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Graphene Magnetite Polymeric Nanocomposites (GMPN)-Array Sensor for Human Brain Tumour Detection Using Specific Absorption Rate (SAR) Technique

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Abstract: Graphene Magnetic Polymeric Nanocomposites-Array sensor is successfully detecting human brain tumour based on Specific Absorption Rate technique. The technique associated with low cost, non-invasive and accurate in detecting tumour. The sensor consists of graphene as the radiating element and Polydimethylsiloxane Ferrite as the substrate in order to realize ultra-wide band radiation (2.5 GHz-12.2 GHz) with high energy (2.5dB-6.7dB) in microwave frequency ranges. Amount of energy absorbed by the human brain indicated the present of tumour. Human brain with tumour absorbed more energy and recorded higher SAR value (2.56 W/kg) compared with human brain without tumour (1.07 W/kg).

Keywords: Graphene, Polydimethylsiloxane, Brain Tumour, Specific Absorption Rate

1. Introduction

Recently, graphene as the radiating material has gained much interested among the communication device community. It can be seen in the magnificent ongoing graphene transistors development process and currently is considered as the potential option for post-Si electronics. In order to realize more flexible applications in communication fields, numerous number of portable wireless communication device are needed align with the prompt development of modern wireless communications. Since patch antennas provide various advantages while achieving operated microwave frequency band, Graphene is utilized as the patch material to replace conventional radiating material such as copper. Comparison study done by [1] found that Graphene patch antennas recorded completely better performance compared to Single Wall CNT, Multi Wall CNT and Copper patch antennas due to several advantages such as nanoscale size (0.33nm), great conductor (10^8, electron travel 1/100 speed of light), lightest material (0.77 mg/1m) and strongest material (150,000,000 psi; 300 x stronger than steel) due to the single layer of carbon atoms packed in a two-dimensional honeycomb lattice structure. Eventhough Copper patch antennas demonstrated good results yet it is slightly less good as compared to Graphene due to Graphene has slightly higher conductivity compared with Copper. It can be concluded that Graphene is the promising future candidate as patch material for patch antennas as well as the sensor for cancer detection purpose.

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On the other hand, PDMS is used due to its unique characteristics especially low permittivity, mixable with other inclusions, flexible, transparent, thermally stable and water resistant (10, 11). In addition, until now there is yet an investigation in exploring the application of magneto-dielectric substrate for UWB antennas in term of its performance such as mutual coupling, correlation coefficient and diversity gain.

Since beginning, cancer is one of the most complicated disease ever exist in the world. In 2030, according to statistics done before, around 13.2 million people will suffer and die due to cancer [2]. Cancer early detection leads to effective treatment to have higher chance to be cure from the disease. Various imaging equipment have been commonly used for detection purpose such as conventional X-ray, magnetic resonance imaging (MRI), computed tomography (CT Scan) and ultrasound technique [3]. Lately, microwave frequency based device has been utilized in tumour detection for one of its medical application. Microwave cancer detection offers several significant advantages compared to others imaging technique including low costs, non-invasive, involves nonionizing radiation and have high accuracy in detecting tumour existence [1]. In Specific Absorption Rate (SAR), microwave cancer detection is realized by the interesting characteristic of the normal tissue and malignant tissue which demonstrated huge difference in term of dielectric property at the microwave frequency. Malignant tissues will record higher dielectric property due to more absorption of electric field compared to normal tissues which help the researcher to identify the tumour presence [4]. Hence, microwave based technique, SAR technique is selected as the alternative method for detection since such technique could accurately detect the presence of the tumour in the brain.

SAR is used to measure the energy rate absorbed by the human body when exposed to electromagnetic field [2]. The rate could be calculated from following scientific formula (1):

$$SAR= (\sigma|E|2)/\rho \qquad (1)$$

where σ is the tissue conductivity (S/m), E is the internal electric field (V/m) and ρ is tissue mass density (Kg/m3). The values of SAR can be categorized as 1g or 10g mass of tissue which equivalence to 1g or 10g spatial average SAR. According to IEEE C95.1:1999, I.6W/kg is the limit value for 1g spatial average SAR while it has been updated as 2W /kg for 10g spatial average SAR based on IEEE C95.1:2005. New emerging of technology, ultra wideband (UWB) systems lead to resolution improvement of the detection. Currently, utilization of UWB antennas promising significant function in cancer detection due to UWB antennas are well suited for medical applications since it offer high gain good return loss compared with most of the conventional compact UWB antennas which have low gain and poor return loss [3].

In this paper, graphene sensor with high gain and better return loss is applied as the sensor combine with PDMS-Ferrite as the substrate in order to detect the brain tumour using SAR technique. A brain phantom model with tumour inside is designed using CST software and is placed close to proposed antenna to measure the desired SAR value. It has been discovered that the SAR rate for the healthy brain model is lower compared to the model with tumour inside where the respective SAR values for both condition are tabulated to see the significant differences.

2. Antenna Design

Fig. 1 shows the geometry of the simulated GMPN-Array sensor from the front, transparent back, top and back view. The sensor consists of four identical circular radiating element made of new material, graphene as well as new combination of Polydimethylsiloxane (PDMS) and nanocomposite polymeric of magneto -dielectric (Ferrite-Fe_3O_4) as the new material for substrate. The radiating element and the substrate have PDMS the thickness of 0.33 nm and 1.6 mm respectively. The patches comprise of four identical circular with diameter of 15 mm are properly connected with quarter wave transformer transmission line. Small dimensions of 80 mm × 45 mm made the UWB antenna suitable enough to be integrated as the sensor or probe in microwave imaging system. Its coplanar waveguide has wide and length of 8 mm and 32 mm respectively. Equal current distribution towards all four patches could be realized by using the quarter-wave transformer impedance matching technique. Quarter-wave transformers of 70.71 Ω are used to have ideal match between the 100 Ω lines and the 50 Ω lines [5]. The sensor associated with flat copper reflector in order for the sensor to have unidirectional radiation pattern by reflecting the back-radiation towards the front. The value for Rd is 20 mm.

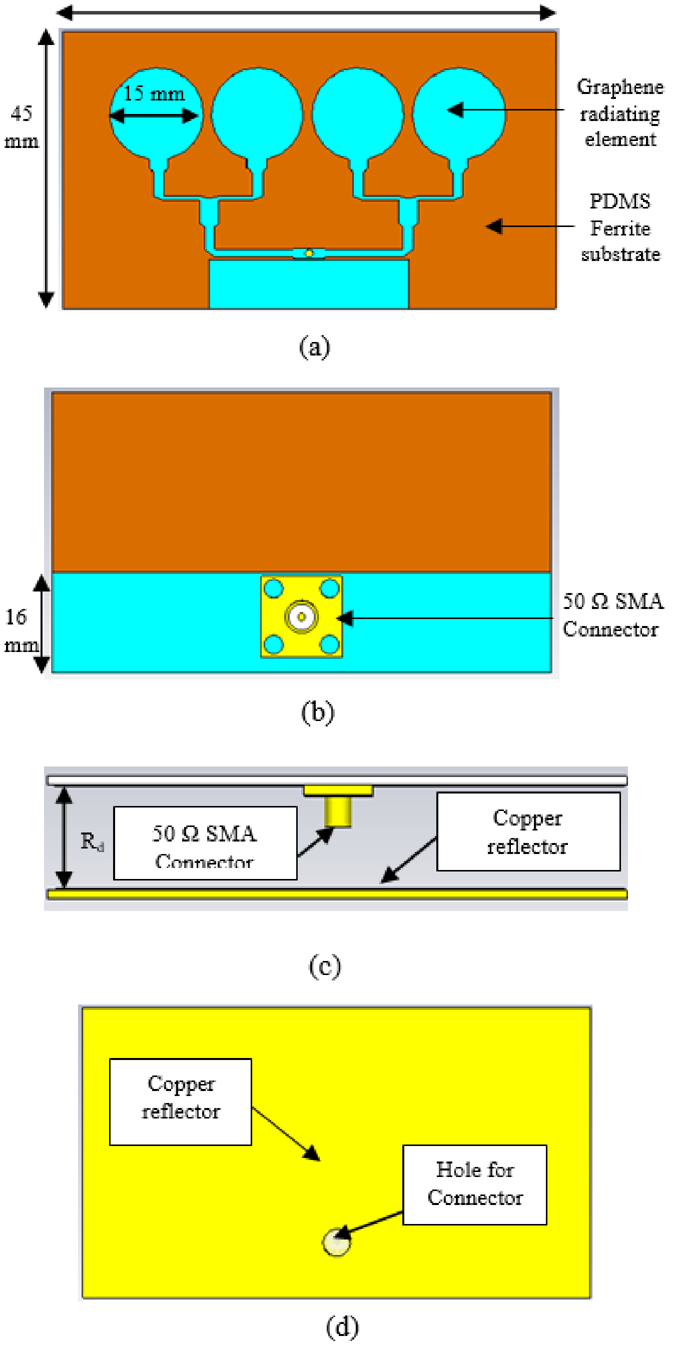

Fig. 1 - GMPN-array sensor simulated structure (a) front view, (b) transparent back view, (c) top view and (d) back view

The sensor recorded ultra-wide band microwave radiation less than -10dB started from 2.5 GHz until 12.2 GHz with high energy transmitted ranged from 2.5 dB to 6.7 dB as shown in Fig. 2 and Fig. 3 respectively. Reflection coefficient value less than -10dB indicated 90% of the energy is transmitted while only 10% is reflected [6].

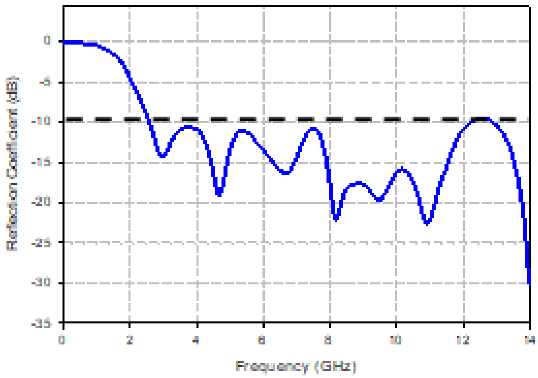

Fig. 2 - Reflection coefficient of GMPN-array sensor

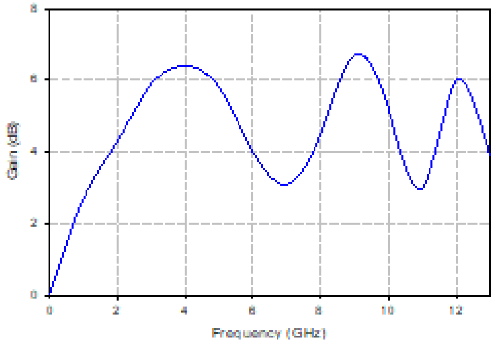

Fig. 3 - Gain of GMPN-array sensor

Fig. 4 show the polar radiation pattern (E-plane) for the proposed sensor at the frequency of 3 GHz, 4 GHz, 5 GHz and 6 GHz. These four particular frequencies recorded among the highest gain of the antenna. The radiation pattern indicates the sensor does radiate over a wide frequency band [13]. The sensor exhibits the lowest and the highest directivity of 3.46 dB and 12.12 dB respectively. The high directivity of the unidirectional antenna due to the present of flat copper reflector located at the back of the sensor promising the good probe or sensor for human brain microwave imaging.

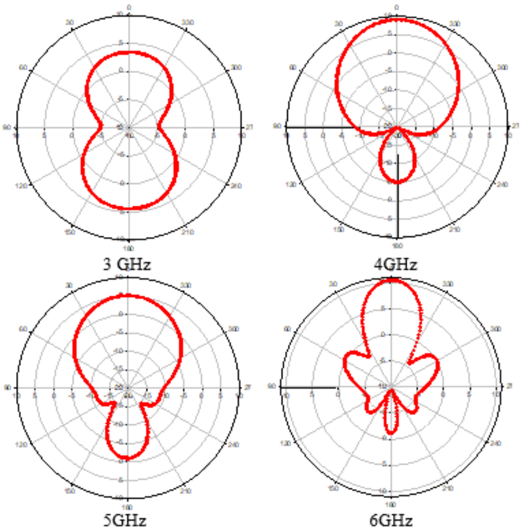

Fig. 4 - Simulated polar radiation pattern in Azimuth plane

3. Results and Discussion

Graphene which has great electrical conductivity of 108 s/m [7] combined with low electrical permittivity of PDMS Ferrite around 2.2 resulted in high energy production [8] which needed to be absorbed by the tumour. Figure 5 illustrated the measurement setup for brain tumour detection using SAR technique. The GMPN-Array sensor is placed 10 mm away from the multilayer human head phantom as the ideal distance to have maximum energy absorption.

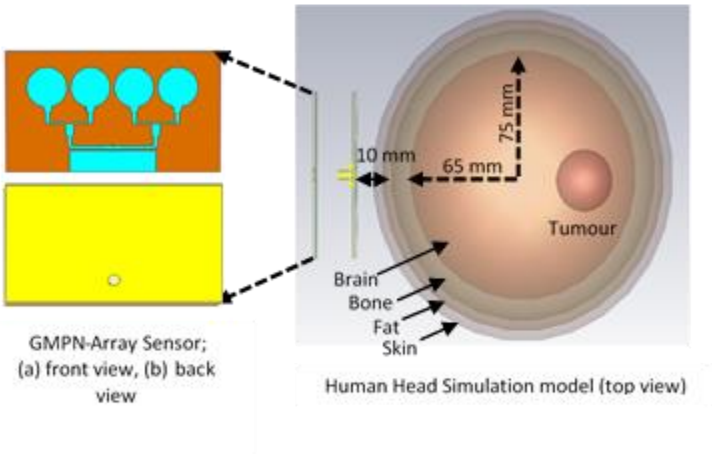

Fig. 5 - Measurement setup for brain tumour detection

The sensor radiated the energy towards two different kind of human head phantoms which are the one with tumour present meanwhile another one is without the tumour present to obtain the different SAR value. On the other hand, in order to predict the exact location of the tumour, the sensor radiated the energy towards nine different areas to cover the whole one sided area of those two phantoms as shown in Fig. 6.

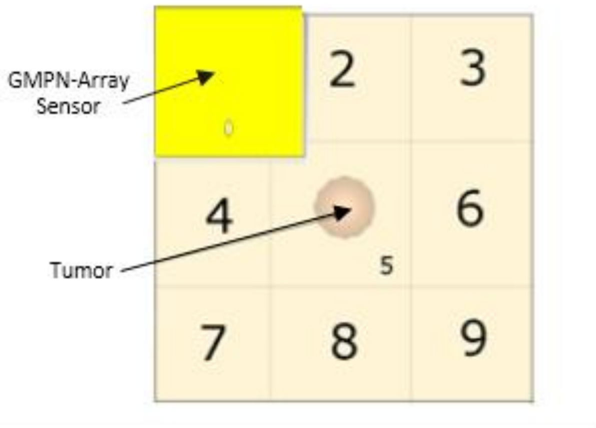

Fig. 6 - Scanning area for head phantom

The highest different in SAR value among the nine scanned areas between phantom with tumour and without tumour among indicate the tumour position at that particular area. The results are tabulated in Table I which proposed the tumour position at the area 5 that recorded the highest SAR difference of 1.49 w/kg. On the other hand, Fig. 7 illustrate the simulation result for SAR using CST software.

Table 1 - SAR Average for 1g tissue in W/Kg

Area	With Tumour	Without Tumour	Difference
1	2.05	1.06	0.95
2	2.31	1.10	1.21
3	2.04	1.08	0.96
4	2.35	1.10	1.25
5	2.56	1.07	**1.49**
6	2.32	1.08	1.24
7	2.05	1.11	0.94
8	2.31	1.10	1.21
9	2.02	1.05	0.97

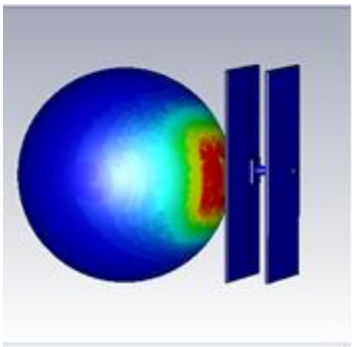

Fig. 7 - Simulation in computer simulation technology (CST) software

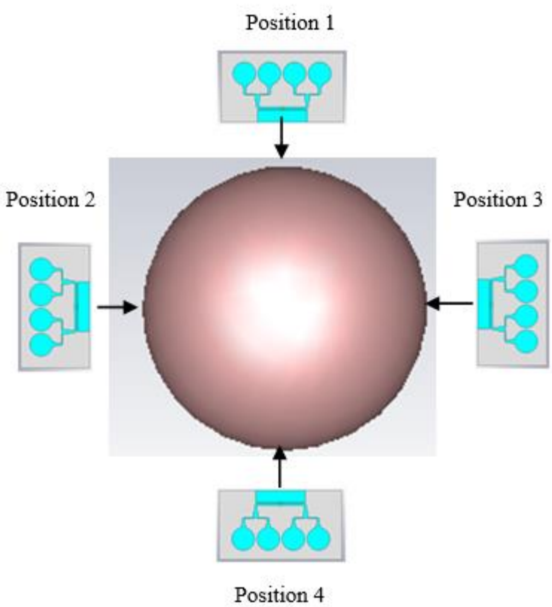

Fig. 8 - Top view head phantom with sensor position

For further investigation, this paper focuses on SAR values when tumour is absence and presence with the sensor is placed at the various position and different distance. Fig. 8 shows the sensor position are located at front (position 2), left (position 1), right (position 3), back of the human head phantom (position 4). The distance between the human head phantom and the sensor are determined by using 10 mm, 20 mm and 30 mm of gap.

Fig. 9 illustrate the distance of the sensor with the head phantom in CST SAR simulation for 10 mm, 20 mm and 30 mm gap meanwhile Table II and III show the result for simulated UWB sensor with human head phantom with tumour and without tumour respectively.

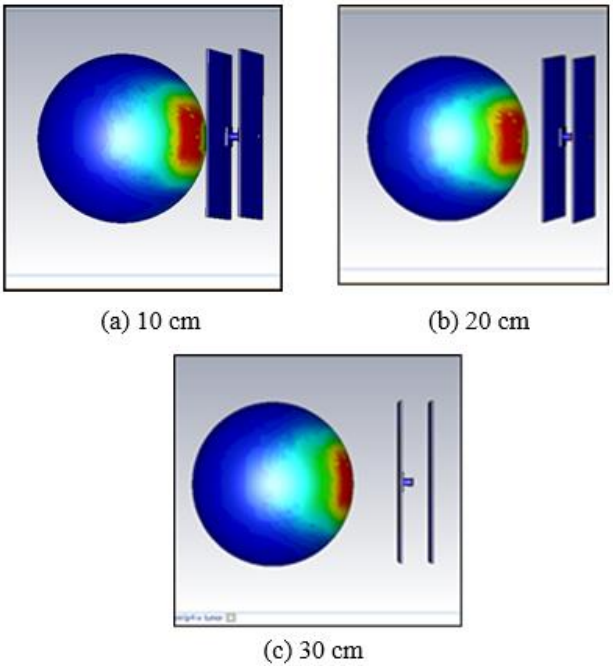

Fig. 9 - Sensor distance from human head model; (a) 10 cm, (b) 20 cm and (c) 30 cm

Table 2 - Simulated result head phantom with tumour

Position	**Distance**		
	10mm Maximum SAR (10g) (W/Kg)	**20mm Maximum SAR(10g (W/Kg)**	**30mm Maximum SAR(10g) (W/Kg)**
P1	3.76393	2.4703	2.20884
P2	3.89465	2.48251	2.28846
P3	4.33292	2.58463	2.29228
P4	4.17513	2.56897	2.29725

Table 3 - Simulated result head phantom without tumour

Position	**Distance**		
	10mm Maximum SAR (10g) (W/Kg)	**20mm Maximum SAR (10g) (W/Kg)**	**30mm Maximum SAR (10g) (W/Kg)**
P1	3.61237	2.35045	2.10687
P2	3.75902	2.3826	2.28181
P3	4.32886	2.46335	2.28677
P4	4.16286	2.45519	2.2947

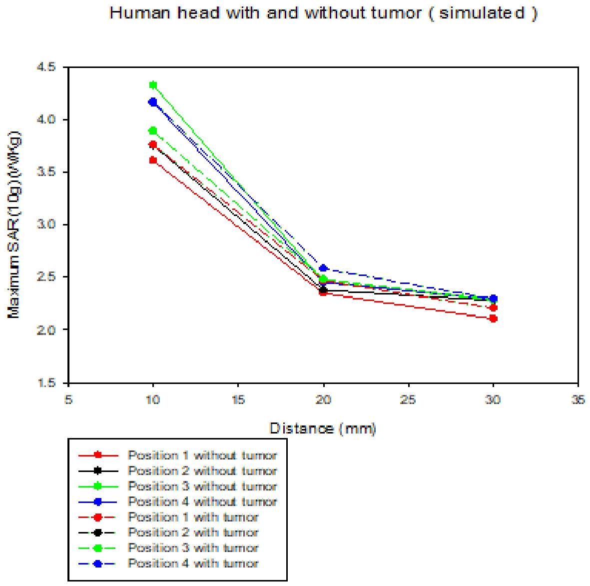

Fig. 10 - Result of simulated human head phantom with tumour and without tumour

Fig. 10 shows the simulated result when the sensor placed close to a human head phantom with 10mm, 20mm and 30mm distance. From the graph, straight line represent sensor position without tumour meanwhile dotted line represent sensor position with tumour.

From Fig. 10, it can be seen that the change of maximum SAR value are bigger and significant for 10 mm gap movement towards 20 mm gap. However, sensor movement from 20 mm towards 30 mm resulted in quite constant SAR values indicated not significant different. This is because 10 mm until 20 mm is the ideal distance for detection, any value above than 10 mm is not suitable since the energy radiated is not adequate enough to penetrate the phantom. Energy has been reduced due to loss towards the environment cause of collision with air molecule.

Fig. 10 also shows sensor located at position 3 which at right phantom with 10 mm distance for with and without tumour have the highest maximum SAR value compared to other position. For sensor at position 3 with tumour, the head phantom absorbs power 4.33292 W/kg meanwhile for without tumour the head phantom absorbs power 4.32886 W/kg. This is due to the sensor is located at the nearest point (position 3) with the tumour in the human head model.

Based on Fig. 10, all sensor positions with the tumour presence have the highest value compared to all the sensor position with the tumour absence. Power absorbed 3.89465 W/kg at position 2 with 10 mm distance with tumour presence and it drop to 3.75902 W/kg at position 2 with 10 mm distance with tumour absence in the phantom. This is because majority of the tumour is made up of liquid such as blood vessel and fat. Liquid able to absorb more power, hence the power will absorb more on the phantom with presence of tumour.

Apart from advantages mentioned before, modifiable dielectric properties, easy to compound with various concentrations, easy fabrication process, flexible, transparent, thermally stable, and low cost are the other interesting characteristics of Graphene Magnetite Polymeric Nanocomposites (GMPN) Sensor [9].

4. Summary

As conclusion, GMPN-Array sensor is successfully detecting human brain tumour based on SAR technique. It is realized by the high performance of the UWB Array antenna which recorded high energy (2.5dB-6.7dB) with wider operated frequency (2.5 GHz-12.2 GHz) due to the presence of grapheme as the radiating material and PDMS-Ferrite as the substrate for the detection sensor. Amount of energy absorbed by the human brain indicated the present of tumour. Human brain with tumour absorbed more energy and recorded higher SAR value (2.56 W/kg) compared with human brain without tumour (1.07 W/kg). The ideal distance UWB array sensor is placed between10 mm and 20 mm away from the human head in order to have maximum energy absorption. The results conclude that the ideal location of UWB array sensor is the nearest to the tumour when it recorded the highest value of SAR compared with other position. Based on simulation result, the presence of tumour resulted in higher maximum SAR value compared with and without the presence of tumour in human head.

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