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# EARLY STAGE CANCER DETECTION TECHNIQUE CONSIDERING THE REFLECTED POWER FROM BREAST TISSUES

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**ABSTRACT**

Ultra wideband (UWB) microwave imaging is the popular image reconstruction technique to be integrated in a medical equipment applied for early breast cancer detection system. The constructed breast cancer detector is low complexity, high accuracy rate, easy to perform tumour detection and low-cost production. To numerically design and to evaluate the electrical properties of the antenna system, a 3D homogeneous breast phantom and their interactions Ansoft HFSS v13 and CST Microwave Studio softwares were utilized. The operational bandwidth of the designed antenna ranges from 3.5 GHz to 7.2 GHz. In fact, the numerical evaluations were carried-out to determine the effect of various tumour sizes (10 mm, 20 mm and 30 mm) and the impact of the distance variations between the breast phantom surface and the tumour position. Towards the appropriate studies the reflected power analysis of the recorded return loss values was undertaken. The simulation results show that by increasing the tumour size, the received reflected power decreases. The effective distance of the early breast cancer monitoring system to work properly is less than 2 cm between tumour and breast phantom surface.

**Keywords:** UWB Microwave imaging, breast cancer, breast tissue, cancer detection, UWB antenna.

## INTRODUCTION

X-Ray Mammography is the most popular technique to apply for tumour detection of breast cancer. However, this method suffered from several limitations. It is ionized radiation with high power microwave electromagnetic waves and frequency more than $10^{15}$ Hz and make electrons bound to atoms and mutate into malignant (Wasusathien *et al.*, 2014) Other limitations include uncomfortable to the patient due to breast compression during examination, high error rate, low sensitivity to detect tumour (Xie *et al*., 2006), (Zhang *et al.*, 2008). This method was also limited to use for specifically applied for the early cancer detection in younger woman with high breast density (Klemm *et al.*, 2009).

For more a decade, researchers have been highly motivated to develop various innovative medical stuffs applicable for a real-time and reliable deseases detection mechanism. Ultra Wide Band (UWB) technique offers a standard to achieve that prime target. In general, UWB medical detection and monitoring system operated under the unlicensed frequencies range spanned from 3.1 GHz to 10.6 GHz according to standards in U.S.A (FCC, 2002), from 3.4 GHz to 8.5 GHz in Europe (ETSI, 2008) and from 2.2 GHz to 10.6 GHz in Singapore (IDA) (Areni *et al.*, 2014), (Karli *et al.*, 2014). UWB signals are non-ionizing radiation and very effective to penetrate into human body tissue. Furthermore, UWB pulses are generally shorter than the target dimensions. Thus, this method is very suitable for biomedical applications because of non-destructive visualization of human organs (Tiang *et al.*, 2014). Antenna as an essential element in any wireless communication systems, in practical manufacturing process of UWB medical equipment, was used as the primary detection tools. The use of antenna to design biomedical applications, especially for cancer detection is increasing during the past few years (Hanafy *et al.*, 2014).

The integration of UWB technology in large varieties of biomedical applications is quite promising and is mostly employed as the medical imaging technique well-known as UWB microwave imaging. The technique is also very attractive to apply for the construction of the breast cancer detection pheripheral. The final design of the medical detection and monitoring prototype is highly possible to be very low complexity; compact antenna, RF, and DC circuits design; users friendly; and inexpensive cost. The use of a wide bandwidth in UWB technology (>500 MHz) allows to reconstruct images with high resolution.

This method is a new approach in imaging technique that employing the antenna stuff to radiate UWB microwave signals onto the breast surface. Backscattered signal generated from the breast tumours will be captured and processed by the antenna unit and the signal processing part, respectively, to determine the tumour presence and to identify the tumour location that might be grow-up on the breast (Bryne *et al.*, 2011), and (Davis *et al.*, 2008).

Various research activities have been reported that utilized the different antenna types for the microwave imaging applications. The interesting research results could be explored in (Xuyang *et al.*, 2015) and N. Ojaroudi and N. Ghadimi (2015). Early stage studies of UWB microwave imaging system

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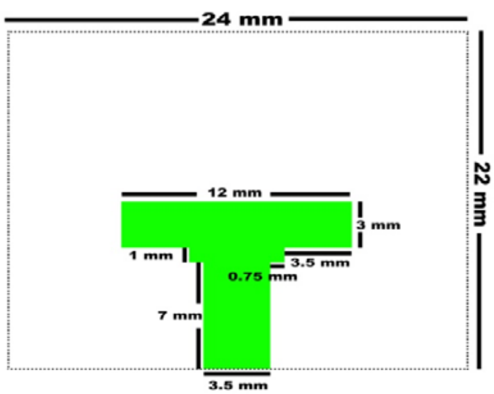
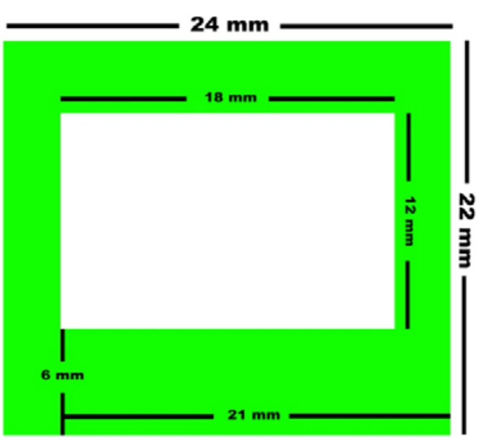
developed at the Department of Electrical Engineering, University of Hasanuddin (UNHAS) was performed by designing the UWB microstrip antenna to meet the UWB technology standard for the medical application. The numerical evaluation of the constructed medical detection system applied for the early breast cancer later tested by inserting the designed homogeneous breast phantom located at the close proximity of the antenna part. The main aims to achieve through the numerical testing is to evaluate how powerful the designed breast cancer detector and monitoring system could perform in a particular condition. The developed medical stuff is expected to accurately and to efficiently performing the highly challenging tasks, i.e. to detect the location and to estimate the size of tumour existed on an homogeneous breast phantom based on the analysis of the return loss characteristic variations.




(a)

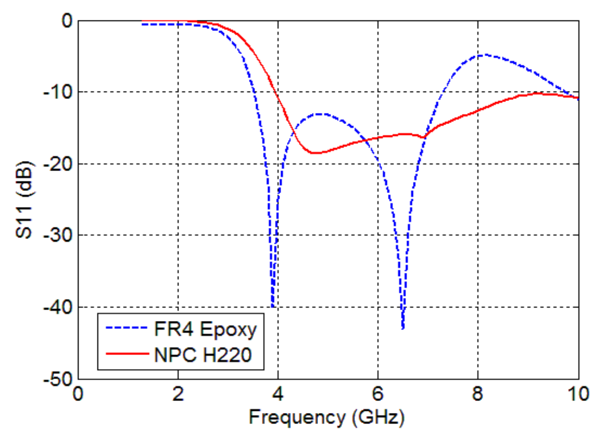



(b)

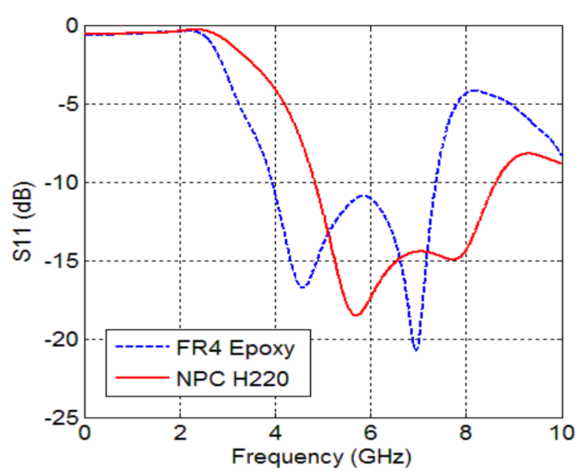
**Figure-1.** Basic structure of UWB microstrip antenna (a) Top View (b) Bottom View.

## UWB ANTENNA MODELLING CONSTRUCTED FOR EARLY BREAST CANCER DETECTION

The modelling of UWB breast cancer detection system performed using Ansoft High-Frequency Structure Simulator (HFSS) v13 and CST Microwave Studio 3D-modelling tools. The main part of the electronic breast cancer detector system is in the form of the antenna unit functioned as the microwave radiating element. During the construction, the antenna unit performance was evaluated using various dielectric materials which formed the antenna patch structure. The generated antenna electrical properties resulted from the numerical computation is then compared to verify the best radiator design outcome. First evaluation carried out by using FR4 Epoxy materials with relative permittivity of 4.4 and loss tangent of 0.02 as the dielectric substrate of the patch. However, in the second evaluation NPC H220 materials with relative permittivity of 2.17 and loss tangent of 0.0005 was used. The basic structure and dimension of antenna is shown in Figure-1. This UWB antenna has a substrate dimensions of 24 mm x 22 mm.




(a)




(b)

**Figure-2.** Simulation results of $S_{11}$ characteristic (a) Ansoft HFSS v13 (b) CST microwave studio.

The numerical evaluation results of the designed antenna with two different dielectric materials are shown in Figure-2. By employing the FR4 Epoxy materials as the substrate of the antenna design may force the radiator to operate in frequency range of 3.5 - 7.2 GHz (3700 MHz bandwidth). While using NPC H220 material as the dielectric substrate of the patch antenna structure the operating will be having the execellent working region at the frequency range of 4-9 GHz (5000 MHz Bandwidth) as shown in Figure-2(a)

In Figure-2 (b), the simulation result implies that the attachment of FR4 Epoxy materials as the dielectric part of the constructed patch antenna for imaging purpose effects to the alteration of resonance frequency. This testing generates the better frequency operation at the range of 4-7.3 GHz (3300 MHz Bandwidth). Meanwhile, by using NPC H220 material, antenna will be well operated in the frequency band of 4.8 - 8.6 GHz (provide 3800 MHz Bandwidth). The evaluation of the two materials with different simulators, i.e. HFSS and CST, showed that the antenna performance operates in a wide bandwidth and meet the technical specification of UWB technology standard. The designed antenna is suitable to use for biomedical applications, especially in breast cancer detection.

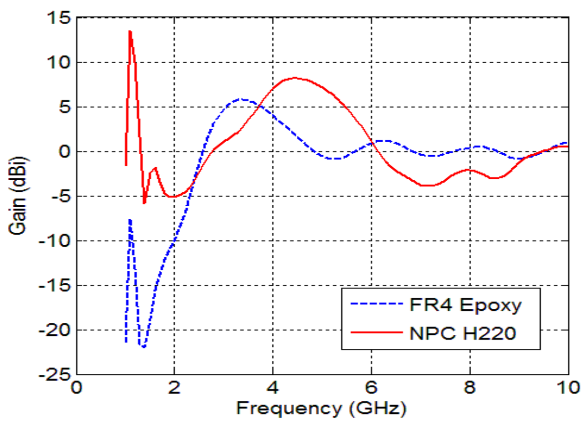
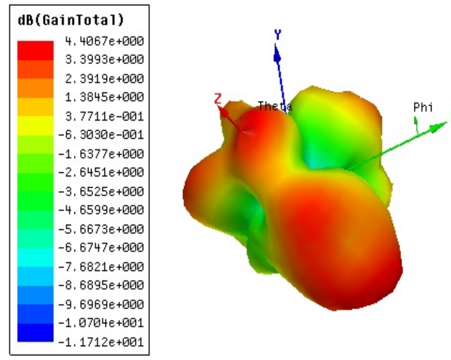
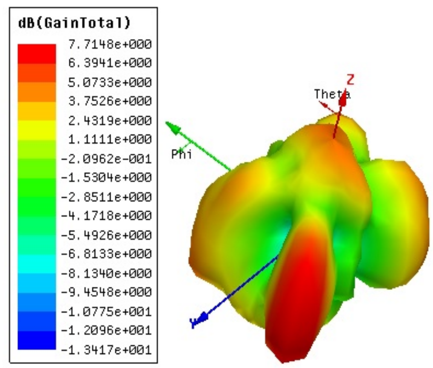



**Figure-3.** Gain comparison of the constructed antenna using two different dielectric materials (i.e. FR4-Epoxy and NPC H220).




(a)




(b)

**Figure-4.** 3D radiation patterns: (a) FR4 epoxy materials (b) NPC H220 materials.

The gain performance of each antenna design, whether using FR4-Epoxy or NPC H220, exhibited two different gain profiles as the function of the frequency operation (see Figure-3). The insertion of FR4-Epoxy as the patch dielectric substrate may force the antenna to be better working on the lower frequency band than the NPC H220 used. The use of NPC H220 will attract the cancer monitoring system to be more powerful to operate at the higher frequency range. The gain of more than 7 dBi could be achieved at the resonant frequency 4.5 GHz. While using FR4-Epoxy the antenna gain provided is approximately 6 dBi at the resonant frequency 3.5 GHz.

The 3D Radiation pattern of UWB microstrip antenna design with two different dielectric materials exhibited very good power radiation in a particular direction. The 3D- pattern properties are shown in Figure-4.

## THE EVALUATION OF ANTENNA DESIGN FOR TUMOUR IDENTIFICATION

The numerical testing to evaluate of how the breast cancer detection system performing the tricky and very challenging function for tumour identification is

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depicted in Figure-5. As clearly seen in the figure that the microstrip antenna design and 3D model homogeneous breast phantom which consists of skin layer, fatty tissue and tumour were computed using the different dielectric characteristics. The dielectric properties of the constructed breast tissues are tabulated in Table-1.

**Table-1.** Dielectric properties of breast phantom.

| | $\varepsilon_r$ | $\mu_r$ | **σ (S/m)** |
|---|---|---|---|
| Skin | 36.587 | 1 | 2.3404 |
| Fatty Tissue | 4.8393 | 1 | 0.26229 |
| Tumour | 67 | 1 | 49 |

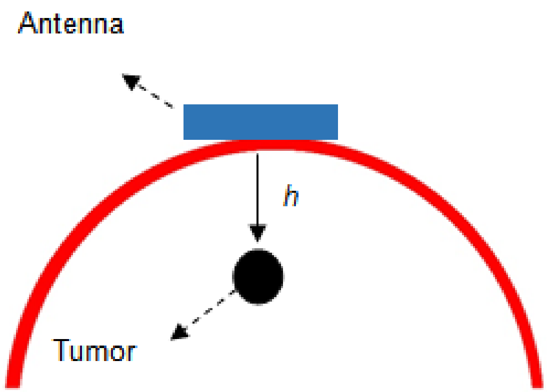


**Figure-5.** The numerical evaluation to studi the reflected signal power variations obtained that scattered back from the breast tissue structures.

The tumour identification process utilizing the constructed breast cancer detector system was numerically tested by collecting the reflected power (~ $S_{11}$ value) of each antenna position. In practice, the antenna unit was moved gently and keep the distance *h* constant to cover all the breast surface (see Figure-5). One should notice that while breast cancer detector is manufactured later on the most common dielectric material available in the local market is in the form of FR4 Epoxy substrate. The dielectric substrate is widely used in the PCB (printed circuit board) material. Therefore, the main concern of the breast cancer detector testing is to focus the experiment to characterize its performance using FR4-Epoxy. The simulation were carried out by changing distance between the breast phantom surface and tumours (*h*) up to maximum limit of breast size using three tumour size variations (10 mm, 20 mm and 30 mm) to evaluate and to analyze the recorded return loss values in the best resonant frequency.

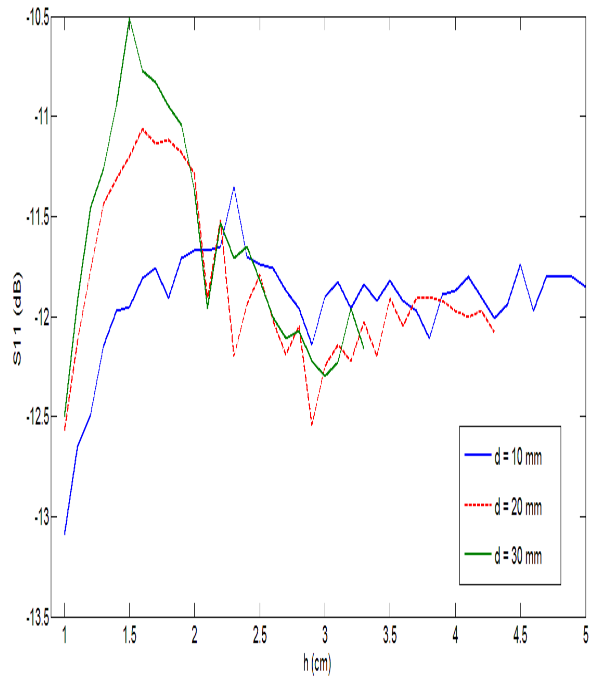


**Figure-6.** The effect of the distance (*h*) and tumour size (*d*) alterations to the return loss value variations.

Figure-6 shows that the size of the tumour will significantly affect on the alteration of the return loss values. The larger the tumour size causes the more power absorbtion suffered by the incident power that illuminated from the antenna system (or the breast cancer detector system). Thus the received reflected power will be smaller. The simulation results show that the effective range to detect the presence of tumours in the breast phantom by analysing the return loss value is at distance of less than 2 cm from the breast phantom surface.

To verify the effect of the tumour size and the distance ***h*** between the breast phantom surface and tumours to obtain the value of the recorded return loss can be performed based on the generated E-Field distribution pattern. This pattern could be completely found while using CST Microwave Studio. The interesting illustration regarding the E-Field distribution pattern recorded during the numerical testing is shown in Figure-7. Figure-7 (a) shows that the maximum radiation energy can still be absorbed by the tumour with tumour size of 10 mm located at the distance *h* of 1 cm. By shifting the tumour position on the z-axis up to *h* of 3 cm causes the received power at tumour is smaller than *h* of 1 cm. This is clearly described in Figure-7 (b).

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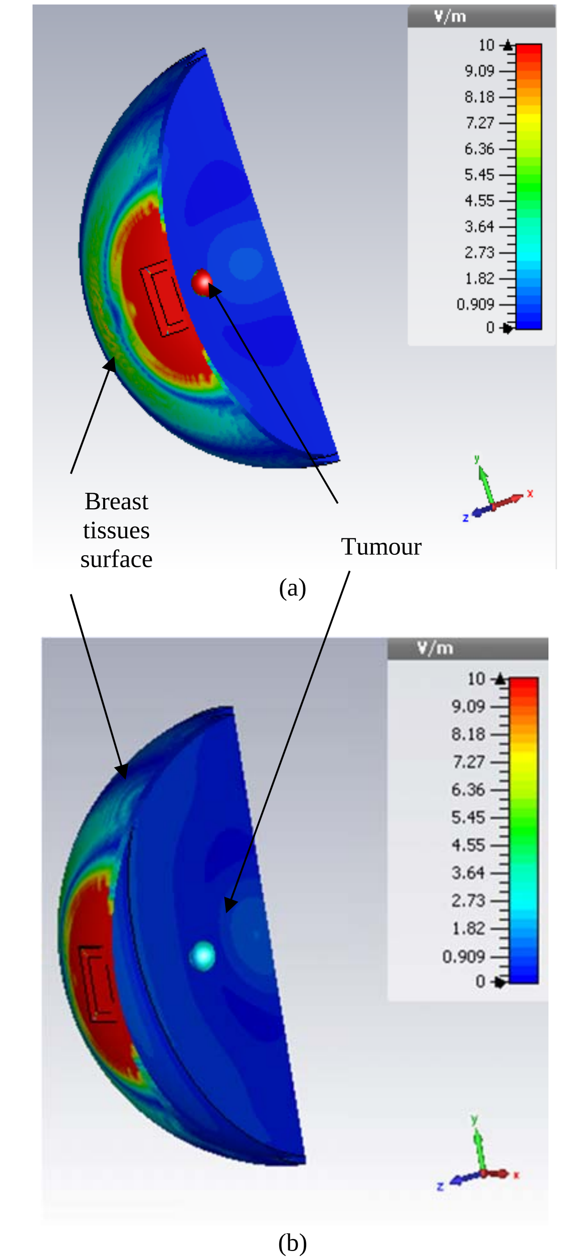


**Figure-7.** E-Field distribution pattern while a tumour existed inside the breast tissue (a) The tumour size of 10 mm at distance of 1cm (b) The tumour size of 10 mm at the distance of 3cm.

One of the very challenging tasks on testing the performance of the constructed breast cancer detection and monitoring system employing the UWB microwave imaging technique is to estimate and to identify the appropriate location and the size of the tumour. There is many technical approach have been proposed previously to address the imaging issue of the breast cancer. The recent research report, for instance in Yin *et al.*, (2015), implemented the breast imaging technique by adopting the robust and artifact resistant (RAR) algorithm to minimize the effect of the summing both the incident signals and skin-fat interface reflections. The algorithm was applied to reconstruct the 3D-image of the breast appropriately by removing the unintended signals to the backscattered signals to obtain the better quality of the breast 3D-image.

However to estimate and to identify the appropriate location and the size of the tumour grow-up inside the breast structure the simple and accurate algorithm could be exploited to achieve the main target of the cancer detection and identification. The numerical experiment as clearly describing in Figure-5 was consistently performed to record the intended reflected power received from the whole breast surface. Figure-8 (a) resembles the breast surface area (viewed from the top side) would be scanned using the applied UWB microwave imaging technique. In the practical evaluation, the whole area and its corresponding $S_{11}$ value (resembles the amount of backscattered power processed further in the microwave imaging equipment) is plotted into the different pixel (15x15 pixels totally). Each received power will be assigned with the different color code, respectively. The antenna system is gently shifted every 12 mm step, whether to move to the right or left sides and to move to the up or to bottom sides, to cover the whole breast surface area. The current numerical testing considered that location of the tumour was assumed to be positioned at the centre point (X-axis = 0 mm and Y-axis = 0 mm). Through the simple imaging technique of the reflected power receiving in the breast cancer detector as portrait in Figure-8 (b) the location and the size of the tumour could be accurately determined.

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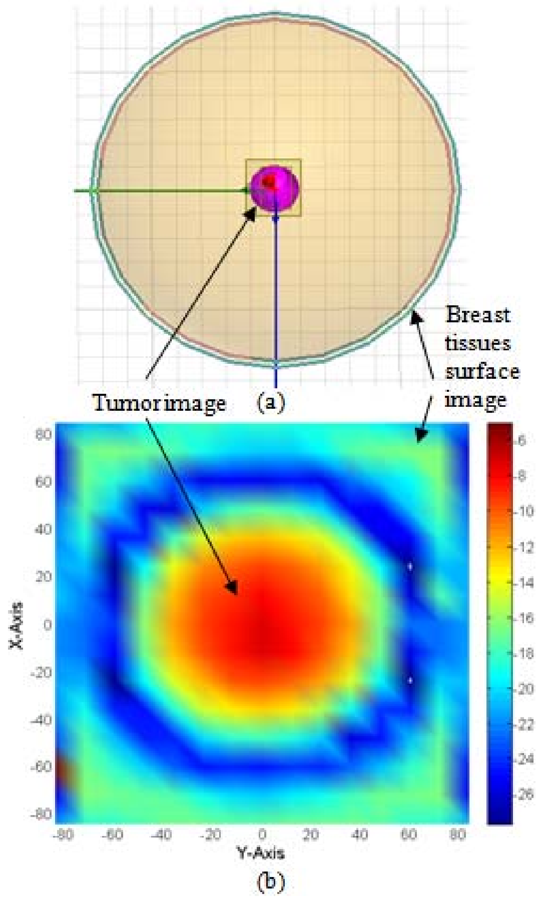


**Figure-8.** 2D-imaging method to estimate the position of the tumour existed inside the breast tissue structure: (a) the breast model viewed from the top (b) the 2D-image for each breast tissue layer based on the different value of reflected power (or $S_{11}$ value).

## CONCLUSIONS

Tumour identification suitable for the early breast cancer detection based on the reflected power analysis from the illuminated breast tissue has been discussed. The simulated antenna has the operation frequency range spanned from 3.5 up to 7.2 GHz and a gain of 4.4 dBi at 3.9 GHz resonance frequency. The antenna and the 3D homogeneous breast phantom have been designed using Ansoft HFSS v13 and CST Microwave Studio. The simulation results show that the greater the size of the tumour existed inside the breast tissue the better the return loss produced. One of the possible reasone that could explain this phenomenon is because the more reflected power received from both the fat and tumour tissues. The effective distance between the surface and the breast tumour phantom is at a distance of less than 2 cm.

## REFERENCES

[1] Wasusathien, W. Santalunai, S. Thosdeekoraphat, T. and Thogsopa, C. 2014. Ultra Wideband Breast Cancer Detection by Using SAR for Indication the Tumour Location. International Journal of Medical, Health and Biomedical and Pharmaceutical Engineering. Vol: 08, No: 7, 2014.

[2] Xie, Y. Guo, B. Xu, L. Li, J and Stoica, P. 2006. Multistatic Adaptive Microwave Imaging for Early Breast Cancer Detection. IEEE Transaction on Biomedical Engineering, Vol. 53, No.8, August 2006.

[3] Zhang, H. Tan, S. Y. and Tan, H. S. 2008. A Novel Method for Microwave Breast Cancer Detection. Progress In Electromagnetic Research, PIER 83, 413-434, 2008.

[4] Klemm, M. Craddock, I.J. Leendertz, J.A. Preece, A. and Benjamin, R. 2009. Radar-Based Breast Cancer Detection Using a Hemispherical Antenna Array - Experimental Results. IEEE Transactions on Antennas and Propagation, Vol. 57, No. 6, June 2009.

[5] Areni, I.S. Palantei, E. Amir, A. Sudirman, A. Buwarda, S. Pratiwi, A.A. Amaliah, A. and Dewiani. 2014. Numerical Evaluation of UWB Antenna Design for Breast Cancer Detection Application. Proceedings Seminar Nasional Microwave Antena dan Propagasi (SMAP) 2014. ISSN : 2252-701x [Indonesia].

[6] Karli, R. Ammor, H. and El Aoufi, J. 2014. Miniaturized UWB Microstrip Antenna for Microwave Imaging. WSEAS Transactions on Information Science and Applications. Volume 11, 2014. E-ISSN: 2224-3402.

[7] Tiang, S. S. Hathal, M. S. Nik Anwar, N. S. Ain, M. F. and Abdullah, M. Z. 2014. Research Article : Development of a Compact Wide-Slot Antenna for Early Stage Breast Cancer Detection Featuring Circular Array Full-View Geometry. Hindawi Publishing Corporation International Journal of Antennas and Propagation Volume 2014, Article ID 309321, 11 pages.

[8] Hanafy, E.A.E.D and Allam, A. 2014. Diagnosis of Breast Tumours using a PIFA antenna. International Journal of Computer and Information Technology (ISSN: 2279-0764 ). Vol. 03 - Issue 05, September 2014.

ARPN Journal of Engineering and Applied Sciences



[9] Bryne, D. O'Halloran, M. Glavin, M. and Jones, E. 2011. Breast Cancer Detection Based on Differential Ultrawideband Microwave Radar. Progress In Electromagnetic Research M. Vol. 20, 231-242, 2011.

[10] Davis, S. K. Veen, B.D.V, Hagness, S.C. and Kelcz, F. 2008. Breast Tumour Charaterization Based on Ultrawideband Microwave Backscatter. IEEE Transaction on Biomedical Engineering. Vol 55 No. 1 January 2008.

[11] Xuyang Li, Jalilyand M, Sit YL, Zwick T., 2015. A Compact Double-Layer On-Body Matched Bowtie Antenna for Medical Diagnosis. IEEE Transactions on Antenna and Propagation (IEEE TAP). Vol: 62, Issue 4, 2015, pp.1808-1816.

[12] N. Ojaroudi and N. Ghadimi. 2015. Omnidirectional Microstrip Monopole Antenna Design for Use in Microwave Imaging Systems. Microwave and Optical Technology Letters. Vol. 57, No.2, February 2015, pp. 395-401.

[13] Yin, T. Ali, F.H. and Reyes-Aldasoro, C. C. 2015. A Robust and Artifact Resistant Algorithm of Ultrawideband Imaging System for Breast Cancer Detection. IEEE Transactions on Biomedical Engineering. Vol. 62, Issue 6, June 2015, pp. 1514-1525.