.5 shows the circular antenna:

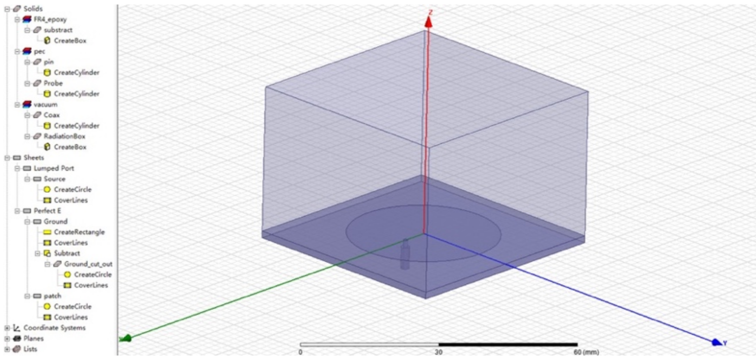


Figure 3.5 Circular patch antenna

IV. Rectangular patch antenna with gap

We use the Matlab to calculate dimension of antenna, and design in HFSS where the Maltab code and detail of design we have attached in the appendix.

We obtain result for design in HFSS:

W(mm)	L(mm)	dL(mm)	Lef(mm)	Wg(mm)	Lg(mm)	y0(mm)
37.26	28.83	0.689	29.7	45.7	37.3	0.5

Table 3.4 Parameters of rectangular patch antenna with gap

The next figure 3.6 shows the rectangular patch antenna with gap

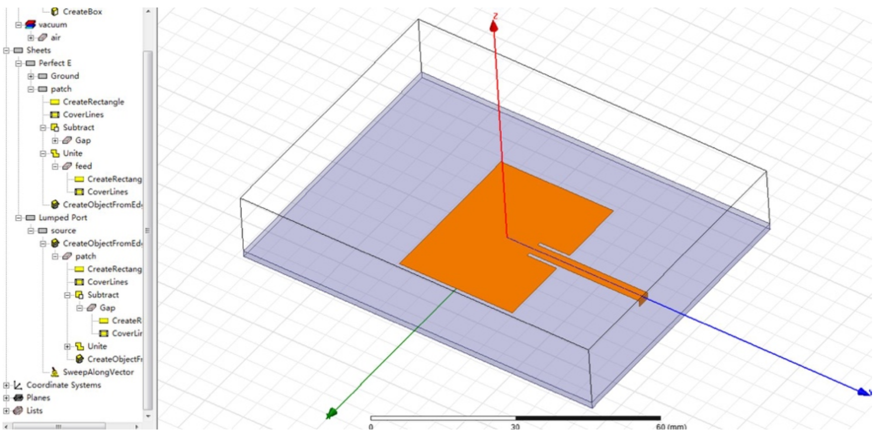


Figure 3.6 Rectangular patch antenna with gap

V. U-slot rectangular path antenna.

All the parameters of U-slot antenna we calculate follow the formula 2.10, 2.11, 2.12 of chapter 2 and with Matlab code from rectangular patch antenna.

We obtain result for design in HFSS:

W(mm)	L(mm)	H(mm)	d(mm)	Ual(mm)	Udl(mm)	Ux1(mm)	Uy1(mm)
35.5	26	1.588	13.5	2.1	4.8	12	19.5

Table 3.5 Parameters of U slot rectangular patch antenna

The next figure 3.7 shows the U-slot rectangular patch antenna

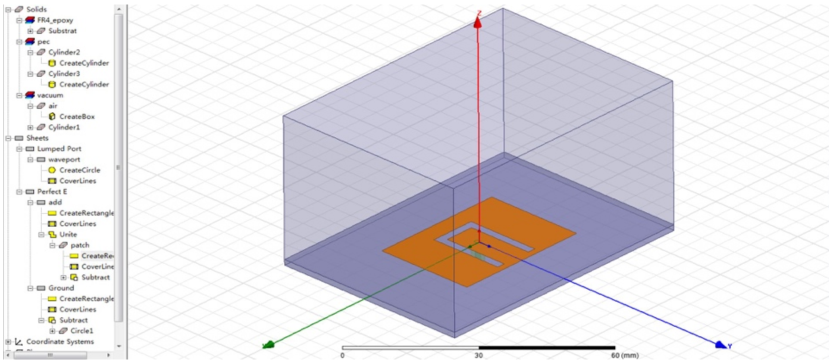


Figure 3.7 U-slot rectangular patch antenna

3.2 Simulation of detection

We are going to simulate the detection of four antennas, the permittivity and conductivity change from the normal breast tissue to the tumor tissue and these changes are used to evaluate electric field and current density distribution [4][1]. The result of simulation in each case will be compared.

We assume that the microstrip antenna can be used to detect the different tissues due to the result of simulation. The simulation is working in the HFSS program.

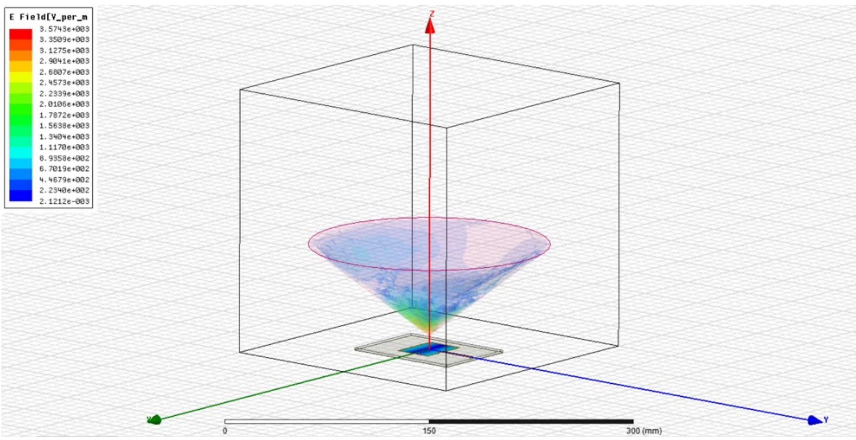
The purposed model for the tissue detection which based on antenna radiation properties. Antenna radiates the signal towards our 3D breast model, and the antenna radiation properties such as electric field and current density can be used to differentiate the tissue [4]. The concept of the detection is the EMF and current density of breast model created by antenna.

In this part, the electric field values and current density distribution over the breast tissue with tumor and without tumor will be investigated, evaluation is presented in next table 3.6:

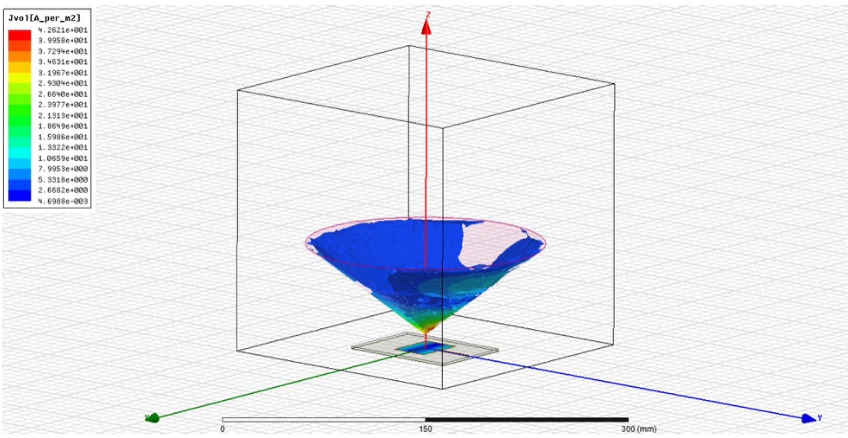
Antenna Structure Name	Max E Field	(V/m)		Max J	(A/m2)	
	With tumor	Without tumor	Differences	With tumor	Without tumor	Differences
Rectangular patch antenna with gap	3.8889×10^3	3.5743×10^3	$\|314.6\|$	46.372	42.621	3.751
Circular Patch antenna	3.2964×10^3	2.8688×10^3	$\|427.6\|$	54.323	52.554	1.769
Rectangular Patch Antenna	7.9332×10^2	1.0097×10^3	$\|-216.38\|$	21.752	18.230	3.522
U slot Patch Antenna	5.6435×10^2	6.2171×10^2	$\|-57.36\|$	14.274	13.964	0.310

Table 3.6 Electric field, and current density values according to each antenna structure

In this work, for the rectangular patch antenna with gap has the best performance in simulation, we can see from the next few figures, the figure 3.8 a) and b) show the electric field values and the current density in case of without tumor.



a) *E field*



b) *Current density*

Figure 3.8 structure of simulation

The structure shows that the antenna is arranged under the breast model which is 10mm distance, all of them under the electromagnetic box with dimension 200mm×200mm×200mm, and the breast model is changing the colour when the value is changing, obviously near the antenna has more radiation, and it attenuates when far from the antenna.

The rest antennas' simulation result has been attached in the appendix*(simulation)*. According to the simulation, we can see that as the antenna patch design changes, electric field values into breast structure have certain alterations.

These difference of volume current density and electric field value are the presence and is major clue for the detection of tissues. Follow this clue, considering laterally that our microstrip antenna detector also can be used in medical area, such as diagnose the breast tumor.

3.3 Manufacturing in LPKF

In this part, LPKF with model ProtoMat E34/E44 figure 3.9 will fabricate the rectangular patch antenna with gap, which has been simulated and studied in the chapter 2. Two antennas are going to build as transmitter and receiver

Figure 3.9 LPKF ProtoMat E44

The design of antenna will be opened in CircuitPro, which is a program of LPKF for converting layout data into actual printed circuit boards: it takes the data from the design software, edits it for production, breaks it down into individual process steps and guides the user, step-by-step, through the manufacturing process. In that way, the microstrip antenna board will be printed by LPKF machine.

After printed the microstrip antenna, the 50-ohm SMA connector will be welded with feed by soldering iron, finally obtained the microstrip antenna product like next figure:

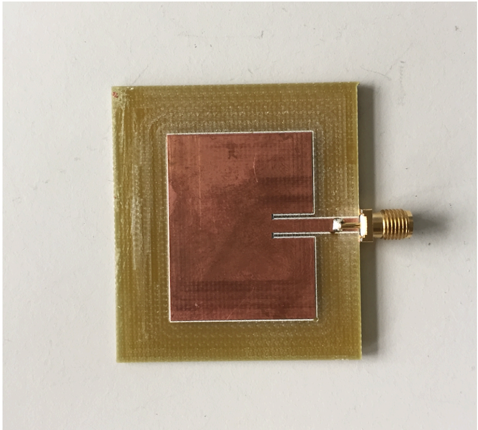


Figure 3.10 Manufactured antenna

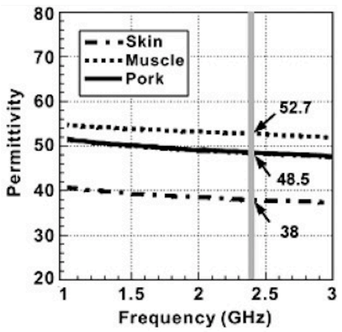
3.4 Test in VNA

Once obtained the microstrip antenna, the detection will be test with VNA, figure 3.11. Because of some reason of experimental ethics, which we can't find tumor tissue to apply in our experiment test, in order to continue our product testing, the beef meat and pork meat will be used as two different tissues, we assume that antenna can detect different value in these two types tissues. All of them are bought from ICA supermarket, after experiment test all of meat are continue used in correct way.

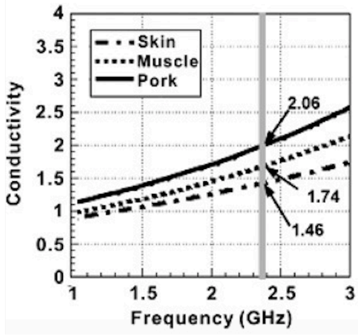
Figure 3.11 Vector Network Analyser

3.4.1 Test introduction

The microstrip antenna detection principle is based on electric conductivity, relative permittivity, in this case the beef and pork have different conductivity and permittivity, the pork meat has the similar properties of tumor, and skin tissue at 2.45Ghz frequency which shows in next figure 3.12 [19]:



a) Permittivity of pork



b) Conductivity of pork

Figure 3.12 Properties of pork

On the other hand, from the reference we know that the conductivity of beef is 0.75, and the permittivity is 44.7 in figure 3.13 [23] [20].

Example #	Product Type	Volume	Electro-Conductivity	Density	Total Moisture Content	Thermal Conductivity	pH
		(mL)	(S/m)	(g/ml)	(%w/w)	W/mC	
16	Chicken	0.015	.75	0.9	68	.46	4.1
17	Beef	0.025	.75	0.95	70	.47	4.5
18	Fish	0.010	1.8	0.96	66	.45	4.5
19	Chicken	0.60	1.2	1.05	85	.52	4.8
20	Beef	1.50	1.5	1.01	82	.51	5.2
21	Fish	0.30	2	1.03	79	.50	5.2
22	Chicken	15	.8	1.1	45	.38	5.5

Figure 3.13 Conductivity of beef

Based on the difference of electrical properties of beef and pork, we use beef 100g as normal *tissue a* with dimension 90mm×50mm×24mm like next figure 3.14:

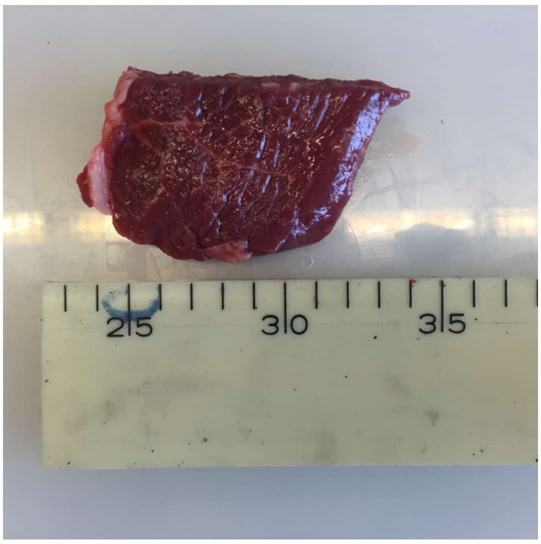


Figure 3.14 100g beef for experiment

The pork is used to do as contrast *tissue b*, it has been made at 5mm, 8mm and 10mm in diameters. The *tissue b* will be put inside the *tissue a* in order to reduce the influence by thickness. Because the SAR should be lower than 2 W/kg, thus, from the formula 2.15 the power should be lower than 1W (30dB), so that the transmitter be set as 8dB which is the maximum output power of VNA, and the antennas are placed 10cm in vertical direction as next figure 3.15:

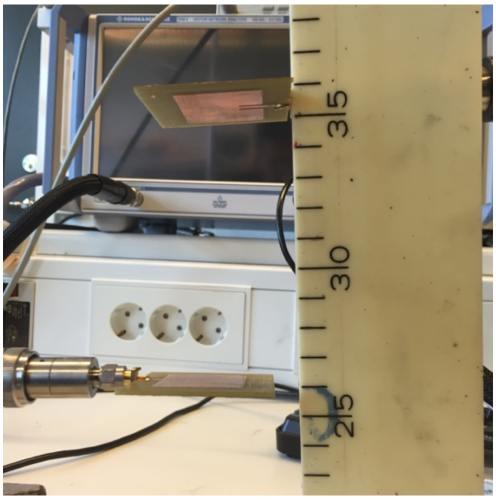


Figure 3.15 The mounting of experiment

The *tissue a* is put above the antenna in order to keep it at the same position. For determine the *tissue b* which can be detected inside of *tissue a*, the value S12 will be checked in VNA.

3.4.2 Test result

The test beginning with 4 individual objects of *tissue b*, then is 6 objects and 8 objects. Three different size of *tissue b* will be tested in the experiment, and take average of three times test result.

- S12 of two antennas

Before begin the experiment, we test the S12 of two antennas in air, it represents the power transferred from Port 2 to Port 1, the value of S12 is -19.2554dB. The results have attached in the appendix *(Test_result)*.

- Without tissue *b* test

We will only test the *tissue a* without *tissue b* in the first as the control group, and we measure the S12, it is -30.9923dB. The result has attached in appendix *(Test_result)*.

- 5mm *tissue b* test

Firstly, test 4 individual objects of *tissue b* inside of *tissue a*, the value S12 respectively are -32.1417dB, -33.1560dB, and -32.8844dB. The average is -32.729dB. The results have attached in the appendix *(Test_result)*.

Secondly, test 6 individual objects of *tissue b* inside of *tissue a*, the value S12 respectively are -33.2505dB, -33.7766dB, -33.5628dB. The average is -33.52dB. The results have attached in the appendix *(Test_result)*.

Finally, test 8 individual objects of *tissue b* inside of *tissue a*, the value of S12 respectively are -35.1540dB, -34.2875dB, and -34.3833dB. The average is -34.6dB. The results have attached in the appendix *(Test_result)*.

- 8mm *tissue b* test

Firstly, test 4 individual objects of *tissue b* inside of *tissue a*, the value S12 respectively are -33.4316dB, -32.4119dB, and -32.2841dB, the average is -32.7092dB. The results have attached in the appendix *(Test_result)*.

Secondly, test 6 individual objects of *tissue b* inside of *tissue a*, the value S12 respectively are -34.1372dB, -34.3513dB, and -34.5765dB, the average is -34.3547dB. The results have attached in the appendix *(Test_result)*.

Finally, test 8 individual objects of *tissue b* inside of *tissue a*, the value S12 respectively are -36.3935dB, -34.5441dB, and -36.0231dB. The average is -35.6537dB. The results have attached in the appendix *(Test_result)*.

- 10mm *tissue b* test

Firstly, test 4 individual objects of *tissue b* inside of *tissue a*, the value S12 respectively are -35.7428dB, -36.6888dB, and -35.0424dB, the average is -35.82467dB. The results have attached in the appendix *(Test_result)*.

Secondly, test 6 individual objects of *tissue b* inside of *tissue a*, the value S12 respectively are -40.8010dB, -39.0898dB, and -36.6337dB, the average is -38.8415dB. The results have attached in the appendix *(Test_result)*.

Finally, test 8 individual objects of *tissue b* inside of *tissue a*, the value S12 respectively are -43.3886dB, -40.9755dB, and -40.9292dB. The average is -41.7644dB. The results have attached in the appendix *(Test_result)*.

The next figure shows the measurement of different tissue detection:

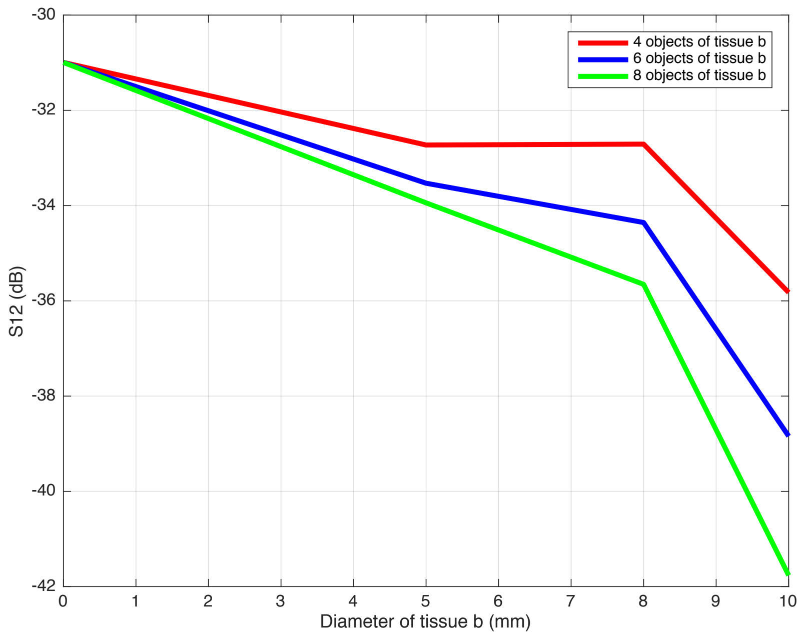


Figure 3.16 Result comparison

It is obviously shows in graphic that when object of *tissue b* gets bigger and more, the result S12 become lower, it means that is easier be detected by our microstrip antenna. Because of the different tissue the bioelectric properties are different, pork has higher SAR than beef, when we put more pork inside, the *tissue b* absorbs more radiation, and S12 will get lower. In this experiment when has 8 individual objects of *tissue b* in 10mm diameters, S12 is in the peak value -41.76dB.

3.4.3 Error correction

After obtained the experiment test result, the standard deviation will be calculated in Excel, in order to quantify the amount of dispersion of our result, which shows in next table:

size of tissue b	number of tissue b	S12(dB)			average of S12(dB)	StDev
5mm	4	-32,1417	-33,156	-32,8844	-32,72736667	0,525067351
	6	-33,2505	-33,7766	-33,5628	-33,52996667	0,264582356
	8	-33,154	-34,2875	-34,3833	-33,9416	0,683761457
8mm	4	-33,4316	-32,4119	-32,2841	-32,7092	0,628871632
	6	-34,1372	-34,3513	-34,5765	-34,355	0,219673371
	8	-36,3935	-34,5441	-36,0231	-35,65356667	0,978512265
10mm	4	-35,7428	-36,6888	-35,0424	-35,82466667	0,826247453
	6	-40,801	-39,0898	-36,6337	-38,8415	2,094716446
	8	-43,3886	-40,9755	-40,9292	-41,76443333	1,406760087

Table 3.7 Experiment result with StDev

From the table we can see that the StDev value mostly around 0.5, lower than 1, only in case of 10mm of *tissue b*, the StDev is 2.09 at 6 individuals of *tissue b* and StDev is 1.4 at 8 *tissue b*. In general, all test results are accuracy and correct, so we can consider that our antenna has ability to make different tumor detection.

4. Conclusion

We have designed and developed a microstrip antenna for detect the different tissues. Different four antennas are simulated with basic 3D breast structure, microstrip rectangular patch antenna with gap which operating at 2.45Ghz is verified to prefer the most suitable one, and it has been manufactured, in order to test the effect of detection. The result that we have tested with different tissues is feasible, it shows that the value has big different between *tissue b* inside and without any other tissue.

From the result of simulation and experiment test we can get conclusion that in this work the rectangular patch antenna with gap is able to differentiate the tissues with different electrical properties, according this clue, we supposed to it also can be used in medical application such as diagnose the breast tumor

On the other hand, we can't prove that if our antenna could detect the breast tumor, because of the experimental ethics, the test couldn't develop in *vivo*, therefore the further work will prove it.

5. Further work

The further work of the thesis is involved the matter of animal experiment, in order to verify the our microstrip antenna can be used to detect the tumor, about this matter, the test will be applied in mice. The test experiment will be developed in two groups, one group of mice will be set as model of tumor, and another set as control experiment group. The S12 value of two groups will be measured and compared. All of experiments process are comply with medical ethics requirement, and it will be developed and realized at one medical university.

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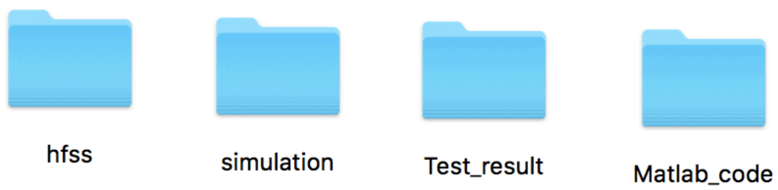
Appendix

The content is distributed in folders and shows in the following structure:



hfss: Contain the 3D breast structure, 4 types antennas design in program HFSS.

simulation: It includes the simulation result of chapter 4.

Test_result: It includes the experiment result in VNA of chapter 6.

Matlab_code: It includes the microstrip antenna calculation code of chapter 3.