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Terahertz Microstrip Patch Antenna for Breast Tumour Detection

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Abstract: Breast cancer is one of the most common cancers among Malaysian women. It is critical to discover strategies to detect the tumour early on. Terahertz (THz) frequency provides excellent qualities for detecting tumours such as low photon energy and non-ionising radiation as compared to prior methods such as mammography, ultrasound, and magnetic resonance imaging (MRI) that use optical to X-ray frequencies. The purpose of this work is to analyse and locate a breast tumour as well as to compute the maximum specific absorption rate (SAR) value. It was designed a THz rectangular microstrip patch antenna with an inset feed. To improve the antenna's performance, graphene was used for the patch and polyimide for the substrate. This antenna covered a bandwidth of 31.6 GHz and worked in the frequency range of 0.283-0.599 THz. To identify the location of a tumour, compute the SAR value, and localize the tumour, SAR simulation was used. The maximum SAR shifted to the tumor's position due to greater absorption rate around its tissue due to higher dielectric constant features. It was calculated that 1e-05g of average mass is required to be less than total tissue mass, which is 2.0063e-05g. SAR study revealed a maximum SAR value of 2.49391e+06 W/kg, which was not more than the overall absorption rate for human body safety. The SAR calculation result revealed that the tumour is within the range of the tumor's initial location.

Keywords: THz Antenna, breast tumour detection, SAR analysis

1. Introduction

Terahertz (THz) frequency lies between long- infrared wave and microwave radiation, between 0.1-10 THz. This location of THz frequency results in the bandwidth being underutilized because it is difficult to control THz via existing electronic components and devices. Other than that, THz was unexplored due to the unavailability of stable femtocell laser and appropriate THz source and detector.

However, THz possess some good properties that are worth studying and investigating further. THz waves can penetrate through materials opaque to other Electromagnetic (EM) spectrums. As THz has low photon energy, the radiation does not affect chemical structure compared to ultraviolet (UV) radiation or X-ray. THz does not expose biological tissue to harmful radiation. It compared other EM spectrums such as visible light that can create photograph, radio wave that can transmit sound, and x-ray that can view human the body while THz waves can create images and transmit information.

THz radiation has a high penetration depth, a low dispersion coefficient, and a high spatial resolution. The rotational, translational, and vibrational responses of materials in the THz range provide information that optical and x-ray do not—the rotational frequencies of numerous gas molecules and THz frequency's weak bond vibration transition features. THz has a high water absorption rate.

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THz can be utilized in security applications as an example for airport security to detect illegal material hidden by the passenger. THz is a better alternative to X-ray scanner because of low photon energy and is safer for the human body. THz sensing and imaging can be used for quality control and process monitoring in manufacturing. THz exploit plastic and cardboard materials that transparent to THz radiation to inspect packaged goods. THz can inspect the food quality and production in food production as THz can measure the moisture content for dried food production. THz can detect differences in water content and density of tissue in medical. It is useful for effective cancer detection as it is safer and less painful. THz radiation also be used for 3D imaging of teeth and provide more accurate and safer than X-ray imaging cancer in dentistry.

THz radiation is less harmful to the human body than other EM spectrums such as X-rays. THz is non-ionizing radiation, and hence it is not harmful to the human body [1]. Ionizing radiation from X-rays endangers human health. Furthermore, THz emits low photon energy, making it impossible to break up the chemical link and modify the tested material

Hence, THz research becomes a promising area to investigate in many areas and applications, especially imaging for security and health purposes. In this work, we focus on THz antenna design for breast tumour detection. Breast cancer disease is one of the leading contributions of death by cancer among women [2]. Every year, 1.38 million were diagnosed with breast cancer with mathematically one of eight women were diagnosed with breast cancer worldwide [3]. In Malaysia, 38.3% of cases were caused by breast cancer. Researchers emphasize the importance of early detection and treatment for breast cancer as the prevention of this disease go unnoticed.

Several methods for breast cancer detection were discovered, such as mammography, ultrasound and magnetic resonance imaging (MRI) utilizing much frequency ranges from optical to X-ray [1]. The disadvantage of X-ray is radiation exposure that can harm the human body and poor contrast in soft tissue [4]. MRI is expensive and has a long acquisition time and limited sensitivity [5]. Lastly, although ultrasound has a high spatial resolution it cannot scan the whole body [6]. Hence, we suggested THz frequency for breast cancer detection as an alternative to existing methods in this work.

We proposed a rectangular microstrip patch antenna consisting of copper as patch, while FR-4 is a dielectric substrate. Improvement was made from the referred antenna by replacing the patch with graphene and polyimide materials as dielectric substrates. Graphene was selected because it has good electrical conductivity, electromagnetism, and electromechanical properties. Polymide was selected as a dielectric substrate as it has low permittivity rate to improve radiation efficiency [7]. The permittivity, electrical conductance, density, heat capacity, and thermal conductance of the tumour breast phantom were calculated using software that included skin, tumour, and tissue. Finally, to localize the tumour, (Specific Absorption Rate) was simulated and analyzed. The maximum SAR was simulated to determine whether they are safe for the human body.

2. Literature Review

2.1 Terahertz Pulse Imaging System

The following discusses several cancer detection methods using THz frequencies for cancer detection using Terahertz Pulse Imaging (TPI) systems. Authors in [12] were the first to report using THz imaging to identify cancer by separating carcinoma from normal tissue. The experiment was carried out with the help of a Terahertz Pulse Imaging (TPI) device using sample holders of sick and normal tissue. TPI systems with increased bandwidth were developed to boost the contrast level in THz images when comparing tumours with histology. As a result of the TPI system's ability to distinguish between cancer and normal tissue, this resulted in a novel application for THz frequency radiation.

Then, the authors in [13] look into the viability of using THz imaging to identify malignancy in breast tumours. The study demonstrates the ability of distinct THz impulse function parameters to detect different types of cancers and distinguish between non-malignant and malignant tumours. The experiment was also carried out using the TPI system to examine two picture parameters linked to the THz impulse function: the minimum value and the ratio of the minimum and maximum of the THz impulse function. Overall, the result indicates that the image created by the Emin parameter is superior to the image produced by the Emin/Emax parameter.

Water-based THz metamaterial design was used in [14] to detect skin cancer by comparing skin cancer and normal tissue's refractive index. The design used the TPI system, refractive index, and reflection coefficient between cancer tissue and normal tissue. The water-based metamaterial design was adopted because it effectively controls skin gene expression.

The supersensitive nano biosensor with several dielectric materials was tested in [15]. An array of split-ring resonators on the dielectric material is used in the design. They conclude that when the distance between the refractive index of a sub-layer and the sample is minimal, the biosensor is more sensitive.

2.2 Microwave Antenna for Cancer Detection

Previously, before THz frequency was considered, many researchers investigated various antenna topologies for microwave breast cancer detection utilizing Ultra-Wide bandwidth (UWB) antenna. Mostly, the UWB antenna designed was operating in the microwave frequency range. Here is the review of papers that utilize Microwave Imaging Technique to detect abnormal tissue with various antenna designs. Authors in [16] investigate microwave breast cancer detection using UWB microstrip slot antenna. Dielectric properties of tissue were used due to malignant tumor has high moisture content than normal. The UWB antenna were proposed using 2 and 6 antennas respectively located either side of the tissue.

[17] propose a high flexible, cost effective and lightweight design for breast cancer detection. It was achieved by designing flexible arrays of single and dual polarization of miniaturized monopole and spiral UWB antenna. The design was based on radar-based breast cancer detection system. It shows that the design can improve the penetration of electromagnetic waves by using the reflector on the antenna.

In [18], the authors suggested the Specific Absorption Rate (SAR) technique to accurately detect different tumour locations inside the breast. The maximum value of SAR was used to indicate the tumour's location. A Rectangular ring-shaped UWB antenna was designed and simulated to evaluate the performance in term of VSWR, gain and radiation pattern.

Authors in [19] proposed pure cotton as substrate and copper for patch and ground. The UWB microstrip antenna design consists of a rectangular substrate patch fed by a rectangular feed line operating at 1.6-11.2 GHz. The advantages of this design are low-cost, non-ionizing and comfortable.

Authors in [20] suggested an antenna with a circular patch antenna as an improvement from a typical rectangular patch antenna. The antenna is designed such that four circular patched together and simulated with high and different frequency and differential approaches can be used for early detection of skin cancer.

Authors in [21] designed a wearable microstrip patch antenna for breast cancer detection. The antenna was designed hexagonal, operating at 2.4Ghz frequency and cotton as the substrate. The SAR analysis shows different values for normal and breast cancer tissue, which can be used for early detection.

In [22] researcher proposed an array of circular patch antennas operating at 2.4GHz made of eight antennas to face the breast phantom directly. Eight rectangular microstrip patch antennas were arranged side by side for an array of circular antennas. The result shows a better image produced and has good impedance matching.

Researchers in [23] design and simulate microstrip patch antenna arrays with defected ground structure (DGS). From the result addition of arrays and defected ground structure can increase the performance criteria of the antenna. Two defected ground structures were designed: dumb-bell-shaped slot DGS and dumbbell circular shape slot.

2.3 Terahertz Antenna for Cancer Detection

As the THz frequency becomes increasingly popular, researchers begin to use it to create antennas for cancer detection. The authors in [24] depict a modification made to an elliptical THz antenna design to improve antenna performance. The original elliptical antenna was improved by changing the ground structure, adding structure and a slot, introducing an Electromagnetic Band Gap (EBG), and adding a shorting pin. The results reveal that the developed antenna can remove the stopband and lower the frequency band to nearly 1 THz.

In [25] authors described the design of a metamaterial THz antenna for detecting breast cancer. The suggested antenna is rectangular with a complementary split-ring resonator (CSRR). The outcome is a performance analysis of the antenna based on all of its design evolutions. The design begins with a simple rectangular patch antenna, modified and equipped with SRR. As a result, the developed antenna exhibits a constant gain and good efficiency.

Authors in [7] utilized THz imaging antenna to detect hyperthermia in cancerous tissue. The proposed antenna consists rectangular patch antenna with graphene nanomaterial and a dielectric substrate with polyimide material. As a result, the antenna design has very low power consumption and high-resolution images, and the SAR value is also acceptable.

Microstrip linear array for cancer detection was simulated in [26]. The simulation was conducted by moving the transmitter and receiver antenna horizontally and vertically to produce the imaging data. Three operating frequencies were tested 0.302 Thz, 0.312 THz and 0.322 THz. The image produced by 0.312 THz gave the best result, providing the best contrast compared to other frequencies.

2.4 SAR Analysis for Tumour Detection

SAR analysis is a measurement of EM radiation absorption rate by tissues. It was used to calculate amount of RF exposure to human body. SAR can help to define the tumour position at the maximum SAR value coordinates. Authors in [27] investigated the usage of SAR analysis to diagnose early stage of breast tumour using UWB antenna. SAR was simulated at different tumor radius (3 mm and 5 mm) with different resonant frequencies like 3GHz, 4GHz and 5GHz. Maximum SAR shows higher value with presence of tumour confirm the existence of a tumour in the breast phantom.

Authors in [28] performing SAR analysis for brain and breast tumour detection using microstrip antenna. They designed flexible antennas to follow the shape of the breast phantom model. Both antenna produced SAR value that do not exceed the maximum standard.

Authors in [29] performing SAR analysis by comparing normal breast and abnormal breast, varying the size of the tumour and breast to locate the tumour to verify the accuracy and limitation of the simulated SAR. The result also shows the effect as the said conditions was varied.

3. Methodologies

The methodologies to carry out the research objectives are planning, design and analysis. Planning stage involves data collection and specifies the software and hardware required. Data collection and software and hardware specification are two main elements. Data collection was conducted to get information and study-related topic. The data on the previous techniques to detect cancer, THz frequency, and implementation of various antenna designs on cancer detection were collected. The method of collection of data was mentioned in the planning stage.

There are two elements in the design stage: breast phantom model and THz antenna. The phantom breast model was designed to replace the biological tissue of a breast, and the parameter of each layer of the model was defined here. Two THz antennas were designed to perform performance comparison. The first antenna was modelled from a reference paper, and the second antenna was designed to improve the reference antenna. This section shows the parameter and calculation work of the antenna. Structure modifications and the material is chosen improved. Then, breast phantom model and THz antenna were set up for simulation in CST Studio Suite software.

In the analysis stage, the method to analyze the performance and characteristics of the antennas was defined. Both antennas were compared in terms of resonant frequency (THz), bandwidth (GHz), Reflection Coefficient (S11) (dB), gain (dB), directivity (dBi), VSWR, HPBW, radiation efficiency and impedance (ohms). SAR was used to measure the maximum absorption rate and localize the breast tumour. All the simulations were taken using CST Studio Suite software.

3.1 Planning

The technique of data collection was started during the planning stage. Data collection was carried out to get information and study-related topics. Data on prior cancer detection methods, THz frequency, and application of various antenna designs on cancer detection were collected.

3.2 Design

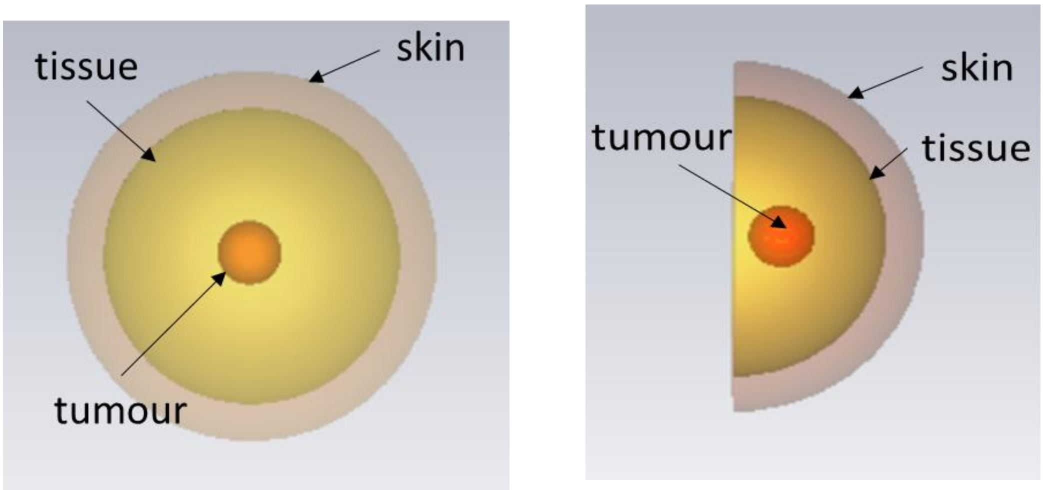
There are two elements to be designed for the analysis: antenna design and breast phantom model. Both antenna and breast phantom models were designed using CST Studio Suite. The antenna was placed in front of the breast phantom model at various locations, and THz frequency radiated from the antenna through the breast phantom model with tumour. Below is a detailed explanation of the antenna design and breast phantom model.

3.2.1 Breast Phantom Model

The natural breast phantom model is characterised using electrical properties such as permittivity and tangent loss. A natural breast is a heterogeneous mass composed of blood, fat, and other biological components. As a result, a semi-hemispherical breast phantom model was created, consisting of layers of tissue such as skin, adipose tissue, and tumour. Fig. 1 shows the three dimensions (3D) of the semi-hemispherical model considered for THz imaging simulation.

Table 1 - Parameter of breast tumour phantom [27]

Tissue	Relative Permittivity F/M
Skin	2.41
Tissue	2.8
Tumor	3.18

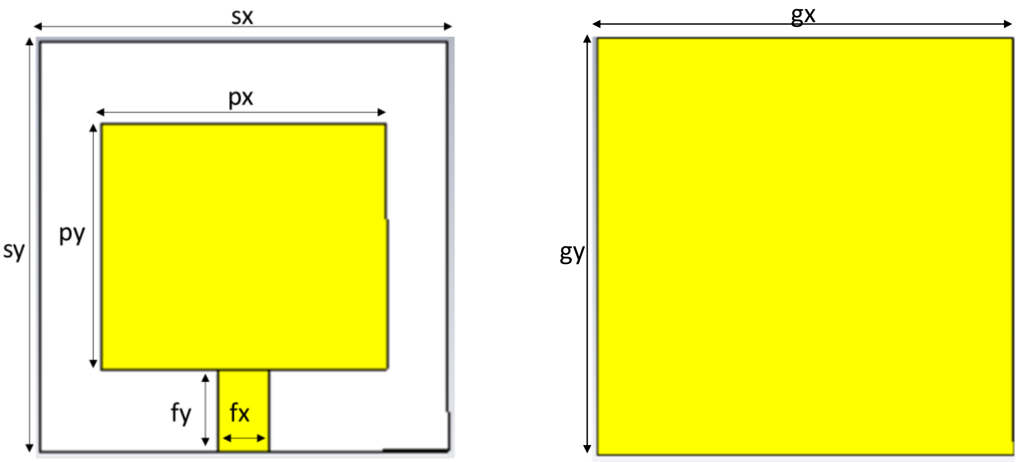


(a) (b)

Fig. 1 - Breast Phantom Model (a) back view and; (b) side view

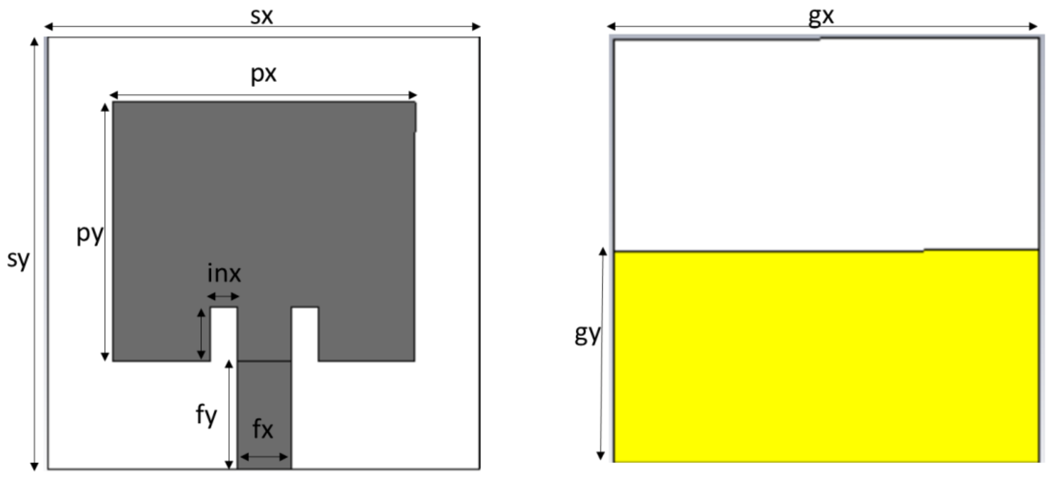
3.2.2 Antenna Design

Reference and proposed antennas are designed. The reference antenna is a rectangular design constructed on a 50 µm thick FR-4 (εr = 4.3) dielectric substrate with the conductive material made of copper as shown in Fig. 3.2. The proposed antenna design presents a rectangular slitted microstrip patch with a reduced ground plane incorporating inset feed with graphene as patch material and polyimide as the dielectic substrate



(a) (b)

Fig. 2 - Reference antenna (a) front view; (b) back view



(a) (b)

Fig. 3 - Proposed antenna (a) front view; (b) back view

Fig. 2 (a) and (b) depict the references antenna's front and back perspective, whereas Fig. 3 (a) and (b) depict the proposed antenna's front and back perspective. Antenna dimension of proposed antenna was defined after performing parametric study on various parameter such as patch length, patch width and ground length. Fig. 5 shows return loss of antenna when the patch width size is increasing. As the patch width increasing the return loss also increasing. The result shows optimum return loss when patch width is 140 µm.

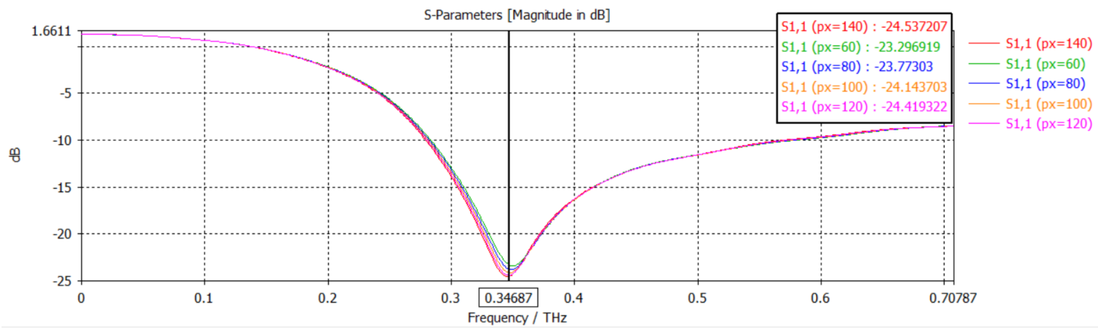


Fig. 4 - Reflection coefficient plot with different sizes of patch width, px

The reflection coefficient of the antenna increases as the patch length increases. The optimum reflection coefficient value is when the patch length is 120 µm. Fig. 5 shows the reflection coefficient plot as the patch length varied from 40 µm to 120 µm.

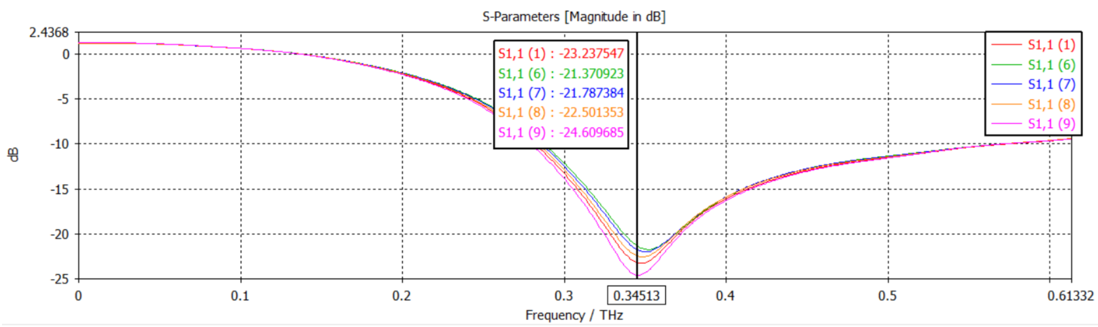


Fig. 5 - Reflection coefficient plot with different sizes of patch length, py

Fig. 6 shows the reflection coefficient plot when the ground length is modified from 100 µm to 200 µm. As the ground length increases, the reflection coefficient shows better results. The optimum reflection coefficient value is when the ground length is 100 µm.

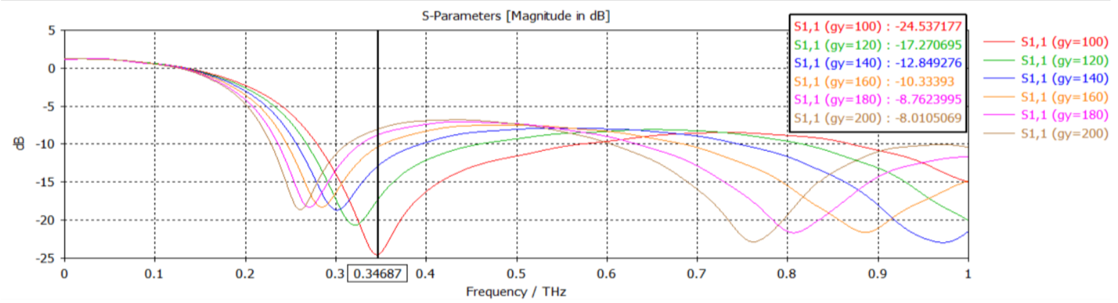


Fig. 6 - Reflection coefficient plot with different sizes of ground length, gy

From the parametric study, the parameter of the antenna dimension was chosen. Table 2 Parameters for antenna dimension for both the reference and proposed antennas.

Table 2 - Antenna dimension of proposed and reference antenna

Antenna Dimensions	Reference Antenna	Proposed Antenna
	Value (µm)	
Length of Substrate, sy	200	200
Width of Substrate, sx	200	200
Substrate thickness, st	50	50
Length of rectangular Patch, py	120	120
Width of rectangular Patch, px	140	140
Rectangular Patch thickness, pt	35	35
Length of Ground, gy	200	100
Width of Ground, gx	200	200
Ground thickness,gt	35	35
Length of Feedline, fy	30	30
Width of Feedline, fx	25	25
Feedline thickness, ft	35	35
Length of Inset Feed, iny	-	25
Width of Inset Feed, inx	-	12.5
Inset Feed thickness, int	-	35

The setup and configuration for doing the simulation from the side view are depicted in Fig. 7. The antenna positioned 250 µm in front of the breast phantom model parallel with centre of both models.

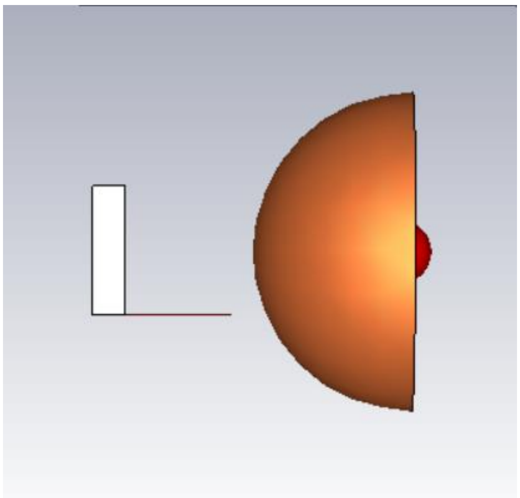


Fig. 7 - Setup and configuration for simulation

3.2.3 Analysis

The technique for the analysis is detailed in this section. Two aspects must be investigated: the performance and properties of the developed antenna and the strategy for localizing and detecting the breast tumour presence. The resonant frequency (THz), bandwidth (GHz), reflection coefficient, S11 (dB), gain (dB), directivity (dBi), VSWR, HPBW, radiation efficiency, and impedance of the antenna were all measured. Bandwidth of antenna was defined by the range between the lower and upper cut-off frequency. CST Studio Suite was used to simulate and analyse the performance. The analysis was conducted to compare the performance of two different antennas.

- Rectangular microstrip antenna without inset feed and without reduced ground made up with copper as patch and FR-4 as a dielectric substrate
- Rectangular microstrip antenna with slit and reduced ground made up with graphene as patch and polyimide as dielectric substrate.
- Total SAR [W/kg] is higher as there is additional layer of tissue absorbed.

4. Result and Discussion

This section discusses the result and discussion. Two key components are antenna design and breast tumour analysis. In this part, the expected outcomes of both elements were reviewed. Preliminary data for the reference antenna and suggested antennas are displayed and discussed. The S-Parameter and VSWR of each antenna will be analysed. The proposed antenna should have a higher S-Parameter value and a lower VSWR value than the reference antenna. The breast tumour site should next be established using SAR analysis, and the maximal SAR value calculated.

4.1 Antenna Design

In this section, the results related to each antenna was discussed. Performance and characteristics of antennas such as reflection coefficient, VSWR, directivity, gain and radiation efficiency were compared. Fig. 8 shows S_{11} for reference and proposed antenna indicated proposed antenna contain better reflection coefficient and bandwidth. From the result, S_{11} reaches a maximum value of -14.57dB at 0.568 THz and a frequency range of 0.5439 THz to 0.5944 THz for reference antenna while proposed antenna resulted in -23.43 dB of reflection coefficient with a centre frequency of 0.35 THz and a frequency range of 0.278 THz to 0.579. This shows proposed antenna has better bandwidth of 30.1 GHz compared to reference antenna of 5.8 GHz. VSWR of reference and proposed are shows in Fig. 9 and 10 respectively. The result demonstrated proposed antenna has better VSWR of 1.21 compared to reference antenna of 1.45.

Fig. 11 and 12 show the maximum gain over resonant frequency for reference and proposed antenna, respectively. Proposed antenna has a higher gain of 3.65 dBi than the reference antenna, which is 2.53 dBi. Fig. 13 compares radiation patterns between the reference antenna and the proposed antenna. It is observed that the reference antenna has a higher directivity of 6.26 dBi than the proposed one, which is 4.37 dBi. The proposed antenna still has better radiation efficiency despite lower directivity based on relationship of gain and directivity. Fig. 14 compares radiation efficiency between the reference and proposed antennas. The proposed antenna has lower radiation efficiency the proposed antenna has higher radiation efficiency of 83% than the reference antenna of 40.4%.

From the results, proposed antenna has better performance than the reference antenna. The antenna's bandwidth is greatly improved by substituting the substrate with polyimide 5.8 GHz to 30.1 GHz. This is due to polyimide having a lower dielectric constant than FR-4. Polyimide also improved overall antenna such as the gain, directivity and VSWR thus resulting in better radiation efficiency. However, polyimide causing the reflection coefficient performance to deteriorate. To encounter this drawback some modifications was made towards reference antenna. The reflection coefficient of proposed antenna was improved after the introduction of inset feed and reduced ground. By replacing the patch with graphene, proposed antenna provides better ratio of gain and directivity thus improving the radiation efficiency.

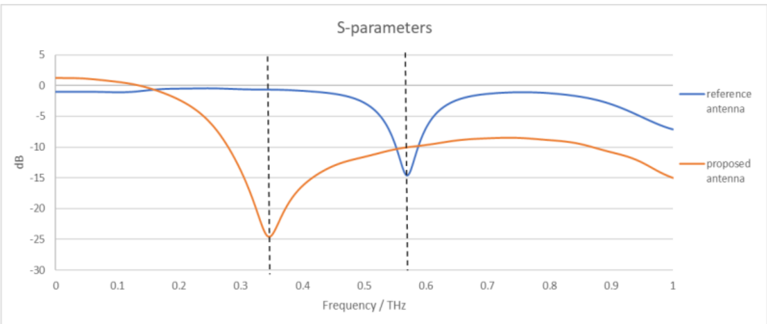


Fig. 8 - S-Parameter of the reference and proposed antenna

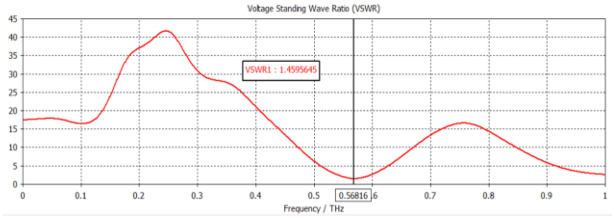


Fig. 9 - VSWR of the reference antenna

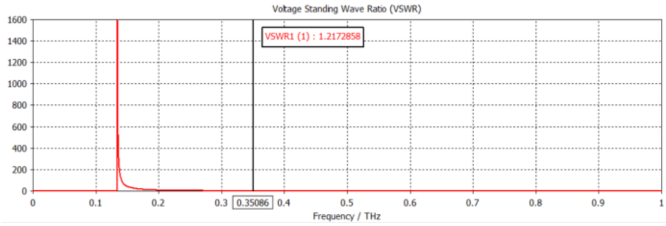


Fig. 10 - VSWR of the proposed antenna

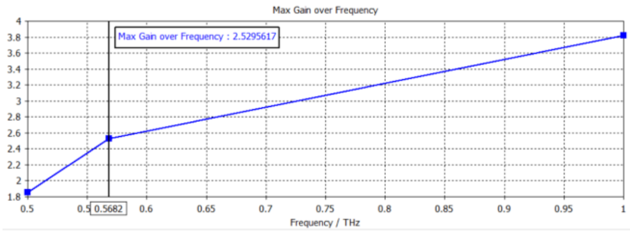


Fig. 11 - Maximum gain of the reference antenna

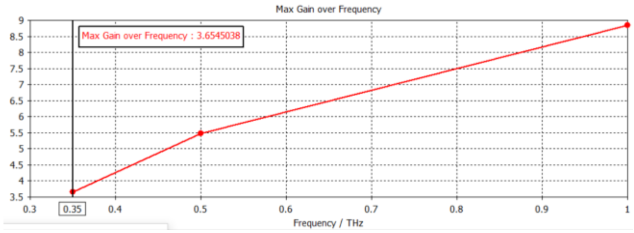
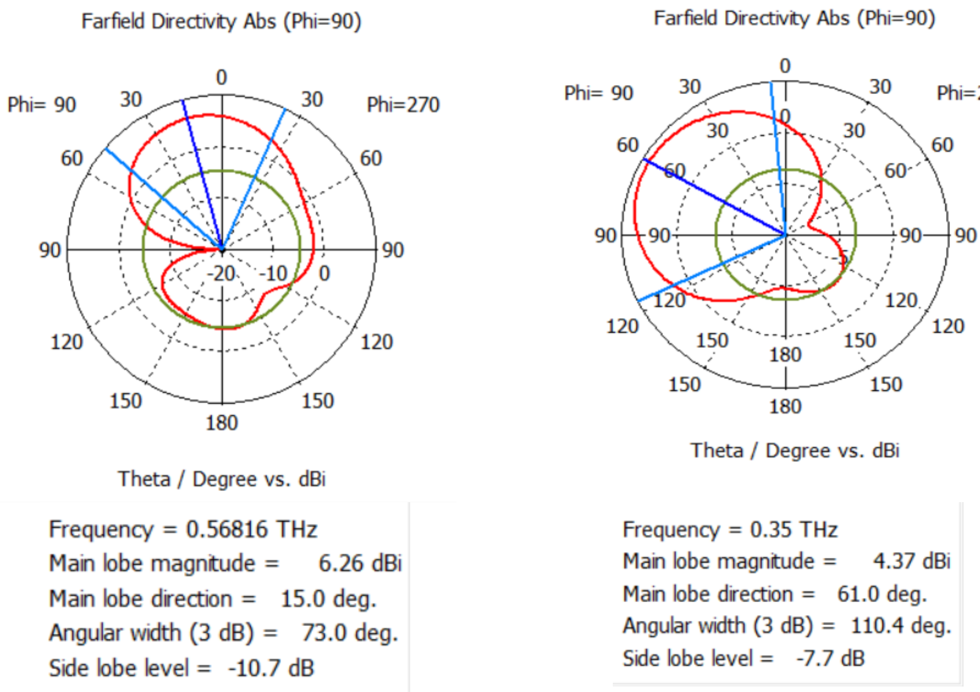


Fig. 12 - Maximum gain of the proposed antenna



(a) (b)

Fig. 13 - Radiation pattern of (a) reference antenna; (b) proposed antenna

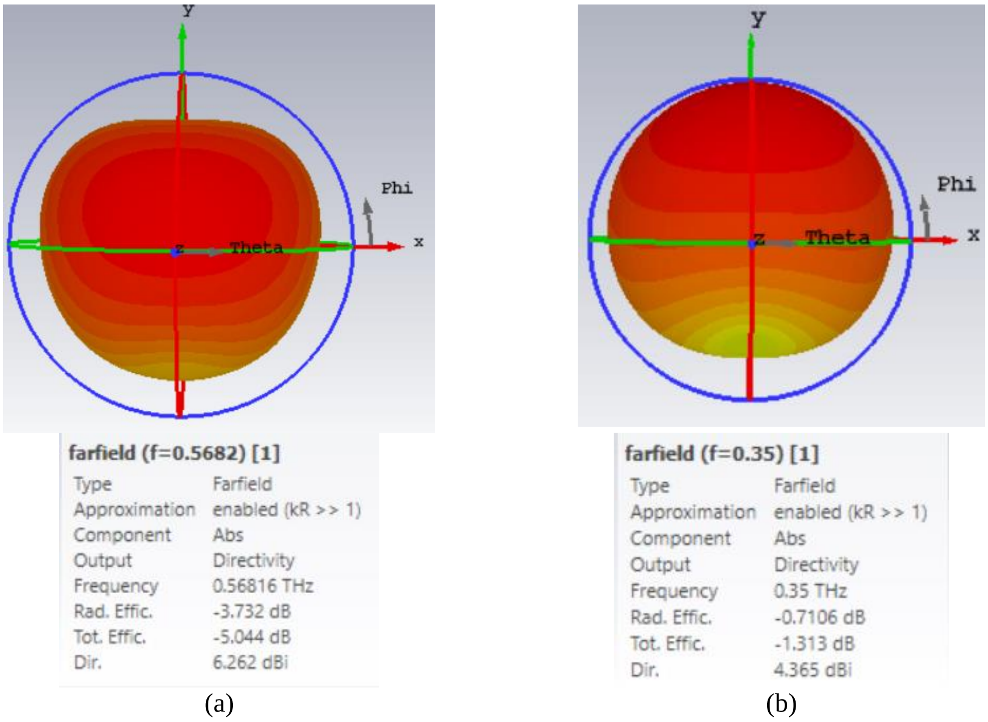


Fig. 14 - Radiation efficiency of (a) reference antenna; (b) proposed antenna

4.2 Tumour Detection

The presence of tumour checked by comparing the reflection coefficient between with and without tumour using proposed antenna. Fig. shows the reflection of coefficient with and without tumour respectively. The reflection coefficient is lower with the presence of tumour.

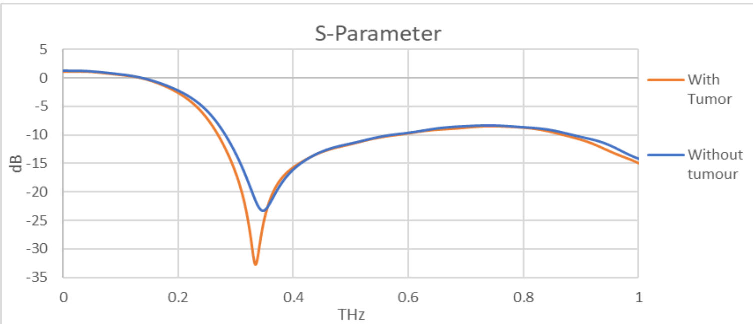


Fig. 15 - Comparison of S11 with and without tumour

4.3 SAR Analysis

Fig. 16(a) and (b) show SAR distribution with and without the tumour, respectively with input power of 1W. SAR distribution shows an only a slight difference between these two models due additional tumour placed was modelled having a minimal total mass of 1.90011e-10 kg. However maximum SAR value was slightly higher (2.49391e+06 W/kg) with the presence of a tumour than in normal breast (2.4681e+06 W/kg) showing the differences of SAR value when tumour is present. This is due to the extra tissue layer being absorbed by SAR. The maximum SAR value of 2.49391e+06 W/kg is far below the maximum whole-body average SAR to provide safety for the human body. This shows the antenna design is safe to use for the human body.

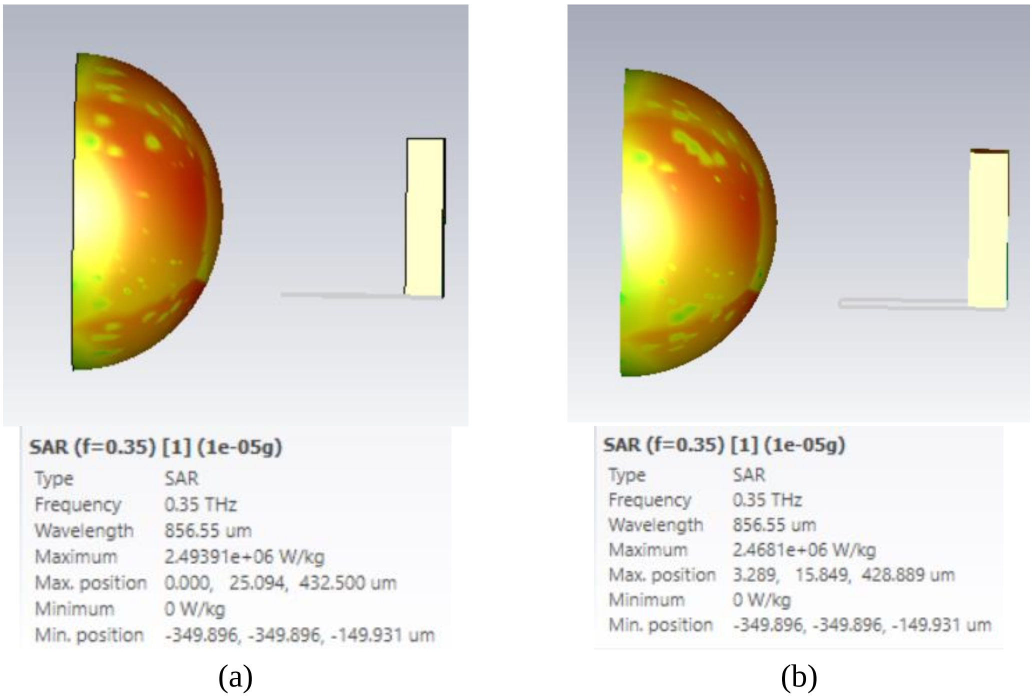


Fig. 16 - SAR distribution (a) with tumor; (b) without tumour

Fig. 17 shows the tumour's exact location in the breast phantom model. The location of tumour is defined away from the local coordinates which is the antenna. This means the coordinate location of the tumour is ranging from (-35, -35,415) to (35,35,485).

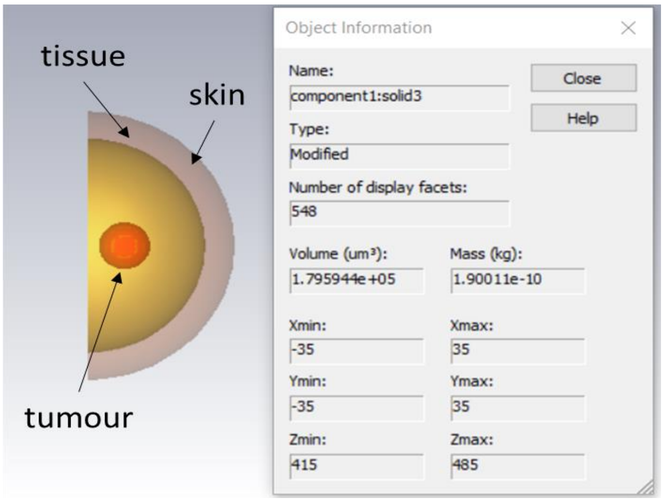


Fig. 17 - Location of the tumour

Fig. 18 shows the results of SAR calculations for averaging mass of 1e-05g at 0.35 THz. From the result given in Fig. 19, the coordinate location of the tumour is located at the maximum SAR value simulated. The coordinate is given by SAR calculation result from Fig. 19 is located at (0.328947, 25.4245, 441.25). Since the coordinate of tumour was placed is ranging from (-35, -35,415) to (35,35,485), SAR calculation result shows the coordinate given is in the range of the exact location where the tumour is placed. This shows the SAR methodologies to locate the tumour is successful.

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=================================================================
SAR Calculation Results
=================================================================

Powerloss density monitor used: loss (f=0.35) [1] at 0.35 THz
Power scaling [W] :             None
Stimulated Power [W] :          0.5
Accepted Power [W] :            0.5
Average cell mass [g]:          1.95466e-11
Averaging method:               IEEE/IEC 62704-1
Averaging mass [g]:             1e-05

-----------------------------------------------------------------
Entire Volume:

Min (x,y,z) [um]:               -349.896, -349.896, -149.931
Max (x,y,z) [um]:               349.896, 349.896, 649.896
Volume [um^3]:                  3.91683e+08
Absorbed power [W]:             0.0849875
Tissue volume [um^3]:           1.87553e+07
Tissue mass [kg]:               1.97095e-08
Tissue power [W]:               0.0350233
Average power [W/um^3]:         1.86738e-09
Total SAR [W/kg]:               1.77697e+06
Max. point SAR [W/kg]:          1.40309e+07

Maximum SAR (1e-05g) [W/kg]:        2.49391e+06
Maximum at (x,y,z) [um]:            0.328947, 25.4245, 441.25
Avg.vol.min (x,y,z) [um]:           -159.527, -134.431, 130.289
Avg.vol.max (x,y,z) [um]:           160.185, 185.28, 450
Largest valid cube  [um]:           0
Smallest valid cube [um]:           0
Avg.Vol.Accuracy     [%]:           0.0001

-----------------------------------------------------------------
Calculation time [s]:       40029
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Fig. 18 - SAR calculations result

5. Conclusion

This paper presents a microstrip patch antenna comprised of graphene as the patch material, copper as the ground material, and polyimide as the dielectric substrate for breast tumour detection is proposed in this work. The reduced ground plane is introduced, and inset feed is incorporated to improve the reflection coefficient to a higher value. Comparison made with reference antenna shows the proposed antenna has S-parameter and VSWR value. The antenna has resonant frequency of 0.35 THz and an operating frequency range of 0.278 THz to 0.579 THz with a bandwidth of 30.1 GHz. The VSWR is at acceptable value which is 1.21. Reference antenna has maximum gain of 2.53 dBi while proposed antenna has maximum gain of 3.65 dBi. Reference antenna has radiation efficiency of 40.4% and directivity of 6.26 dBi while proposed antenna has radiation efficiency of 83% and directivity of 7.63 dBi.

The method and SAR calculations is shown in this work. The calculation result provides the SAR analysis such as coordinate of breast tumour and maximum SAR value. The breast phantom model with tumour shows higher value of maximum SAR of 2.49391e+06 W/kg than normal breast of 2.4681e+06 W/kg. The maximum SAR value shows the EM is safe for the human body as the value is far below the safe value 0f 0.4 W/kg. The result from the SAR calculation gives an accurate coordinate location of the tumour (0.328947, 25.4245, 441.25). It is within the range of the tumour's actual location, from (-35, -35,415) to (35,35,485).

In conclusion, in this work we study the potential of THz antenna to detect breast tumours using a rectangular microstrip patch antenna with reduced ground and inset feed. Preliminarily, we show proposed antenna has better performance and characteristics. Improvements can further make to the antenna to improve the performance. SAR analysis is made to locate the tumour and calculate maximum SAR value.

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