Ultra Wideband Breast Cancer Detection by Using SAR for Indication the Tumor Location

Wittawat Wasusathien, Samran Santalunai, Thanaset Thosdeekoraphat, Chanchai Thongsopa

***Abstract*—**This paper presents breast cancer detection by observing the specific absorption rate (SAR) intensity for identification tumor location, the tumor is identified in coordinates (x,y,z) system. We examined the frequency between 4-8 GHz to look for the most appropriate frequency. Results are simulated in frequency 4-8 GHz, the model overview include normal breast with 50 mm radian, 5 mm diameter of tumor, and ultra wideband (UWB) bowtie antenna. The models are created and simulated in CST Microwave Studio. For this simulation, we changed antenna to 5 location around the breast, the tumor can be detected when an antenna is close to the tumor location, which the coordinate of maximum SAR is approximated the tumor location. For reliable, we experiment by random tumor location to 3 position in the same size of tumor and simulation the result again by varying the antenna position in 5 position again, and it also detectable the tumor position from the antenna that nearby tumor position by maximum value of SAR, which it can be detected the tumor with precision in all frequency between 4-8 GHz.

***Keywords*—**Specific absorption rate (SAR), ultra wideband (UWB), coordinates and cancer detection.

I. Introduction

BREAST cancer is the most of cancer that can be occurred in women, and it is the killer of the women over 40 years old. The American statistics in 2013 are exhibited, an estimated of women over 40 years old are In Situ 64,640 cases, invasive 232,340 cases, and death 39,620 peoples. Form the statistics, it shown that breast cancer is the main problem in women [1].

In currently, breast cancer detection technology that used to diagnosing the breast have been widely, include X-ray (Mammography), Ultrasound, MRI (Magnetic Resonance Imaging), and other. However, these technologies have some issue form limitations. Such as, compression of the breast and ionizing radiation form X-ray which using very high energy electromagnetic radiation and frequency more than 10^{15} Hz, that made the electron is unbound form the atom, and mutated to malignant [2], ultrasound is the basic technique for diagnosing breast tumor, but this technology is very low potential to used for detection, because of an ultrasound is used echo of sound wave and the reflection of sound wave will be processed to breast image and wave reflect accuracy is depended on body dimension, that made an ultrasound have high false rate, MRI is a kind of high performance technology by using magnetic field to align the protons of the hydrogen atom to be resonance, and used radio frequency signal to triggered to produce high resolution images, but disadvantage of MRI is along with the high costs associated with MR imaging and very complex.

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Recently, in a medical application the microwave frequency has been applied for breast tumor detection. Microwave breast cancer detection is an alternative of low costs technique and noninvasive for detected the tumor. It can be avoidable an ionizing radiation and compression of the breast, and have high accuracy to detected breast tumor. The basic technique for detecting breast tumor is based on significant of dielectric property that contrast between normal tissues and malignant tissues at the microwave frequency. As a high dielectric property of malignant tissues, therefore, electric field and absorption loss will more than normal tissues, so we can be identified breast tumor location [3]-[5].

In this paper is presented UWB breast cancer detection by using electric field. A system overview on this research is based on electric field intensity of tissues and can identify the breast tumor location. Breast tumor will be detected due to dielectric property that large difference between normal breast tissues and malignant tissues. For an overview of this system, the UWB patch antenna is used for transmitter [6], breast phantom model is considered in fatty tissue only, skin, glandular and other tissues are ignored to reduce the system complication. The results are created and simulated by using CST Microwave Studio. The work is proposed breast cancer detection by considering SAR intensity. System model is portioned to two sections, that is breast model and antenna model, breast model is created in normal breast and breast embedded tumor cell with dielectric property that realistically, and the antenna is used for UWB patch antenna that have characteristic of S11 below -10 dB at 3.6 - 8.4 GHz. This work is simulated by using CST microwave studio. 4-8 GHz of Frequency is used to simulation the breast cancer detection at random location of tumor, by changing the antenna for five locations and observed maximum value of SAR for identified tumor location.

II. Models

A. Breast and Tumor

In the development and study of breast phantom model, it is important to have a basic understanding of the anatomy. The female breast has three major breast structures: adipose tissue, Glandular tissue, and connective tissue, and dielectric property in each tissue are studied too.

The breast model in this paper is ignored other structures except an adipose tissue, that make it simple to analyzed the result. The breast model is created as a hemispherical shape, with radians of 50 mm, and tumor model is created as a spherical shape, with diameters of 5 mm. Dielectric property is modeled by using Debye dispersion [9]-[11], and can be obtained normal breast (fatty) and tumor dielectric property that shown in Table I at 6 GHz.

TABLE I
DIELECTRIC PROPERTY AND CONDUCTIVITY OF BREAST AND TUMOR MODEL AT 6 GHZ [10]

	Fat	Tumor
ε_r	9.5	46
σ (S/m)	0.4	3.4

B. UWB Antenna

The propose UWB antenna that used for this paper is a bowtie patch antenna [6]-[8]. The antenna consists of half bow shape with two sides with symmetrical shape, and ground plane at the bottom of patch. A PCB type FR-4 is used for antenna design, substrate thickness 0.8 mm with dielectric constant 4.5 and loss tangent 0.02, and copper thickness 0.035 mm. The geometry of bowtie patch antenna is illustrated in Fig. 1 and dimension of this antenna is shown in Table II with $\theta_1 = 45^{\circ}$ and $\theta_2 = 144^{\circ}$. The operational bandwidth of UWB antenna should be return loss below -10 dB in range of 3.1 – 10.6 GHz. In this antenna, the simulation result of return loss of antenna is illustrated in Fig. 2 with 3.6-8.4 GHz at S11 below -10 dB. An antenna is used discrete port and excitation signal by using Gaussian pulse 10 GHz bandwidth with amplitude 1 V.

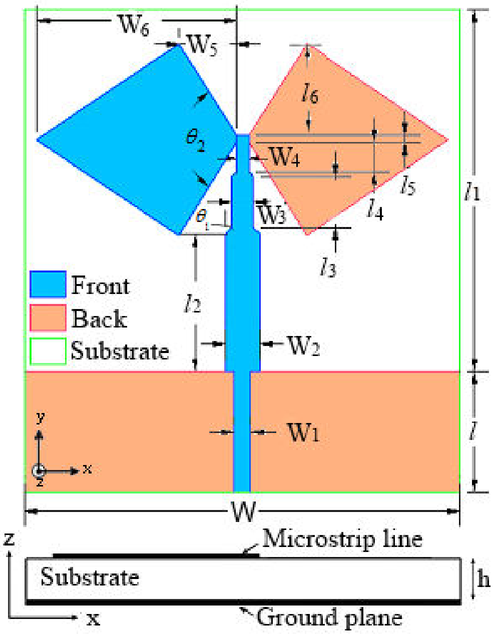

Fig. 1 UWB bowtie patch antenna geometry [6]

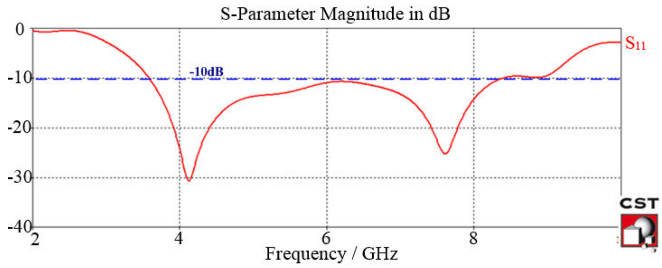

Fig. 2 S11 characteristics of UWB bowtie patch antenna with return loss below -10 dB between 3.6 – 8.4 GHz

TABLE II
UWB BOWTIE PATCH ANTENNA PARAMETER DIMENSION

Parameter	Dimension (mm)
W	36.5
W_1	2
W_2	3
W_3	2.5
W_4	1.5
W_5	3.5
W_6	13.5
l	10.5
l_1	30
l_2	10.5
l_3	3.65
l_4	2
l_5	1.5
l_6	6.85

C. Specific Absorption Rate (SAR)

SAR is a measure of the rate at which energy is absorbed by the human body when exposed to electromagnetic field [12], [13]. For related to electromagnetic energy, it can be calculated from electric field in tissue as (1)

$$SAR = \frac{\sigma |E|^2}{\rho} \quad (1)$$

where E is the rms electric field (V/m), σ is tissue conductivity (S/m) and ρ is tissue mass density (Kg/m^3)

In this paper, we used SAR for identification the tumor location and calculated SAR by using CST microwave studio, and used average values of SAR in 1 g tissue. The set up of system model for SAR detection is illustrated in Fig. 3, and SAR in this system simulation is depended on direction radiation pattern of antenna. Radiation patterns of this antenna are illustrated in Fig. 4 in both E-plane and H-plane. Antenna patterns have an effect on SAR intensity and precision to detected, depend on direction of radiation patterns of antenna, which an antenna that have wide beam-width can be detected the tumor well in a wide range and if an antenna have direction of radiation patterns correspond to the tumor position, it will be detected the tumor in accuracy location.

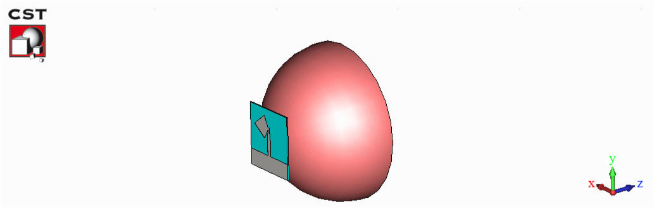

Fig. 3 Breast model with patch antenna (breast tip is at the origin)

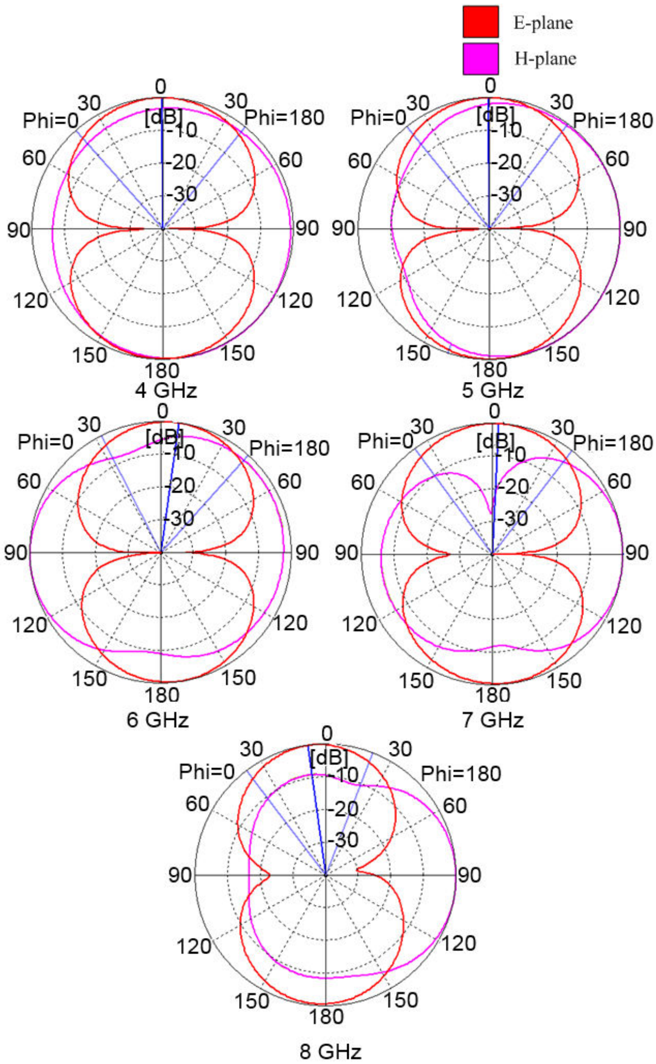

Fig. 4 The simulated of E-plane and H-plane radiation patterns for bowtie antenna at 4-8 GHz, red line is E-plane, pink line is H-plane, and blue line is shown the radiation patterns

In Fig. 4 is shown simulation of radiation pattern for bowtie patch antenna that used in this paper. If consideration in E-field, it will be observed that radiation pattern in each frequency between 4-8 GHz there will be pattern shape in similarly. At 4 GHz have the widest radiation patterns for each frequency that use in the work, therefore at 4 GHz will most appropriate to use for detecting. At 5 GHz and 7 GHz are quite well and have straight direction of radiation patterns, which that can be detected the tumor well too. At 6 GHz have an obtainable radiation patterns, but it have direction slope to the right side, therefore, if we used 6 GHz for detection the tumor, SAR intensity will be strong in the right side more than left side, but we can be rotated the antenna for suitable. At 8 GHz have the narrowest beam-width for each frequency that use in the work, and have direction slope to left side, therefore at 8 GHz is dull to use for detecting.

III. Simulation and Result

In the first, we compared the simulation data between value of SAR in the breast without tumor and value of SAR in breast with tumor to look for the frequency that suitable for our system. The model set up is shown in Fig. 3, tumor diameter 5 mm is inserted in breast model at (0,0,10) location and central of patch antenna is placed at the origin, away from the breast tip 5 mm. Tables III and IV are shown the total SAR, maximum SAR and coordinate of maximum SAR in each frequency, this results are simulated in 1 g tissue mass average. Total SAR and coordinate are illustrated with nearby in each frequency. At 6 GHz, the maximum SAR in normal breast and breast with tumor are little to difference, at 5, 7, and 8 GHz have maximum SAR slightly more 6 GHz. Anyway, the frequency that discussed above can be detected tumor in location nearby the tumor that inserted in the breast, but from the maximum SAR in 4 GHz is the most distinction between maximum SAR in normal breast and breast with tumor between 0.40163 and 0.997267 respectively, which that may be make opportunity to detect tumor is more accurate.

TABLE III
SAR Average in 1 g Tissue and Maximum SAR Coordinate in a Breast without Tumor

Frequency (GHz)	Total SAR (W/kg)	Max SAR (W/kg)	Max SAR Coordinate (x,y,z), (mm)
4	0.01660	0.40163	1.33,7.03,6.11
5	0.01767	0.42693	1.33,7.03,6.11
6	0.03986	0.88968	0.38,7.03,6.11
7	0.01102	0.17234	-3.67,9.47,6.11
8	0.01167	0.15151	8.14,3.59.6.11

TABLE IV
SAR Average in 1 g Tissue and Maximum SAR Coordinate in a Breast with 5 mm. of Tumor

Frequency (GHz)	Total SAR (W/kg)	Max SAR (W/kg)	Max SAR Coordinate (x,y,z), (mm)
4	0.0242433	0.997267	0.375,1.78,9.625
5	0.0189309	0.779072	0.375,1.26,9.625
6	0.0228495	0.941562	0.375,1.78,9.625
7	0.0174804	0.446675	1.06,1.775,9.625
8	0.0195102	0.354248	1.06,1.258,9.625

TABLE V
MAXIMUM SAR AND COORDINATE IN A BREAST WITH 5 MM. OF TUMOR FOR 5 LOCATION OF ANTENNA, TUMOR AT (20,20,20)

Antenna location (x,y,z), (mm)	Max SAR Coordinate (x,y,z), (mm)				
	4 GHz	5 GHz	6 GHz	7 GHz	8 GHz
0,0,-5	1.0625, 7.025, 6.011	1.063, 7.025, 6.011	0.375, 7.025, 6.011	-2.81, 9.434, 6.011	8.139, 4.63125, 6.011
0,20.25,-5	0.375, 36.25, 16.75	0.375, 36.25, 16.75	-0.38, 35.08, 15.63	4.8056, 32.75, 14.6	18.54, 20.875, 19.625
0,-20.25,-5	0.375, -24.156, 9.29	0.375, -24.156, 9.29	-0.375, -24.16, 9.29	-2.81, -21.78, 8.197	-3.771, -21.781, 8.197
18.25,0,-5	20.28, 19.625, 20.625	20.28, 19.63, 20.63	20.28, 18.5, 19.625	20.84, 18.5, 19.625	23.075, 5.775, 8.1973
-18.25,0,-5	-27.25, 7.025, 10.383	-28.36, 7.025, 11.48	-27.25, 7.03, 10.38	-23.92, 5.775, 9.29	-22.806, 3.594, 8.197

TABLE VI
MAXIMUM SAR AND COORDINATE IN A BREAST WITH 5 MM. OF TUMOR FOR 5 LOCATION OF ANTENNA, TUMOR AT (-10,-25,15)

Antenna location (x,y,z), (mm)	Max SAR Coordinate (x,y,z), (mm)				
	4 GHz	5 GHz	6 GHz	7 GHz	8 GHz
0,0,-5	1.0625, 7.025, 6.0113	1.0625, 5.78, 6.011	0.375, 7.025, 6.05	-2.573, 9.471, 6.05	-2.5729, 9.4708, 6.05
0,20.25,-5	0.375, 36.25, 16.75	-0.375, 35.08, 15.63	0.375, 35.08, 15.95	4.806, 32.75, 13.75	5.9167, 30.417, 12.65
0,-20.25,-5	-8.25, -24.51, 14.375	-8.25, -24.51, 14.38	-9.38, -25.13, 15.38	-8.25, -24.51, 14.38	-8.25, -25.131, 14.375
18.25,0,-5	20.28, 19.625, 20.625	28.361, 5.78, 11.55	27.25, 5.775, 10.45	26.139, 8.275, 9.35	23.917, 5.775, 8.2506
-18.25,0,-5	-27.25, 7.025, 10.383	-29.47, 7.025, 11.55	-27.25, 7.03, 10.45	-22.81, 5.775, 8.25	-22.81, 3.594, 8.2506

TABLE VII
MAXIMUM SAR AND COORDINATE IN A BREAST WITH 5 MM. OF TUMOR FOR 5 LOCATION OF ANTENNA, TUMOR AT (-30,10,20)

Antenna location (x,y,z), (mm)	Max SAR Coordinate (x,y,z), (mm)				
	4 GHz	5 GHz	6 GHz	7 GHz	8 GHz
0,0,-5	1.0625, 7.025, 6.01	1.063, 5.775, 6.011	0.375, 7.025, 6.011	-2.813, 9.175, 6.01	8.139, 4.70116, 6.011
0,20.25,-5	0.375, 36.25, 16.75	-0.38, 35.08, 15.625	-0.38, 35.08, 15.63	4.806, 32.75, 13.66	5.917, 30.417, 12.569
0,-20.25,-5	0.375, -24.1562, 9.29	-0.375, -24.16, 9.29	-0.375, -24.16, 9.29	-2.81, -21.78, 8.197	-2.8125, -21.78, 8.197
18.25,0,-5	20.28, 19.625, 20.625	28.36, 5.775, 11.47	27.25, 5.775, 10.38	26.14, 8.588, 10.38	23.9167, 5.775, 8.197
-18.25,0,-5	-29.38, 9.73, 19.625	-28.25, 9.175, 19.63	-29.38, 9.18, 19.63	-29.38, 9.18, 19.63	-30.28, 9.175, 19.625

However, frequency between 4-8 GHz will used in examination the accuracy of tumor detection, to prove that in each frequency, how is the maximum SAR coordinate in breast with tumor for 5 mm diameter. In the next simulation, we will simulate by changing the tumor to 3 difference locations in the same size at (20,20,20), (-10,-25,15), and (-30,10,20) respectively, and simulated in 5 locations antenna (0,0,-5), (0,20.25,-5), (0,-20.25,-5), (18.25,0,-5), and (-18.25,0,-5) respectively.

Table V is demonstrated simulation result of breast that inserted the tumor 5 mm. at (20,20,20) location, on changing the location of antenna to 5 points, and adjusting frequency between 4-8 GHz. In this table is demonstrated, at the antenna location (18.25,0,-5), the coordinates of maximum SAR is the most approached to the tumor location, which frequency 4-7 GHz can be detect maximum SAR at the coordinate close to tumor at (20,20,20), but at 8 GHz is detected maximum SAR at (23.075,5.775,8.1973), which it not to close the tumor location, and other antenna in another points are failed to detect tumor.

In Table VI is demonstrated maximum SAR coordinate at tumor locations (-10,-25,15), and can detect the tumor for the antenna location at (0,-20.25,-5). From this table can be observed, maximum SAR coordinates at antenna location (0,-20.25,-5) are close at approximately (-8.25,-24.51,14.38) in frequency 4, 5, 7, 8 GHz, and at 6 GHz can be obtained maximum SAR at (-9.38,-25.13,15.38), which 6GHz is the most accurate for tumor location (-10,-25,15). And other antenna locations are failed to detection.

And in Table VII, the maximum SAR coordinates for antenna location at (-18.25,0,-5) are the most accurate with great at all frequency, but at 4 GHz is the most greatly accurate to detect at (-19.38,9.73,19.625). However, frequency from 5-8 GHz was precision enough for instead the frequency at 4 GHz. In the other hand, the other locations of antenna are failed to detection. Although, the antenna at (18.25,0,-5) is liable to detect, but it also considered difference from the tumor location.

In this simulation results are clearly shows that the tumor can be detected by using SAR, but we must be varying the location of antenna around the breast in detection. Due to the small size of patch antenna that made the pattern is not spread cover breast model and understand to results in each frequency from 4-8 GHz.

IV. CONCLUSION

This paper demonstrated breast tumor can be detected by considering the different of the power that absorbed in normal tissue and malignant tissue. Because of distinction of dielectric property in normal tissue and malignant tissue difference highly. In simulation result, the 4-8 GHz frequency is used for this system. In the first examination, 4 GHz is the frequency that has highest distinction of SAR between normal and malignant tissue, which it may be the most accurate frequency for detection tumor, but for examination, frequency from 4-8 GHz can be detected greatly, except at tumor (20, 20, 20), at frequency 8 GHz is failed to detection. In this simulation, the tumor is inserted in the breast model at random location, and changing an antenna position into five locations around the breast. For the simulation, the results are shown that the tumor in the breast can be detected when antenna is close to the tumor location, as shown in above table. So from the results in this paper can be concluded, detection of breast cancer will be examined in several position around the breast for accuracy.

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