METHODS OF TUMOR DETECTION USING MICROWAVE TECHNOLOGY: A REVIEW

Myzatul Diana Daud[1], Mohd Azlishah Othman[1] and Mohd Fairuz Iskandar Othman[2]
[1]Microwave Research Group, Centre for Telecommunication Research and Innovation (CeTRI), Faculty of Electronic and Computer Engineering, Universiti Teknikal Malaysia Melaka, Malaysia
[2]Communication, Multimedia, Network and Systems Research Group, Centre of Advanced Computing Technology, Faculty of Information and Communication Technology, Universiti Teknikal Malaysia Melaka, Malaysia
Email: azlishah5533@gmail.com

ABSTRACT

The present study, which is a part of a series of comparative studies, aims to find out the type of techniques for tumor detection. The tumor detection usually used is mammography, where is it being quite sensitive to the lesions in the breast by compressing the breast on X-ray image. But it still due to exposure to ionizing radiation with the way of diagnoses method by breast compression and furthermore mammography is not sensitivity for early-stage tumor detection but only for the best and effective medical treatment. So the engineers and scientists are motivated to make improvement in alternative or complementary technologies for breast imaging techniques which technique is can promise the procedure is safe, simple to perform, reasonable cost, existing convenience, sensitive to the tumors and methods of screening for breast cancer has been established namely, ultrasound, mammography and magnetic resonance imaging (MRI). More important is comfortable to patients. The result of analysis from the engineers and scientists found and propose microwave imaging is the best method for breast cancer detection and they had proven their experiment. In addition, their upgrade this method to become more sensitive which is can detect early-stage breast cancer namely microwave imaging via space-time (MIST) beam forming. To optimize measurement moderate endogenous dielectric contrast between normal and malignant tissues and increase the spatial resolution at microwave frequencies is more challenging.

Keywords: tumor detection microwave imaging (MIST) beam forming.

INTRODUCTION

The ultimate goal of this paper is make sure which method is completely having all of the characteristics to detect tumor and to studies about ultrasound, mammography, MRI and microwave imaging. The ideal method must low risk, simple to perform, reasonable cost, existing convenience, sensitive to the tumors, minimal discomfort, easy to refer and lastly their results is consistent. The last decade, have been applying tissue-penetrating which the interior of the breast radar technique to locate strong scattering targets within the breast but non-invasively with low-power microwave-frequency electromagnetic waves [2].

A recently U.S. Institute of Medicine (IOM) review that the current state of X-ray mammography technique still mostly effective for breast diagnoses but have exposure to ionizing radiation, not enough sensitive to detect tumor and discomfort for patients. They also suggest other technologies for breast cancer screening [7-8]. They also had studies for others method such as ultrasound, MRI and PET scan where have problems in accuracy, high cost and need long time to diagnosis regular screening purpose [8]. This evidence is further strengthened the weakness of X-ray mammography by Li Xu *et al*. [15] it have limit to apply in the early stage tumor detection. Even though in the field of medical imaging so far had a limited contributions, with the exception of magnetic resonance imaging (MRI) systems. Magnetic resonance imaging, useful for examining women with implants, is expensive and currently unproven as a screening tool [7]. But still it has some demerits like invasive detection, compression of the breast tissues, radiation and discomfort to the patient which should be rectified and can be rectified in the proposed microwave imaging methodologies [10]. Earlier, we focus at dielectric properties, where is include the permittivity and conductivity of materials in microwave imaging. Usually permittivity percentage between the normal and malignant tissues is 10-20% is enough to provide backscattered energy. Furthermore, dielectric properties of healthy or cancerous breast tissues at radio and microwave frequencies have been the subject of research since 1984; Chaudhary *et al*. [19] measurement in the frequency of 3MHz-3GHz, their research proven that the normal and malignant breast was discarded in dielectric properties A recently approached by Lazebnik *et al*. [20, 24-25] perform the dielectric properties by extensive characterization based on the different types of tissues. There are normal tissue, malignant tissue and breast tissues obtained from breast reduction and cancer surgeries. All types of tissues performed in the frequency range of 0.5-20 GHz.

The interest in the microwave imaging is at microwave frequencies. For several decades have been explored microwave frequencies have three breast imaging methods: breast imaging with passive, breast imaging with hybrid, and breast imaging with active. Passive methods incorporate radiometers to measure temperature differences in the breast, detecting tumors based on their increased temperature compared to healthy breast tissue and more translucent to microwaves then IR signals. Example of radiometers system is ONCOSCAN and another example is Dicke radiometer and incorporates six radiometers working in parallel to decrease acquisition time.

A hybrid method induces acoustic imaging, use microwave to illuminate the breast and more energy to selective and rapidly heat tumors. Ultrasound transducers detect pressure waves generated by the expansion of the heated tissues, filtered and record the signals transmitted through the object. And then time domain signals are recorded at a number of locations and displayed as an image. Clinical results have been obtained with CTT that show tissue structure in the breast [8]. STT has successfully imaged phantoms and clearly indicates interfaces between materials [8]. An active method is classical approaches to reflect microwave signals involve transmitters illuminating the breast with microwaves measured. Correlation between the incoherence, separation, object dimensions and contrast in properties of inhomogeneity making the inverse scattering problems difficult to solve at microwave frequencies but different with the wavelength where the wave go through various scattering together with the object to be reconstructed. In addition, some other approach namely confocal microwave imaging performing for active microwave breast imaging [8]. These three different methods to microwave breast imaging are illustrated in Figure-1.

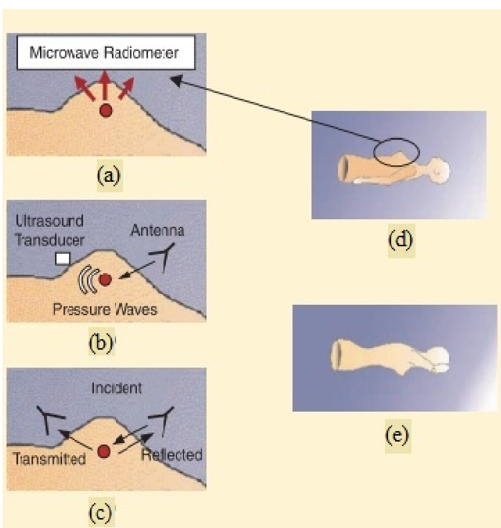

Figure-1. A methods of breast imaging at microwave frequencies: (a) Passive method implemented when had some area temperature increase which corresponds to tumors. (b) Hybrid method using heat with microwaves. Tissue expansion produced pressure waves and ultrasound transducers detect the pressure waves. (c) Active method has involve breast illuminated with microwaves and images formed by energy transmitted or reflected from breast. The Figures on the right showed the patient configurations for (d) planar and (e) cylindrical systems [8].

Some attention has been directed towards the microwave tomography and ultra-wideband (UWB) radar imaging for breast cancer detection because these techniques are still under development. In addition, most of the histological methods applied UWB radar imaging. In tomography image involves reconstructions using an inverse and forward scattering to recover the spatial distribution of the complete dielectric properties in the breast. In contrast to tomography, the proposed UWB radar approaches seek only to identify the existence and location of significant backscattered energy from malignant breast tumors [4].

For the latest method histological studies, method to estimate the risk for metastatic relapse or progression is the detection of circulating tumour cells (CTC) in cancer patients' blood by immune ocytochemical or molecular assays [22]. CTC to detect the few rare malignant cells in several millilitres of blood containing billions of red blood cells and tens of millions of leukocytes, extremely sensitive and specific methods are required that are able to process the large amount of cells in a relatively short period of time. However, the CTC still lack in the identification of markers specifying the metastatic potential of single CTCs and the selection and in-depth analysis of MICs with emphasis on druggable targets [22].

Confocal microwave imaging (based on radar imaging technique) [21] focuses backscattered signals to create images that indicate regions of significant scattering [8]. CMI detect and localize permitting millimetre - sized tumors after spatial focusing overcomes the challenges of breast heterogeneity and they simulate their data by using the finite-difference time-domain (FDTD) method. Furthermore, they illuminate the breast models with ultra-wideband (UWB) to obtain backscatter signals from the breast. The ultra-wideband nature of this approach enhances spatial resolution [8]. 5GHz bandwidth a required for 1 cm or less in breast tissue (assuming $\varepsilon r = 9$) resolution. From their observation, when frequency is increase the tendency tissues was loss so the upper limit frequency is around 10 GHz. Illuminated breast model simulating by an antenna excited with a differentiated Gaussian pulse which is their centre frequency near 4 GHz and full-width half-maximum bandwidth of 6 GHz. The only one antenna is present per simulation buy the way illuminating antenna record the reflections. The histological study the antenna is physically scanned to different locations, and simulations are repeated at each location when to create synthetic array. In addition, the focused at each element of the array from the record the reflections and then the images was form. In this context, reflections from the tumor to be the signal and all other contributions as clutter [8]. CMI was detected and localize the tumor and then the forming images with planar and cylindrical orientations are shown in Figure-2 as suggestion by Elise *et al*. [8].

METHODOLOGHYS

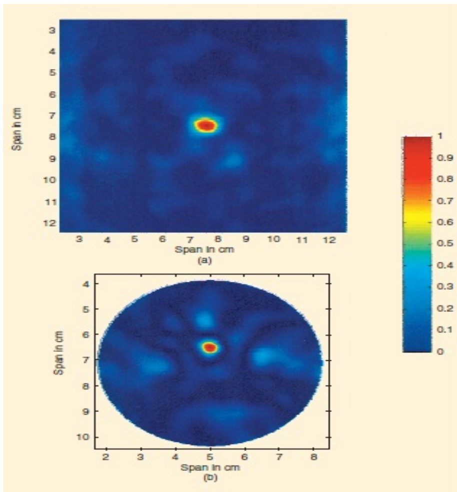

Figure-2. CMI images breast models shown: (a) planar system and (b) cylindrical system.

For the latest studies in microwave imaging is quasi-multistatic MIST beamforming method where is upgrade for the early detection of breast cancer while maintaining the characteristics of the previous nonionizing, no breast compression, less offensive than x-rays and low cost [12]. The significant dielectric contrast between normal and malignant breast tissues is the physical basis for microwave imaging. This physical basis must ensures that any tumor present in the breast tissue will provide backscattered energy because it used to detect the tumor after breast illuminating by microwave radiation. There are several different approaches for UWB radar imaging to acquire backscattered energy, so there have three categories which is monostatic, bistatic, and multistatic. Firstly, monostatic case is record the backscattered signal with the transmitting antenna itself. Synthetic aperture generated when the antenna emitted whole breast. The second is bistatic case uses two antennas, one single transmitting antenna and another one single receiving antenna. Lastly, multistatic case one transmitting antenna illuminates tissue the same period a network that has multiple antennas and placed it around the breast and recorded backscattered signal. In addition, the actual aperture used in multistatic system almost same with the synthetic aperture used in monostatic case can produce better imaging results where Xie *et al*. [26] was describe about approach of multistatic. The multistatic approach using received signals that propagate thru different paths to acquires more information about the tumor. In the multistatic approach, they only used subset of the multistatic channels which variant to resultant in “quasi-multistatic” [12] architecture. In addition, Craddock *et al*. [31] was developing multistatic imaging system while a simple delay and sum (DAS) [30], [32] and a robust capon beamforming (RCB) based adaptive method [33], [26]-[29] developed and proved for other multistatic imaging algorithms and measurement of phantom containing a malignant lesion simulating with endogenous dielectric properties. Changes in the dielectric properties of the contrast agents are considered inclusion and simulate a second set of measurements. Next the measurements will reconstructed individually by DBIM and changes between the two reconstructions is imaged.

For the 2D algorithm, it cannot detect the target accurately because the collection 2D imaged in–plane data in the region is so small to fall between two sequential imaging slices. Therefore, microwave image improve to 3D reconstruction scheme it depend with accuracy and quality in reconstructed images and the development it is depend on increment number of measurements in 3D data acquisition process. In past studies, the propagation fact of the electromagnetic field through the tissue 3 dimensional phenomenon by using parallel computing techniques graphical user interface (GUI) in MATLAB for reconstructing 3D microwave images [3]. Another study use conformal UWB sensor optimizations included the breast model tissue have been performed apply by Ansoft High-Frequency Structure Simulator (HFSSv11) software [16] and also the CST Microwave Studio 2008 has been used for time-domain pulse studies and the fidelity calculations a computer program has been written in MATLAB also.

DISCUSSIONS

In the present investigation, the hybrid methods use microwave to selectively heat to the high conductivity malignant tissues than surrounding normal tissues and ultrasound transducers expands heated tissues to detect pressure waves generating, so sense acoustic signals induction and produce the images [10].

Histological microwave tomography has two antennas; transmitting antennas illuminating the breast in the microwave region and receiving antennas collecting the scattering fields on particular domain. Then reconstructions approaches (proposed by different researchers) are used to reconstruct recover the spatial distribution of the complete dielectric properties in the breast. To get the function of position must determine the permittivity and conductivity distribution by observation of dielectric and/or conductivity profile of the breast [10]. It precedes the measured data in the form of scatters, i.e., the properties of the observed objects which differ from those in the normal or healthy state of the imaged volume. Thus, the tumor which is more electrically similar surrounded around the healthy tissue becomes more difficult to detect. In the electrical properties of a scatter to the host medium has some different which is in embedded and referred as “contrast” Contrast is ratio (percentage) between permittivity and/or the conductivity of the scatter to the host medium. The researcher was explained that permittivity and conductivity of the malignant tissues was higher when contrast between normal and malignant tissue is large.

Also, the presence the emerging ultra-wideband microwave (UWB) imaging gives better result with the advantages in detecting malignancies than existing one. Moreover, the breast tissue phantoms (artificial objects of human tissues or organs) are often used to illustrate the typical electrical parameters of breast tissues which are of the major type's lies in the frequency range of 3-10.6 GHz [6-8]. There is an electrical similarity between tumors and healthy fibroglandular tissues, but it varies in low-water-content fatty tissue. However, it does mean the researcher stop to develop this diagnostic systems even though X-ray mammography has the contrasts as low as 4-10% for breast-cancer diagnostics. The contrast agents are used to improve the imaging quality for microwave tissue imaging applications [10].

It is important to note this issue of the limited resolution of the imaging system. But Hagness *et al*. [2] were improved to determine detection sensitivity imaging system by using role of the regularization technique. Although the resolution of the imaging system can be improved, but still have issues on the basis of information independent for this technique. The issue occurred when the dimension of a tumor decreases into the regime below one half-wavelength; the magnitude of the scattering also decreases below the measurement sensitivity of the system. This problem also can exist even the dimensions is larger due to the low dielectric contrast between malignant and the healthy fibro glandular tissue. Lastly, the solving problem through the enhancement of tumor contrast with exogenous contrast agents and using differential imaging scheme to capture their effect [2].

CONCLUSIONS

Our study revealed several methods or techniques in detect the tumor. Our support those of other studies that the UWB radar imaging is good for making improvement. The present work detects how to upgrade the radar imaging 3 GHz which is can reduce the exposure to ionizing radiation. To get 3 GHz there should improvement the performance in the selection and development of imaging methods, regularization techniques, modeling, optimization and constraint solution.

The dielectric and/or conductivity profile of the breast used to determine the permittivity and conductivity distribution which is the function of position and then then the data in the form of scatters, namely the properties observed of the scatter to the host medium which is the imaged volume will measured. The important issue is in resolution remains and their fundamental is relying with wavelength, contrast, and measurement sensitivity points. By the way, the increment in information content of the measurement data directly has the potential to improve the detection performance of microwave.

REFERENCES

[1] E.C. Fear and M.A. Stuchly. 2000. Microwave Detection of Breast Cancer. IEEE Transactions on Microwave Theory and Techniques. 48(11).

[2] J.D. Shea, P. Kosmas, B.D. Van Veen and S.C. Hagness. 2010. Contrast-enhanced Microwave Imaging of Breast Tumors: A Computational Study using 3-D Realistic Numerical Phantoms.

[3] Amir H. Golnabi, Paul M. Meaney, Neil R. Epstein and Keith D. Paulsen. 2011. Microwave Imaging for Breast Cancer Detection: Advances in Three-Dimensional Image Reconstruction.

[4] Xu Li, Shakti K. Davis, Susan C. Hagness, Daniel W. van der Weide and Barry D. Van Veen. 2004. Microwave Imaging via Space-Time Beamforming: Experimental Investigation of Tumor Detection in Multilayer Breast Phantoms. IEEE Transactions on Microwave Theory and Techniques. 52(8).

[5] Essex J. Bond, Xu Li, Susan C. Hagness and Barry D. Van Veen. 2003. Microwave Imaging via Space-Time Beamforming for Early Detection of Breast Cancer. IEEE Transactions on Antennas and Propagation. 51(8).

[6] Werner Wiesbeck, Grzegorz Adamiuk and Christian Sturm. 2009. Basic Properties and Design Principles of UWB Antennas. Invited Paper, Proceeding of the IEEE. 97(2).

[7] Committee on Technologies for the Early Detection of Breast Cancer. 2001. Mammography and Beyond: Developing Technologhies for the Early Detection of Breast Cancer. S.J. Nass, I.C. Henderson, and J.C.Lashof, Eds. National Cancer Policy Board, Institute of Medicine, and Commision on Life Studies, National Research Council.

[8] Elise C. Fear, Susan C. Hagness, Paul M. Meaney, Michal Okoniewski and Maria A. Stuchly. 2002. Enhancing Breast Tumor Detection with Near-Field Imaging. IEEE Microwave Magazine.

[9] Susan C. Hagness, Elise C. Fear and Andre Massa, Guest Editorial. 2012. Special Cluster on Microwave Medical Imaging. IEEE Antennas and Wireless Propagation Letters. Vol. 11.

[10] S. Raghavan and M. Ramaraj. 2012. An Overview of Microwave Imaging towards for Breast Cancer Diagnosis. Progress in Electromagnetics Research Symposium Proceedings, Moscow, Russia, August 19-23.

[11] Xu Li, Essex J. Bond, Barry D. Van Veenand Susan C. Hagness. 2010. An Overview of UltraWideband Microwave Imaging via Space-Time Beamforming for Early-Stage Breast-Cancer Detection. 8 October.

[12] Martin O'Halloran, Edward Jones and Martin Glavin. 2010. Quasi-Multistatic MIST Beamforming for the Early Detection of Breast Cancer. IEEE Transactions on Biomedical Engineering. 57(4).

[13] Xubo Wang, AnhDinh and Daniel Teng. 2010. A Carrier-based UWB Transceiver in CMOS 90nm for Biomedical Radar Sensing and Sensor Communications. Proceedings of 2010 IEEE International Conference on Ultra-Wideband.

[14] T. Bertuch, P. Knott, H. Wilden, O. Peters. 2011. Wide-Band Radar Front-End Calibration for Imaging SAR Experiments with Conformal Antenna Array. EuCAPConvened Papers.

[15] Li Xu, Xia Xiao, Takamaro Kikkawa. 2013. Ultra-wide band microwave image reconstruction for early breast cancer detection by norm constrained capon beamforming. Mathematical and Computer Modelling. 58: 403-408.

[16] Seyed Mohammad reza Razavi zadeh. 2013. A New UWB Link Set-Up for Breast Tumor Detection. IEEE, Broadcast Engineering Department of IRIB University, Tehran, Iran.

[17] Qian Zhou, Zhiqun Li, Zongming Duan, Zengqi Wang. 2013. Design of 2-3.5GHz Transmitter Front-End. 3rd International Conference on Multimedia Technology (ICMT).

[18] Y.L. Qi, X.L. Yang, W.X. Tan, Y.P. Wang and W. Hong. 2013. Research on the Microwave Snapshot Imaging Radar Based on Antenna Array. Science and Technology on Microwave Imaging Laboratory, Beijing, China.

[19] S.S. Chaudhary, R.K. Mishra, A. Swarup and J.M. Thomas. 1984. Dielectric properties of normal and malignant human breast tissues at radiowave and microwave frequencies. Indian J. Biochem. Biophys. 21: 76-79.

[20] Abas Sabouni, Camerin Hahn, SimaNoghanian, Edward Sauter and Tim Weiland. 2013. Study of the Effects of Changing Physiological Conditions on Dielectric Properties of Breast Tissues. ISRN Biomedical Imaging. pp. 1-5, Vol. 2013.

[21] Meilian Xu, Parimala Thulasiraman and Sima Noghanian. 2011. Microwave tomography for breast cancer detection on Cell broadband engine processors. Journal of Parallel Distributed Computing.

[22] Simon A. Joosse and Klaus Pantel. 2013. Biologic Challenges in the Detection of Circulating Tumor Cells. American Association for Cancer Research, January 2.

[23] Bouzid Mhamdi, KhaledGrayaa, TaoufikAguili. Microwave imaging of dielectric cylinders from experimental scattering data based on the genetic algorithms, neural networks and a hybrid micro genetic algorithm with conjugate gradient.

[24] M. Lazebnik, L. McCartney, D. Popovic *et al*. 2007. A large-scale study of the ultrawideband microwave dielectric properties of normal breast tissue obtained from reduction surgeries. Physics in Medicine and Biology. 52(10): article 001, 2637-2656.

[25] M. Lazebnik, D. Popovic, L. McCartney *et al*. 2007. A large-scale study of the ultrawideband microwave dielectric properties of normal, benign and malignant breast tissues obtained from cancer surgeries. Physics in Medicine and Biology. 52(20): 6093-6115.

[26] Y. Xie, B. Guo, L. Xu, J. Li, and P. Stoica. 2006. Multistatic adaptive microwave imaging for early breast cancer detection. IEEE Trans. Biomed. Eng. 53(8): 1647-1657.

[27] Y. Xie, B. Guo, J. Li, and P. Stoica. 2006. Novel multistatic adaptive microwave imaging methods for early breast cancer detection. EURASIP J. Appl. Signal Process. 2006: 1-13, (Article ID 91961).

[28] B. Gao, Y. Wang, J. Li, P. Stoica and R. Wu. 2005. Microwave imaging via adaptive beamforming methods for breast cancer detection. Presented at the Prog. Electromagn. Res. Symp., Hangzhou, China.

[29] B. Gao, Y. Wang, J. Li, P. Stoica and R. Wu. 2006. Microwave imaging via adaptive beamforming methods for breast cancer detection. J. Electromagn. Waves Appl. 20: 53-63.

[30] R. Nilavalan, S. Hagness and B. D. Van Veen. 2003. Numerical Investigation of breast tumour detection using multi-static radar. Inst. Electr. Eng. Electron. Lett. 39(25): 1787-1789.

[31] I. J. Craddock, R. Nilavalan, A. Preece and R. Benjamin. 2005. Experimental investigation of real aperture synthetically organised radar for breast cancer detection. In Proc. IEEE AP-S Int. Symp. Washington, DC. 1B: 179-182.

[32] X. Li and S. Hagness. 2001. A confocal microwave imaging algorithm for breast cancer detection. IEEE Microwave Wireless Compon. Lett. 11(3): 130-132.

[33] E. Fishler, A. Haimovich, R. Blum, D. Chizhik, L. Cimini and R. Valenzuela. 2004. MIMO radar: An idea whose time has come. In Proc. IEEE Radar Conf., Philadelphia, PA. pp. 71-78.