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EARLY DETECTION OF BREAST CANCER USING ULTRA WIDE BAND SLOT ANTENNA

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Abstract *-- Breast cancer is the transformation of normal cells in the breast area into a malignant tumor, which is the second largest disease as a cause of death for women. Early detection is one way to avoid significant risks in breast cancer. X-ray mammography and magnetic resonance imaging (MRI) techniques are used to detect breast cancer. However, those techniques have several limitations. Ultra-wideband (UWB) microwave imaging, approved by The Federal Communications Commission (FCC) in the United States, has promising capabilities in detecting breast cancer. Microwave imaging uses a microstrip antenna that has the advantage of convenience, potentially low cost, and is a non-ionized and safe alternative. In this paper, the ultra-wideband microstrip antenna for breast cancer detection is proposed. The antenna was designed by adding some rectangular slots on a rectangular patch to meet the UWB specifications. The antenna works well at 8.41 GHz to 10.29 GHz with directivity of 6.451 dBi and SAR value of 1.6 W / kg. The antenna was simulated with breast phantom. The tumor sizes of 6 mm and 10 mm are added to evaluate the E/H fields and current density with and without tumor. The highest E-Field value of 928.8 V / m was obtained at 10 GHz with a 10 mm tumor size. The highest H-Field value of 4.06 V / m was achieved at 10 GHz with a 6 mm tumor size. From the simulation, the E/H-field and current density are higher if there is a tumor in the breast compared to the breast without the tumor.*

Keywords: *Ultra-Wideband (UWB); Microstrip Antenna; Breast cancer; Specific Absorption Rate (SAR)*

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INTRODUCTION

Breast cancer is the transformation of normal cells in the breast area into tumor cells in a multistage process that usually develops from pre-cancerous lesions to malignant tumors. Breast Cancer is the type of cancer most experienced by women. The causes of disease are several factors, namely, tobacco use, being overweight or obese, an unhealthy diet with a lack of intake of vegetables and fruits, lack of physical activity, alcohol use, sexually transmitted HPV infection, hepatitis infection or other, ultraviolet radiation, urban air pollution, indoor smoke from the use of household solid fuels (World Health Organization, 2018).

Breast cancer can spread significantly and often does not cause significant symptoms. Therefore, treatment sometimes does not give excellent or late results, so prevention is a necessary step. Prevention that we can do to prevent breast cancer is by prolific mastectomy and preventive measures using tamoxifen besides those women who are classified as low to moderate risk need to connect their lifestyle because a healthy lifestyle has the effect of reducing the risk of cancer (Srinivasan & Gopalakrishnan, 2019; Wender et al., 2018; Rasjidi, 2009).

According to the International Agency for Research on Cancer (IARC) on the latest global cancer data, cancer burden rises to 18.1 million new cases and 9.6 million cancer deaths in 2018. In breast cancer, there were 2,088,859 cases, and 626,678 of them caused death (International Agency for Research on Cancer, 2018). So to reduce the number of people living with cancer needed knowledge about the dangers of breast cancer, the cause, how to prevent it, and how to treat it.

Early detection is one way to avoid significant risks in breast cancer. X-ray mammography and magnetic resonance imaging (MRI) techniques are used to detect breast cancer. However, those techniques have several limitations, for example, unable to distinguish between benign and malignant tumors and the discomfort experienced in the process of mechanical stress (Rasjidi, 2009; Yumnisari, Nugroho, & Daud, 2017). Mammography dan MRI methods are expensive (Tayel, Abouelnaga, & Desouky, 2018; Rasjidi, 2009).

UWB microwave imaging has promising capabilities in detecting breast cancer. Microwave imaging uses microstrip antennas so that it has the advantage of convenience, potentially low cost, and is a non-ionized and safe alternative (Alsharif, & Kurnaz, 2018). The Federal Communications Commission (FCC) in the United States has permitted the commercial distribution of UWB devices and governs UWB devices working on 3.1 GHz to 10.6 GHz bandwidth for medical purposes (Rahayu & Pohan, 2018; Dewiani et al., 2015; Rasjidi, 2009; Mudrik, 2011; Rahayu, Ngah, & Rahman, 2010; Kahwaji et al., 2016; Mansoor, Tan, & Latif, 2017). These researchers have discussed various UWB antenna structures. In the paper (Dewiani et al., 2015) uses a rectangular microstrip antenna with return loss as a parameter to detect breast cancer. Another article (Yumnisari, Nugroho, & Daud, 2017) uses a design of a Vivaldi microstrip antenna that successfully detects breast cancer by analyzing differences in the values of E-Field, H-Field, and current density.

With the allocation of the wide 7.5 GHz frequency band ranging 3.1–10.6 GHz, UWB with the inherent potential for producing extremely narrow time domain pulses has enhanced the capacity of large data acquiring or transmission with a potential for generating high-resolution images. So the use of UWB antenna is highly lucrative in achieving better results for microwave breast imaging (Kahar et al., 2014). In this paper, an ultra-wideband microstrip antenna design is performed by adding rectangular slots for breast cancer detection by analyzing the return loss, E-Field, H-Field. Moreover, the current density. The proposed antenna was simulated by breast modeling with 6 mm and 10 mm of tumor sizes. Antenna design and breast modeling and simulation were carried out using CST Microwave Studio.

METHOD

Determination of Specifications

UWB radar imaging as a means of detecting breast cancer, is a technique that uses a short pulse, or a synthesized pulse constructed from a frequency sweep, is directed into the breast and one or more receive antennas then detect the reflected signals. Such radar-based systems are capable of producing high-resolution images without the need for complicated reconstruction algorithms, due to the wideband nature of the UWB signals. A critical part of any detection scheme is the antenna design. To obtain high resolution, accurate images the antennas must be able to radiate signals over a wide band of frequencies while maintaining the fidelity of the waveform over a large angular range (Gibbins et al., 2010). E/H field and current density are the parameters required for the antenna radiate the signals with high resolution. Antenna for breast cancer detection uses UWB technology because it has a wide enough bandwidth to be stable in-band operations. There are specifications in the UWB antenna, listed in Table 1, as follows:

Table 1. Basic antenna specification

Parameter	Specification
Type of Antenna	Single Patch with Rectangular Slot
Frequency	3.1GHz – 10.6GHz
Bandwidth	≥500 MHz
Return loss	≤-10dB
Voltage Standing Wave Ratio (VSWR)	≤2

The antenna was designed using FR-4 substrate (ε_r = 4.3, h = 1.56 mm) and copper patch and ground material. There are several formulas used to determine the antenna geometry, including.

Calculation of the Width (W):

$$W = \frac{c}{2f_0\sqrt{\frac{(\varepsilon_r + 1)}{2}}} \tag{1}$$

where:
W is Width of the Patch
c is Speed of light: 3 x 10^8
f_0 is Resonance Frequency
ε_r is relative Permittivity of the dielectric substrate

Calculation of the effective dielectric constant is based on the thickness, dielectric constant, and the width of the patch antenna.

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}} \tag{2}$$

where :
ε_{eff} is dielectric constant
h is thickness

Calculation of effective length:

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{eff}}} \tag{3}$$

Calculation of the length extension ΔL:

$$\Delta L = 0.412h\frac{(\varepsilon_{eff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{eff} - 0.258)\left(\frac{W}{h} + 0.8\right)} \tag{4}$$

Calculation of actual length of the patch:

$$L = L_{eff} - 2\Delta L \quad (5)$$

Substrate Width Calculation (W_s), Substrate Length (L_s), Ground width (W_g) and Length of Ground (L_g):

$$Wg = 6.h + W \quad (6)$$

$$Lg = 6.h + L \quad (7)$$

To calculate the dimensions of the transmission line using equations:

$$B = \frac{60\pi^2}{Z_0\sqrt{\varepsilon_r}} \quad (8)$$

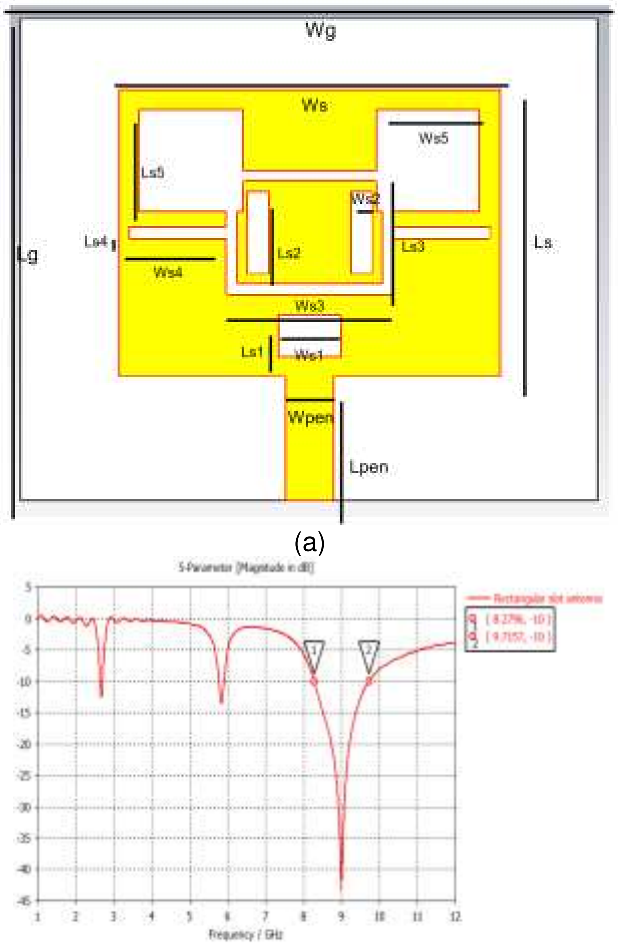
$$W = \frac{2h}{\pi}\{B-1-\ln(2B-1)+\frac{\varepsilon_r-1}{2\varepsilon_r}[\ln(B-1)+0,39-\frac{0,61}{\varepsilon_r}]\} \quad (9)$$

During the design process, some characterizations and optimizations are performed on the antenna to meet the performance of the required parameters. Additional rectangular slots are needed to improve the antenna performance.

The overall antenna dimensions are listed in Table 2.

Table 2. Antenna Dimension

Parameter	**Description**	**Dimension** (mm)
Ws	Substrate Width	27.76
Ls	Substrate Length	23.3
h	Substrate Thickness	1.56
Wp	Patch Width	18.4
Lp	Patch Length	13.943
T	Patch Thickness	0.025
Wg	Ground Width	27.76
Lg	Ground Length	23.3
Tg	Ground Thickness	0.025
Wpen	Feed line Width	2.358
Lpen	Feed line Length	6
Ws1		3
Ws2		1
Ws3	Slots Width	4.7
Ws4		4.7
Ws5		5
Ls1		2
Ls2		4
Ls3	Slots Length	0.5
Ls4		0.5
Ls5		4.95



(a)

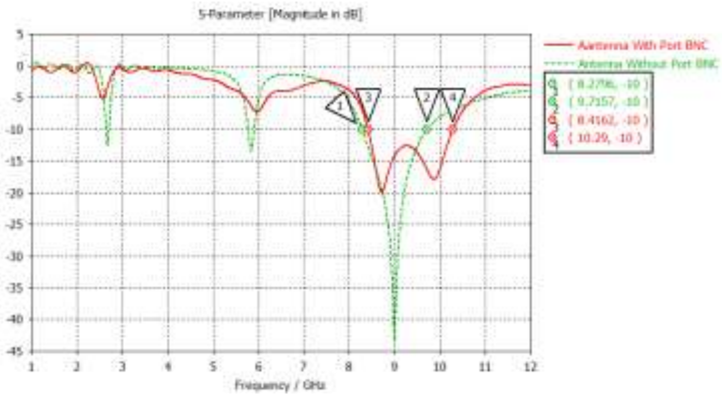
(b)

Figure 1. (a) UWB rectangular slot patch antenna with the full ground plane (b) Return loss (S11)

Fig. 1 shows a UWB rectangular slot patch antenna with the full ground plane and the simulated return loss of antenna. The antenna meets the requirements of ultra-wideband technology. It is noted that the return loss of -43.2 dB is obtained at a frequency of 8.27 GHz to 9.7 GHz with a bandwidth of 1.44 GHz.

Antenna with BNC Port

The antenna is connected to a 75 Ohm BNC port to maximum transfer power and the matching signal. Fig. 2 shows the comparison of return loss before and after using the BNC port. The return loss of the antenna with BNC port increases around -20 dB with a wider bandwidth. The directivity of the slot antenna with the BNC port is 6.451 dBi.



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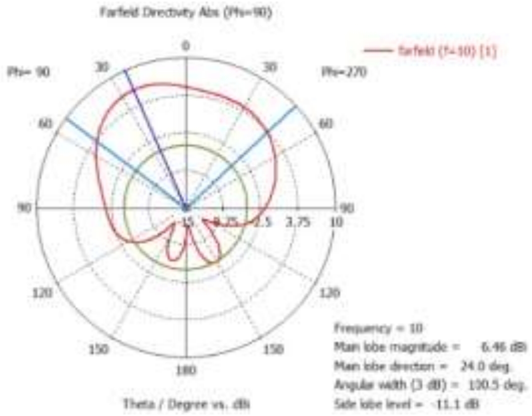

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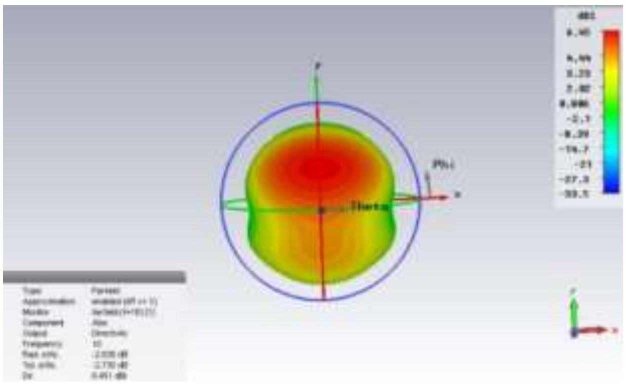


(c)

Figure 2. (a) return loss of antenna without and with BNC port (b) Radiation pattern of the antenna with BNC port (c) Directivity of the antenna with BNC port

Breast Modelling

Modeling breast tissue structures in Fig. 3 is designed with electrical parameters listed in Table 3. The tumor size used in the simulation was 6 mm and 10 mm. The analysis is carried out on the simulation results obtained on the value of the electromagnetic parameters of the antenna using modeling breast tissue structures without tumors and with tumors.

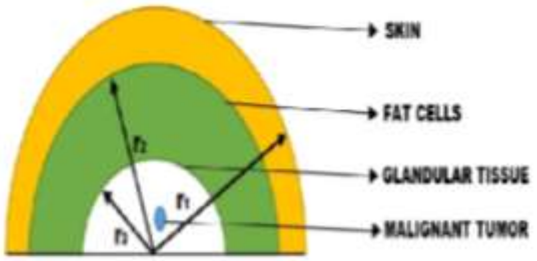


Figure 3. Modeling breast tissue structures

Table 3. Parameter of the breast model

Breast Tissue	relative permittivity ε_r (F/m)	conductivity σ (S/m)	Thickness (mm)
Skin	36	4	5
Fatty tissue	9	0.4	15
Glandular tissue	11 - 15	0.4 - 0.5	40
Tumor	50	4	(r = 3-5)

RESULTS AND DISCUSSION

The detection process is done by simulating an antenna with a breast model of 120 mm in diameter. The antenna is positioned above the breast modeling with a distance of 5mm which is simulated at a frequency of 9 GHz and 10 GHz.

Fig. 4 shows the SAR value obtained without a tumor of 1.6 W/kg that already fulfills the safety standard to be used on the breast.

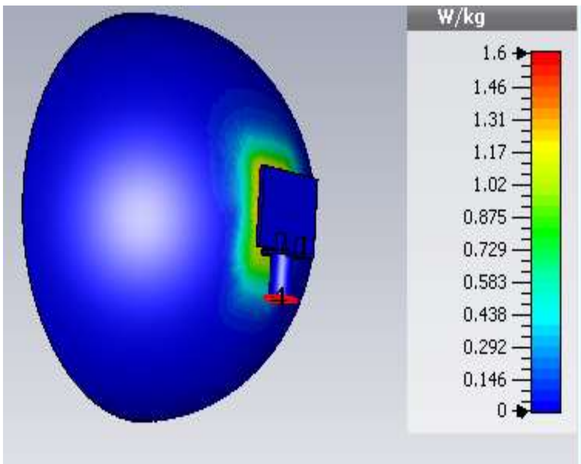


Figure 4. SAR value

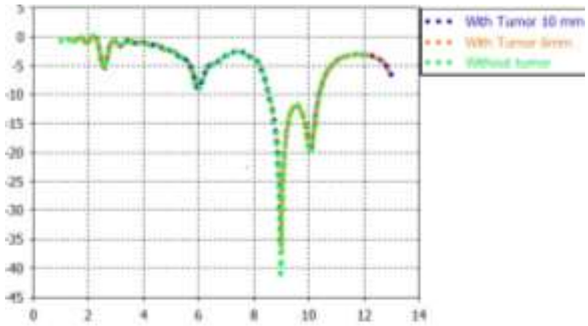
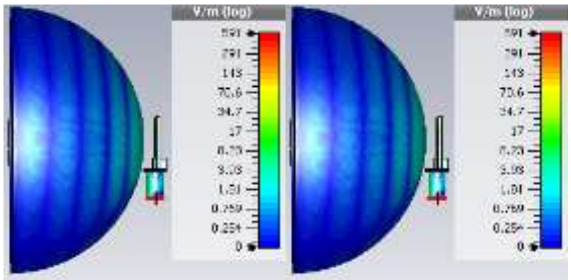


Figure 5. Comparison of the return loss of antenna simulations with phantom breast without tumors and with tumors.

In Fig. 5, the simulated return loss with breast phantom without tumor is -40.96 dB. Antenna with the phantom breast that has a tumor, the return loss increases -35.82 dB for the tumor of 6 mm and -35.64 dB for the tumor of10 mm.

Fig. 6 shows the simulation results of an antenna with breast phantom in the E-field parameter. At frequency 9 GHz, the E-filed value is 591.1 V/m where the tumor is 6 mm and 591.3 V/m for tumor 0f 10 mm. At frequency 10 GHz, the E-filed value is 929.4 V/m where the tumor is 6 mm and 929.8 V/m for tumor of 10 mm.



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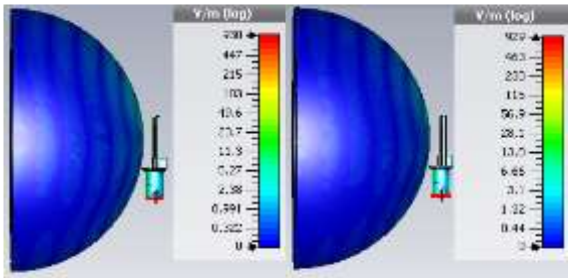
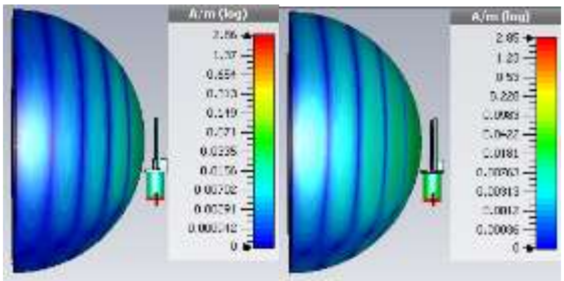


(b)

Figure 6. (a) E-field in frequency 9 GHz with tumor 6 mm(left), and tumor 10mm (right). (b) E-field in frequency 10 GHz with tumor 6 mm(left), and tumor 10mm (right).



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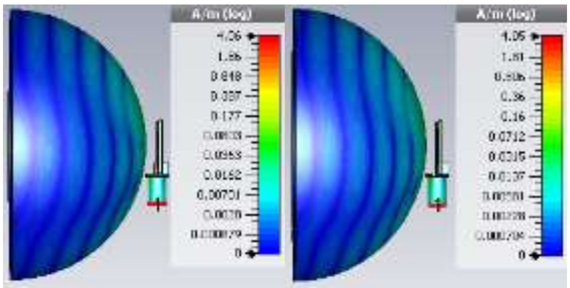


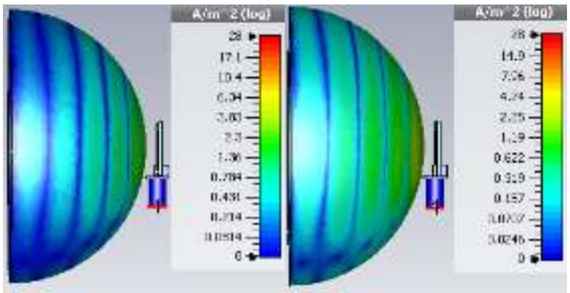
(b)

Figure 7. (a) H-field in frequency 9 GHz with tumor 6 mm(left), and tumor 10mm (right). (b) H-field in frequency 10 GHz with tumor 6 mm(left), and tumor 10mm.

Fig. 7 shows the simulation results of an antenna with breast phantom in the H-field parameter. At frequency 9 GHz, the H-filed value is 2.856 V/m where the tumor is 6 mm, and the tumor is 10 mm with an H-field value of 2.848 V/m. At frequency 10 GHz, the H-filed value is 4.06 V/m where the tumor is 6 mm, and the tumor is 10 mm with an H-field value of 4.048 V/m.

Fig. 8 shows the simulation results of an antenna with breast phantom in the current density parameter. At frequency 9 GHz, the current density value is 27.95 A/m² where the tumor is 6 mm, and the tumor is 10 mm with a current density value of 27.98 A/m². At frequency 10 GHz, the current density value is 33.7 A/m² where the tumor is 6 mm, and the tumor is 10 mm with a current density value of 33.7 A/m².

Fig. 9 shows the results of antenna simulations with breast phantom. At frequency 9 GHz, the E-field value is 589 V/m, the H-field value is 2,833 V/m, and the current density value is 27.93 A/m². At frequency 10 GHz, the E-field value is 924.3 V/m, the H-field value is 4.046 V/m, and the current density value is 33.55 A/m².



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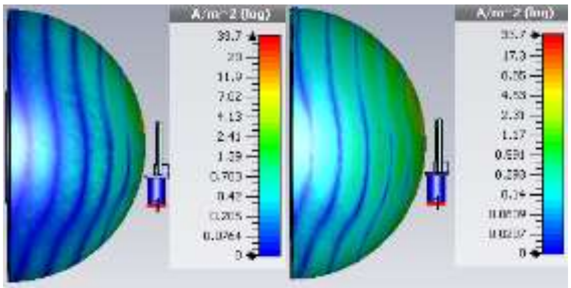
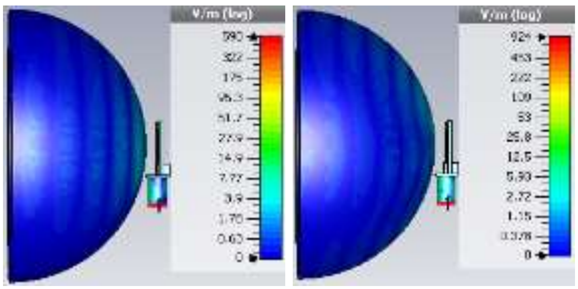


(b)

Figure 8. (a) Current density in frequency 9 GHz with tumor 6 mm(left), and tumor 10mm (right). (b) Current density in frequency 10 GHz with tumor 6 mm(left), and tumor 10mm.



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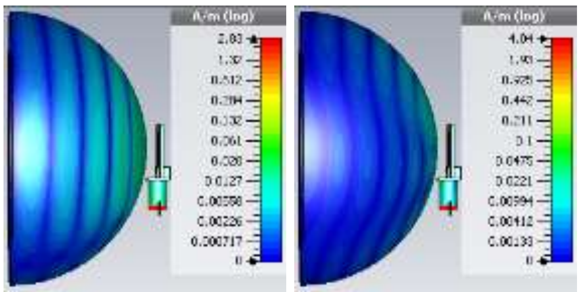

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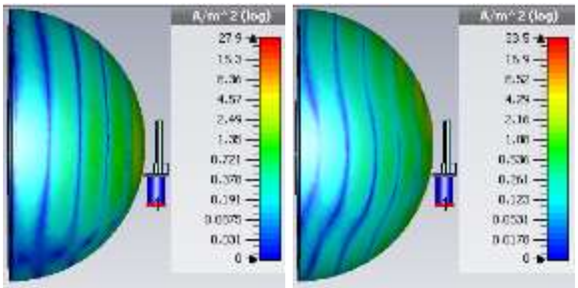

(c)

Figure 9. (a) E-field without a tumor in frequency 9 GHz (left), and 10 GHz (right). (b) H-field without tumor in frequency 9 GHz (left), and 10 GHz (left) (c) Current density without a tumor in frequency 9 GHz (left), and 10 GHz (right).

Table 4. Antenna simulation results with phantom breast

Antenna	E-Field (V/m)	H-Field (V/m)	Current density (A/m²)
Without tumor (9 GHz)	589.7	2.833	27.93
Without tumor (10 GHz)	924.3	4.036	33.55
With tumor 6mm (9 GHz)	591.1	2.856	27.95
With tumor 6mm (10 GHz)	929.4	4.06	33.7
With tumor 10mm (9 GHz)	591.3	2.848	27.98
With tumor 10mm (10 GHz)	929.8	4.048	33.7

Analysis of UWB antenna as a function of breast cancer detection is done by comparing the parameters of E-Field, H-Field, and current density as tabulated in Table 4. The highest E-Field value of 928.8 V / m was obtained at 10 GHz with a 10 mm tumor size. The highest H-Field value of 4.06 V / m was achieved at 10 GHz with a 6 mm tumor size. The high frequency has resulted in high current density, as shown in this simulation. The maximum current density of 33.7 A/m^2 was obtained at 10 GHz. The effect of tumor sizes is less significant to the current density.

CONCLUSION

UWB microstrip slot antenna as a breast cancer detector was successfully designed. During the antenna design, several characterizations and optimization are carried out. The antenna works well at 8.41 GHz to 10.29 GHz. Comparisons of parameters E-fields, H-fields, and current densities to detect breast cancer are well performed. The E/H-field and current density are higher if there is a tumor in the breast compared to the breast without the tumor

REFERENCES

Alsharif, F., & Kurnaz, C., (2018). Wearable Microstrip Patch Ultra Wide Band Antenna for Breast Cancer Detection. In *41st International Conference on Telecommunications and Signal Processing (TSP)*, Athens, Greece (pp. 1-5). http://doi.org/10.1109/TSP.2018.8441335

Dewiani, D., Amir, A., Palantei, E., Areni, I. S., & Achmad, A. (2015). Movement effect on electrical properties of UWB microwave antenna during breast tumor diagnostic scanning. In *2015 IEEE Asia Pacific Conference on Wireless and Mobile (APWiMob)*, Bandung, Indonesia (pp. 188-191). http://doi.org/10.1109/APWiMob.2015.7374972

Gibbins, D., Klemm, M., Craddock, I. J., Leendertz, J. A., Preece, A., & Benjamin, R. (2010). A comparison of a wide-slot and a stacked patch antenna for the purpose of breast cancer detection. *IEEE Transactions on Antennas and Propagation*, *58*(3), 665-674. http://doi.org/10.1109/TAP.2009.2039296

International Agency for Research on Cancer (2018). *IARC Annual Report*. https://www.iarc.fr/wpcontent/uploads/2018/09/pr263_E.pdf. Accessed on November 25, 2018

Kahar, M., Ray, A., Sarkar, D., & Sarkar, P. P. (2014). A UWB microstrip monopole antenna for breast tumor detection. *Microwave and Optical Technology Letters*, *57*(1), 49-54. http://doi.org/10.1002/mop.28773

Kahwaji, A., Arshad, H., Sahran, S., Garba, A. G., & Hussain, R. I. (2016). Hexagonal microstrip antenna simulation for breast cancer detection. In *2016 International Conference on Industrial Informatics and Computer Systems (CIICS)*, Sharjah, United Arab Emirates (pp. 1-4). http://doi.org/10.1109/ICCSII.2016.7462400

Mudrik, A. (2011). Antena prinsip dan Aplikasi. *Graha Ilmu, Yogyakarta*.

Mansoor, F., Tan, T., & Latif, S. I. (2017). The performance of an Ultra-wideband elliptical ring monopole antenna with a humanoid breast phantom. In *2017 IEEE International Symposium on Antennas and Propagation & USNC/URSI National Radio Science Meeting*, San Diego, CA, USA (pp. 105-106). http://doi.org/10.1109/APUSNCURSINRSM.2017.8072095

Rasjidi, I. (2009). *Deteksi dini dan pencegahan kanker pada wanita*. Jakarta: Sagung Seto.

Rahayu, Y. & Pohan, I.A. (2018). Design of Rectangular with 3 Slot Microstrip Antenna for Application LTE 2.1 GHz. *SINERGI*, *22*(2), 127-131. http://doi.org/10.22441/sinergi.2018.2.009

Rahayu, Y., Ngah, R., & Rahman, T. A. (2010). Various slotted UWB antenna design. In *2010 6th International Conference on Wireless and Mobile Communications,* Valencia, Spain (pp. 107-110). http://doi.org/10.1109/ICWMC.2010.96

Srinivasan, D. & Gopalakrishnan. (2019). Breast Cancer Detection Using Adaptability Antenna Design. *Journal of Medical Systems,* *43*(177). https://doi.org/10.1007/s10916-019-1314-5

Tayel, M. B., Abouelnaga, T. G., & Desouky, A. F. (2018, May). UWB high gain antenna array for SAR based breast cancer detection system. In *2018 5th International Conference on Electrical and Electronic Engineering (ICEEE),* Istanbul, Turkey (pp. 311-316). http://doi.org/10.1109/ICEE2.2018.8391353

Wender, R.C., Brawley, C.W., Fedewa, S.A., Gansler, T., & Smith, R.A. (2018). A blueprint for cancer screening and early detection: Advancing sreening's contribution to cancer control. *CA: A Cancer Journal for Clinicians, 69*(1), http://doi.org/10.3322/caac.21550

World Health Organization (2018). *Cancer*. http://www.who.int/news-room/fact-sheets/detail/cancer. Accessed on November 25, 2018

Yumnisari, M., Nugroho, B. S., & Daud, P. (2017). Perancangan dan Simulasi Antena Mikrostrip Ultra Wideband untuk Deteksi Kanker Payudara. In *Proceeding of Seminar Nasional Inovasi dan Aplikasi Teknologi di Industri SENATI 2017*, Malang, Indonesia, *3*(1), (pp. 40-1)