ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

MICROWAVE IMAGING TECHNIQUE USING UWB SIGNAL FOR BREAST CANCER DETECTION

Siti Hasmah binti Mohd Salleh, Mohd Azlishah Othman, Nadhirah Ali, Hamzah Asyrani Sulaiman, Mohamad Harris Misran and Mohamad Zoinol Abidin Abd. Aziz
Microwave Research Group, Centre for Telecommunication Research and Innovation (CeTRI), Faculty of Electronics and Computer Engineering, Universiti Teknikal Malaysia Melaka (UTeM), Durian Tunggal, Melaka, Malaysia
E-Mail: sitihasmah87@gmail.com

ABSTRACT

Microwave Imaging modalities used for breast cancer detection currently are not sufficient for society's need. The key features for microwaves technique for tumor detection by the observation at microwaves frequencies, the dielectric contrast of permittivity and conductivity between normal and malignant tissues. This project focuses on the experimental of reflection coefficient in complex frequency domain obtained using vector network analyzer transform into time domain using Inverse Fast Fourier Transform (IFFT). Breast phantom is illuminating from various points with short UWB microwave pulse generated by RF Horn antenna with frequency of 1GHz -10GHz and the collected backscattered energy is being analyzed and simulated using Microwave imaging algorithms to identify the presence and localization of the tumors. The experiment represent medium form by a rectangular shape of container filled with oil and small size of 3cm stone as a reflected target that represent as a malignant tissues in the breast sample.

Keywords: microwave imaging, time domain, breast cancer detection, breast phantom.

INTRODUCTION

Microwave Imaging (MI) for breast cancer detection, as a screening and monitoring tools has recently attracted attention among a large number of researcher groups (Fear, Meany and Stuchly, 2003) (Hashemzadeh, Fhager and Persson, 2006) (Li, Bond, Van Veen and Hagness, 2015) (Meaney, Paulsen, Hartov and Crane, 2015) (Nilavalan, Leendertz, Craddock, Preece and Benjamin, 2004). This approaches based on the significant contrast of electrical properties, permittivity and conductivity between normal and cancerous tissue at microwave frequencies (Chaudhary, Mishra, Swarup and Thomas, 1984) (Joines, Zhang, Li and Jirtle, 1994) (Surowiec, Stuchly, Barr and Swarup, 1988). MI becomes one of the most promising imaging modalities for biomedical applications like strokes and cancer monitoring. Therefore, MI can serve substantial functional knowledge for breast health and can be used for breast cancer detection and treatment response monitoring tools since it can detect the cancer at earlier stage.

A study on a development of Microwave Imaging technique for earlier tumour detections using Synthetic Aperture Radar (SAR) has been carried out in this paper by focusing more on breast cancer detection since it is a leading factor of women death worldwide according to American Cancer Society (ACS) (Fang, Meaney and Paulsen, 2004). Breast cancer is a common type of cancer in women (American Cancer Society, Inc, 2007) (Parkin, 2001) (Sundhedsstyrelsen, 2005) (Sundhedsstyrelsen, 2006) compared to others killer cancer. Hence, early detection is very significant for effective treatment (Michaelson *et al*., 2002) in order to long live survival promises. The studies also focus on the developments of the imaging algorithms.

A simple experiment has been setup by using a two different electrical contrast material which is soy oil (normal tissue) and pieces of stone (malignant tissue) contained in the size of 6cm x 6cm x 10cm of a rectangular tank. Then, a piece of 1cm diameter stone was place at the middle of tank. By using Horn antenna at the frequency range of 1GHz to 10GHz, the location of the stone has being measured in region of 6cm x 8cm which is approximately to location of stone and the scattered wave was seen through Vector Network Analyzer (VNA) and the data is recorded. Then, the data recorded was analyzed in Matlab to get the 2D and 3D plotting graph by using Matlab Algorithms.

The main objectives of this project are the ability to developed Microwave Imaging modalities for cancer detection by using Vector Network Analyzer (VNA) which can capture pulses of bandwidth up to 20GHZ. The VNA will enable the frequency and time domain measurement of scattered waves that reflected from the breast sample with UWB microwaves pulse. The purpose of the project is to design a method for breast cancer imaging technique that can produce the most accurate performance analysis. This technique is possibly to capture the more accurate about the existing and the features of tumor in the breast from microwaves frequency. Thus, this project can help radiologists to ease their diagnosis as well.

There are four remainder section of this paper which is each section will elaborates details about the topics. The following section of literature review will elaborates about the history, some case studies in microwave imaging for breast detection based on breast phantoms and the algorithms used for image formation. In Section III is the detail about the methodology of this project which is the explanation about the flow of project, the requirement needed. The implementation of image formation algorithms will briefly explain and discusses in this part. The final output and result from the measured

VOL. 10, NO. 2, FEBRUARY 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

data that has been analyzed and simulate are presented in Section IV in this paper.

LITERATURE REVIEW

There are variety of methods have been used and testes by few researchers for detection of breast cancer using microwave imaging approaches. This part will describe the efficiency of chosen method for detection and image formation algorithm by making comparisons from a few journal and research.

The key features of microwave imaging breast cancer detection are the significant contrast between the conductivity and the permittivity of normal and tumor in the microwave frequency. The difference in scattering parameters between normal and cancerous tissue occurs due to the difference in dielectric constant. Permittivity is a complex number and the complex permittivity of a material, ε^* which defined as

$$\varepsilon^* = \varepsilon' - j\varepsilon'' \quad (1)$$

Where $j = \sqrt{-1}$, ε' real part of dielectric constant
ε''= imaginary part of the dielectric loss factor

Loss factor can also represent by conductivity σ :

$$\sigma = \omega\varepsilon_0\varepsilon'' \quad (2)$$

Where angular frequency ω =2πf, f is the frequency and ε_0 is the permittivity of free space (ε_0 = 1).
The relative permittivity ε_r defined as:

$$\varepsilon_r = \frac{\varepsilon'}{\varepsilon_0} \quad (3)$$

To express the losses in the material, the total dielectric loss tangent, tan δ can be used and defined as

$$\tan\delta = \frac{\varepsilon''}{\varepsilon_0} \quad (4)$$

Microwave Imaging via Space Time (MIST) Beamforming have been introduce by Hagness *et al* in University of Winsconsin (Joines, Zhang, Li and Jirtle, 1994). There are two categories of position arrangement through this system which is:

i. Planner of flattened position in which multiple antenna are placed on the breast surface.
ii. Pendant or cylindrical position whereas patient lying by facing down with breast extending through the hole of treatment Table.

Since the scattered signal measured by s11 is in frequency domain, hence an Inverse Fast Fourier Transform (IFFT) is used to transform the signal to time domain. Time domain backscatter signal are analyzed and an artifact removal has been applied using data adaptive algorithm to remove the early time artifact at the received signal of tumor reflection. The conversion from frequency domain to time domain used to get better signal by removing the noise and ripple from the time domain signals. Besides, the other advantages include the better signal-to noise ratio (SNR). Therefore IFFT have been applied as the transformation process of frequency domain to time domain signals.

METHODOLOGY

Figure-1 show the flow chart for the general process have been done through experiment setup from the measured of incident field until the image formation of tumor detection in this project.

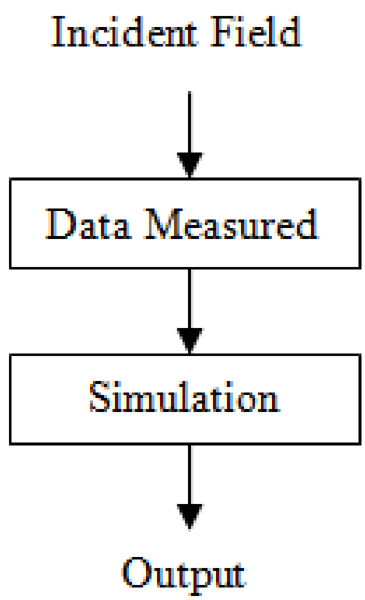


Figure-1. General process flowchart.

A. Experiment setup

In this project, an experiment setup has been done using a few materials with difference in electrical properties (permittivity and conductivity). Figure-2 illustrates the system configuration for the experiment setup of breast phantoms that represent the supine position of patient lying during treatment. A container contains with a liquid that represent as normal tissues and a small stone in 1cm diameter as a tumor embedded at the bottom in the liquid. A single RF horn antenna that connected to VNA N5242A has been placed near the surface of flattened breast phantom as per illustrated in Figure-3.

ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

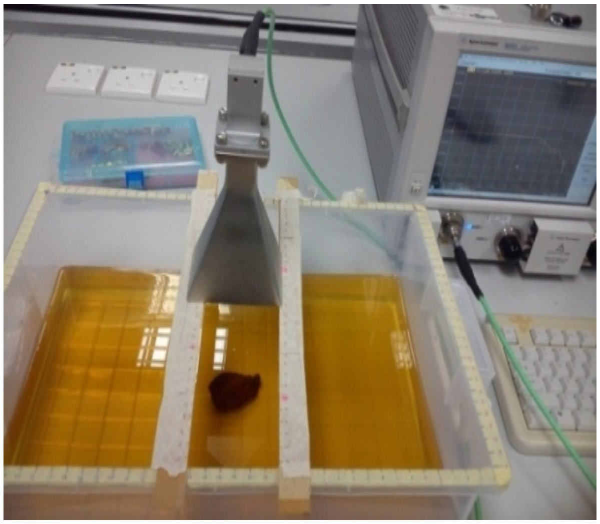


Figure-2. An experiment setup.

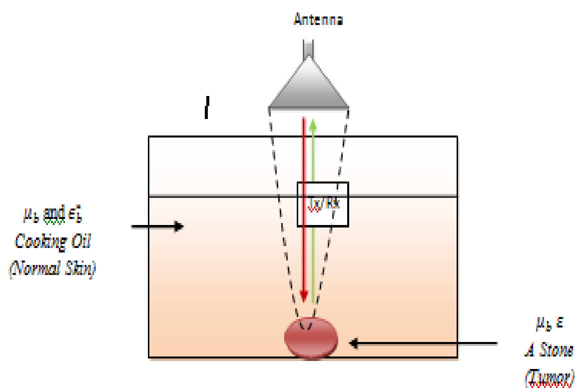


Figure-3. Planar illustration of experiment setup.

The main point in microwave imaging is the dielectric contrast between difference materials of breast phantoms. Thus, a few features of the materials must be in consideration especially in term of dielectric properties. Soy oil is a low water contained that have the dielectric properties approximately to normal breast tissue which is ε_r = 2.6 with σ = 0.05 S/m at 6GHz. The open ended coaxial probe approaches is used to measured the the dielectric of the materials (Li, Liu and Song, 2004).

The breast phantom is illuminating sequentially in x and y horizontal position by 1cm increment up to 36 point by using RF Horn antenna to produce the area of scattered signals at the presence of tumor. Whereas x is 6cm and y =6cm point of antenna position make it become 6cm x 10cm array and 201 frequency samples recorded at each position of antenna. The scattered signal from the transmitting and receiving of microwave frequency from the antenna is measured through vector network analyzer in frequency domain. UWB microwave pulse generated by antenna at frequency of 1GHz -10GHz.

B. Image reconstruction algorithm

The time domain backscatter signal from the tumor reflection measured by using s11 of VNA has been analyzed. In this study, Microwave Imaging via Space Time (MIST) beamforming algorithms are used to simulate the measured data for the image formation of tumor detection and location since it is better technique for monostatic radar.

Figure-4 shows the process of image formation. Raw data represent the scattered signal received from any position under consideration and the area with tumor and without tumor are subtractions in order to obtain the tumor. Then, the time delay and total sum imaging are applied to get the spatial focusing of the backscattered signals for image formation of tumor location.

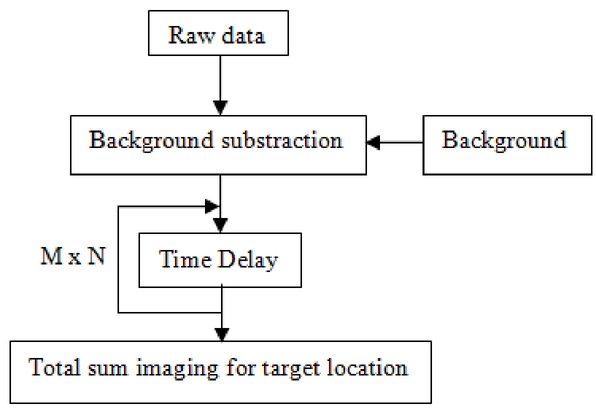


Figure-4. Imaging reconstruction flowchart.

Since the scattered signal measured by s11 is in frequency domain, hence an Inverse Fast Fourier Transform (IFFT) is used to transform the signal to time domain. Time domain backscatter signal are analyzed and an artifact removal has been applied using data adaptive algorithm to remove the early time artifact at the received signal of tumor reflection.

There are *K* + 1 sample of monostatic scattered along x axis when the horn antenna illuminating the breast phantom horizontally with total length S_{k+1}. The scattered signal magnitude *P* at each antenna position can be represent as equation below.

$$P(x_m, y_n) = \sum_{k=1}^{K+1} s_k(t - \tau) \quad (5)$$

where

$$\tau = \frac{2\sqrt{\varepsilon_r}\sqrt{(x_k - x_m)^2 + (y_k - y_n)^2}}{c}$$

$$x_k = k\Delta x, \quad (6)$$

$$x_m = m\Delta x,$$

$$y_n = n\Delta x,$$

Coordinate of radar position = (x_k, y_k). Received time domain sample data = s_k(t), τ is round trip delay between pixel (x_m, y_n) and coordinate of radar position

ISSN 1819-6608

(x_k, y_k), (x_m, y_n) is image position D_x, D_y = Imaging area, $\Delta x = D_x/M$ is the resolution in horizontal, $\Delta y = D_y/N$ is the resolution in vertical range Δt is the pulse width, while C is light velocity.

The energy from each antenna position can be obtained by using sum and squares of the received signals.

$$E(d) = \sum_k |y_k(f) e^{\frac{4\pi}{\lambda} r_k}|^2 \quad (7)$$

Whereas phase compensation represented by;

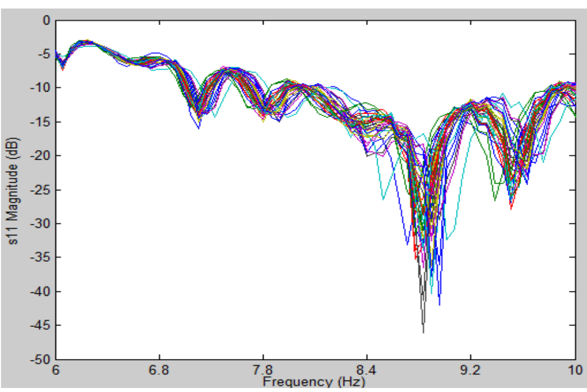
$$e^{-\frac{4\pi}{\lambda} r_k}$$

And scattered range, r

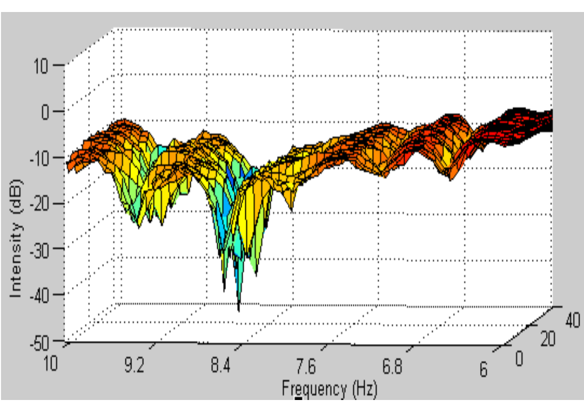
The beamformer is scanned at difference antenna locations represented as function location.

RESULT AND DISCUSSIONS

Figure-5 (a) High scattered region from tumor reflection at 8.8GHz, (b) Surface plot for the reflected coefficients without applying beamforming, in this graph the tumor location cannot be identify due to clutter signals (c): Result in Time Domain after frequency domain transformation.



(a)



(b)

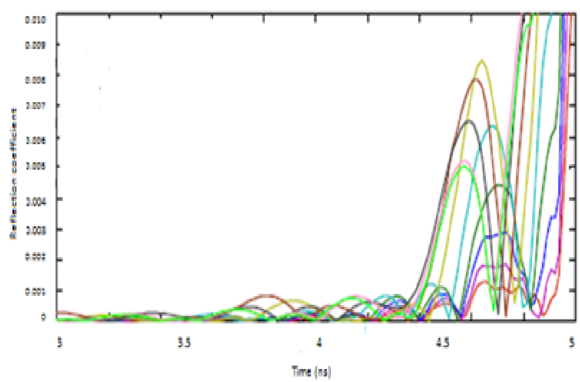

(c)

Figure-5. The graph a) High scattered region from tumor reflection at 8.8GHz, b) Surface plot for the reflected coefficients without applying beam forming an c) result in time domain.

From the Figure at (c) above show the reflected coefficient slightly increase when the antenna position move approximately to the malignant tissue.

CONCLUSIONS

This paper presents alternatives of breast cancer detection using MIST beamforming algorithm. Besides, the material used with the difference dielectric properties also been discussed.

These results are promising as the characteristic of the breast sample used are almost similar with normal skin of real breast.

There are only a simple result have been shown here. The 3D experiment is not performed although the promising result was obtained due to the limitation in antenna and lack development of scanning system. Hence, the simple model has been develop in this paper can be a foundation for 3D system enhancement.

There are also a few enhancement can be made in order to improve the functionality and operation with this system for more accurate image formation of tumor. Some of them are

a) Real-time detection: by using more realistic shape and inhomogeneous that mimicking the real dielectric properties of breast tissue.
b) Overcome the limitations: able to use in varying diameter of tumor and background of breast sample.
c) Giving effectives experiment setup using a Multistatic antenna or antenna array.
d) Using better algorithm that can remove all clutter and undesired signal which can produce noise during the image formation.

ACKNOWLEDGEMENTS

I would like to thank first and foremost, to thank Ministry of Education and Universiti Teknikal Malaysia Melaka, Malaysia (UTeM) for financial assistance under project grant RAGS/2013/FKEKK/TK02/03/B00032.

Special dedication to kind-hearted project coordinating supervises lectures, student, parents, public and those involved directly and indirectly for their moral supports, contribution and cooperation in completing this paper. I also want to express my gratitude and respect to all those for being helpful when needed whether directly or indirectly.

REFERENCES

American Cancer Society, Inc. 2007. Cancer Facts & Figures 2007. American Cancer Society.

Chaudhary, S., Mishra, R., Swarup, A., and Thomas, J. 1984. Dielectric properties of normal & malignant human breast tissues at radiowave and microwave frequencies. Indian Journal Of Biochemistry & Biophysics. 21(1): 76.

Fang, Q., Meaney, P., and Paulsen, K. 2004. Microwave image reconstruction of tissue property dispersion characteristics utilizing multiple-frequency information. Microwave Theory And Techniques, IEEE Transactions On. 52(8): 1866-1875.

Fear, E., Meany, P., and Stuchly, M. 2003. Microwaves for breast cancer detection?. Potentials, IEEE. 22(1): 12-18.

Hashemzadeh, P., Fhager, A., and Persson, M. 2006. Experimental Investigation of an Optimization Approach to Microwave Tomography. Electromagnetic Biology And Medicine, 25(1), 1-12.

Joines, W., Zhang, Y., Li, C., and Jirtle, R. 1994. The measured electrical properties of normal and malignant human tissues from 50 to 900 MHz. Medical Physics, 21(4), 547-550.

Li, F., Liu, Q., and Song, L. 2004. Three-dimensional reconstruction of objects buried in layered media using Born and distorted Born iterative methods. Geoscience And Remote Sensing Letters, IEEE, 1(2), 107-111.

Li, X., Bond, E., Van Veen, B., and Hagness, S. 2015. An overview of ultra-wideband microwave imaging via space-time beamforming for early-stage breast-cancer detection. Antennas And Propagation Magazine, IEEE, 47(1), 19-34.

Meaney, P., Paulsen, K., Hartov, A., and Crane, R. 2015. An active microwave imaging system for reconstruction of 2-d electrical property distributions. Biomedical Engineering, IEEE Transactions On, 42(10), 1017-1026.

Michaelson, J., Silverstein, M., Wyatt, J., Weber, G., Moore, R., and Halpern, E. et al. 2002. Predicting the survival of patients with breast carcinoma using tumor size. Cancer, 95(4), 713-723.

Nilavalan, R., Leendertz, J., Craddock, I., Preece, A., and Benjamin, R. 2004. Numerical analysis of microwave detection of breast tumours using synthetic focussing techniques. Antennas And Propagation Society International Symposium, 2004. IEEE. 3: 2440-2443.

Parkin, D. 2001. Global cancer statistics in the year 2000. The Lancet Oncology. 2(9): 533-543.

Sundhedsstyrelsen. 2005. Cancer registered 2001 (foreløbige tal for 2002-2003). Copenhagen, Denmark: Sundhedsstyrelsen Danish National Board of Health.

Sundhedsstyrelsen. 2006. Kræftstatistik Baseret På Landspatientregisteret 2000 - 2004. Copenhagen, Denmark: Sundhedsstyrelsen Danish National Board of Health.

Surowiec, A., Stuchly, S., Barr, J., and Swarup, A. 1988. Dielectric properties of breast carcinoma and the surrounding tissues. Biomedical Engineering, IEEE Transactions On. 35(4): 257-263.