EARLY DETECTION OF TUMOR IN BRAIN USING MONOPOLE ANTENNA

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Abstract - *In this paper, a monopole antenna is designed, analyzed at 2.45 GHz ISM band on a glass-reinforced epoxy laminate material (FR-4) substrate for early detection of brain tumor. FR-4 is used as a substrate due to its low loss tangent, flexible, and moisture resistant properties. By the implementation of slotting method, the size of this antenna is reduced to 36 × 39 mm². The printed antenna exhibits 857MHz bandwidth ranging from 2.14 GHz to 2.99 GHz frequency. It shows a radiation efficiency of 74.5 % with a realized gain of 1.49 at 2.45GHz frequency. The Monostatic Radar approach is considered to detect brain tumor by analyzing the variations in received signals from the head model with and without tumor. The maximum specific absorption rate (SAR) distribution at 2.45 GHz frequency is calculated. The compact size and flexible properties make this monopole antenna suitable for early detection of brain tumor.*

Key Words: *Monopole Antenna, Brain Tumor, Monostatic Radar and specific absorption rate (SAR)*

1. INTRODUCTION

Statistics categorizes stroke as the second most common reason for death [1] and the third most reason for disability [2]. If the treatment is ensured faster for stroke patients, the possibilities of recovery are higher. The traditional brain stroke detection techniques are Computed Tomography (CT), Positron Emission Tomography (PET), Magnetic Resonance Imaging (MRI), Electroencephalography (EEG), Magneto-encephalography (MEG), Magnetic Induction Tomography (MIT), and Electrical Impedance Tomography (EIT) [3].

An alternative screening technique which can be administered bedside or in an ambulance is necessary for point of care detection and early screening[4]. Paramedics can provide crucial information about the patient's symptoms and the test results to the hospital on the route. Brain stroke detection using Electromagnetic Impedance Tomography (EMIT, a non-invasive medical imaging technique using microwave devices) is gaining significant momentum as a surrogate technique to the state-of the art screening techniques.

In EMIT based brain stroke detection scheme, antenna plays a crucial role. In literature, different EMIT based stroke detection techniques can be found which use rigid and flexible antennas [3–10]. Munawar et al. utilized EMIT technique using microwave signals to detect stroke [3]. Mobashsher et al. used a 3D wideband unidirectional antenna with an overall dimension of 70 × 60 × 15mm³ designed on 1.52-mm-thick GIL GML 1032 substrates to detect the stroke [5].

They presented a technique based on the contrast of reflection phases for stroke detection collecting scattered signals from the antennas and investigating them to reduce the strain of the system. Mohammed et al. used variations in the reflection coefficients to detect stroke using an array of eight tapered slot antennas (TSA), each with dimensions of 24 × 24 × 0.62mm³ on a Rogers RT6010 substrate [6]. Wu and Pan used directional folded antennas with a dimension of 81.2×80×1.6mm³, each on an FR-4 substrate to detect stroke. They classified the results from the human brain model simulation by algorithms, such as PCA and LDA classification algorithms to verify the efficacy of the antenna and found accurate classification [7].

Jamlos et al. detected stroke with an ultra-wideband antenna with a dimension of 80×45×1.57mm³ designed on a Taconic (TLY-5) substrate[8]. The authors used the Inverse Fast Fourier Transform (IFFT) for easier analysis of *S*-parameters and smoothing '*mslowess*' procedure to filter out the noise for accurate results. Using an array of 8 antennae with a dimension of 70 × 30mm², each printed on a 75-µm-thick PET substrate, Bashri et al. investigated a wearable head imaging system [9]. Alqadami etal. used a flexible and wideband 8-element array antenna with a dimension of 85×60×4mm3 based on a multilayer PDMS polymer substrate to detect brain stroke with a head imaging system [10].

Above discussed investigations take time for effective image reconstruction [11] and have strong multipath reflections due to array configuration [12, 13]. All these techniques used rigid substrates except Bashri etal. [9] and Alqadami et al.[10]. Though Bashri et al. and Alqadami et al. used flexible substrates, these antennas have comparatively larger dimensions due to the array configuration. Md. Ashikur Rahman, et.al, a compact slotted disc monopole antenna is designed and printed on a PET substrate for early detection of brain stroke. The size of this antenna is reduced to 40 × 38mm². Silver nano particles (AgNPs) ink is used due to its high conductivity (6.3 × 107 S/m) [14] and anti-oxidation properties unlike copper nano particles (CuNPs) ink which is extremely vulnerable to oxidation in the air [15]. PET substrate is preferred to other flexible substrates such as photo paper due to its low loss tangent and moisture resistant properties.

Current research on EMIT based stroke detection is focusing on antennas that are compact and conformal to improve the resolution and accuracy of the results.

In this paper, a compact slotted disc monopole antenna is designed and printed on a FR-4 substrate for early detection of brain stroke. The size of this antenna is reduced to 36 × 39 mm² as compared to earlier reported antennas for stroke detection [5, 7–10]. FR-4 substrate is preferred to other flexible substrates such as photo paper due to its low loss tangent and moisture resistant properties.

The Monostatic Radar (MR) approach is considered to detect brain stroke due to its simplicity. Also, the SAR distributions of this antenna are calculated at 2.45GHz frequency for a maximum power level of 20 dBm in CST Microwave Studio.

2. ANTENNA GEOMETRY

The proposed circular microstrip patch antenna fed by a microstrip line is shown in Figure 1, which is printed on the FR4 Epoxy substrate with a size of Substrate width 36 mm and substrate length 39 mm (i.e., Ws × Ls = 36×39 mm²), the thickness of 1.6 mm and relative dielectric constant of 4.4, length of the feed line 5.58 mm, and width of the feed line 3.12 mm. The proposed antenna is connected to a connector for signal transmission.

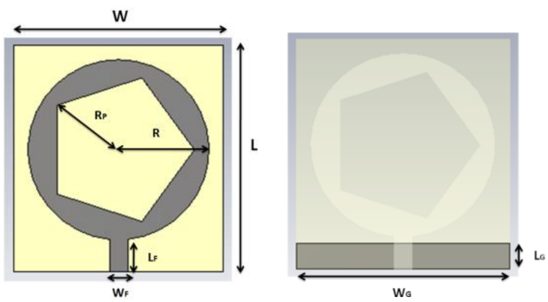

Figure 1: Design Model of the proposed antenna.

Table 1: Design parameters of the proposed antenna.

Variable Name	Symbol	Unit (mm)
Width of substrate	W	36
Length of substrate	L	39
Width of the feeding line	W_F	3.12
Thickness of FR-4 substrate	T	1.6
Length of feeding line	L_F	5.58
Radius of circular disc	R	15.5
Length of one side ground plane	L_G	4.33
Width of one side ground plane	W_G	36
Radius of pentagonal slot	R_P	13.5

The patch is connected to a microstrip feed line with a radius of 15.5 mm. A partial ground plane is printed on the bottom surface of the substrate, which is the same width as the substrate width (Wsub). To cover a much better frequency band pentagonal slot has been taken on the patch. All the Optimized design parameters and corresponding values for the proposed circular microstrip patch antenna are listed in Table 1.

3. MODELING OF HUMAN HEAD PHANTOM

The wearable antennas require a detailed analysis of the interaction of the antenna with the human body. A 7-layer human head model and single layer stroke model are designed and analyzed for 2.45 GHz frequency in this section. The head model including layers of skin (dry), fat, muscle, skull, dura, cerebrospinal fluid, and brain is shown in Figure 2. The proposed antenna is placed at a distance of $2D^2/\lambda$ that denotes the separation distance of the proposed antenna with the human head model. The electrical properties such as permittivity (ε_r) and conductivity (σ) of the 7-layer model along with the thickness of skin (dry), fat, muscle, skull, dura, cerebro-spinal fluid, and brain respectively. The single-layer stroke model (Tumor) is considered to be a spherical blood clot with an 18 mm radius shown in Figure 3. The values of the body tissue dielectric parameters are computed using a 4-Cole-Cole Model [16].

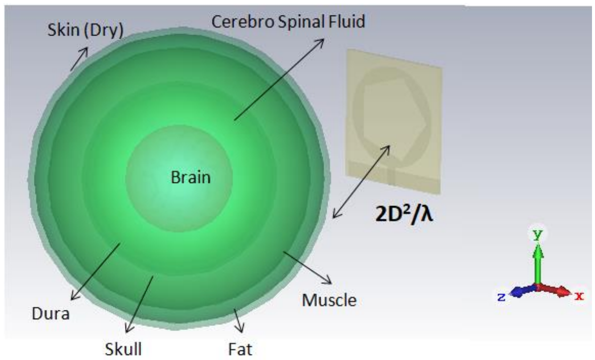

Figure 2: 7-layer human head model with the proposed antenna

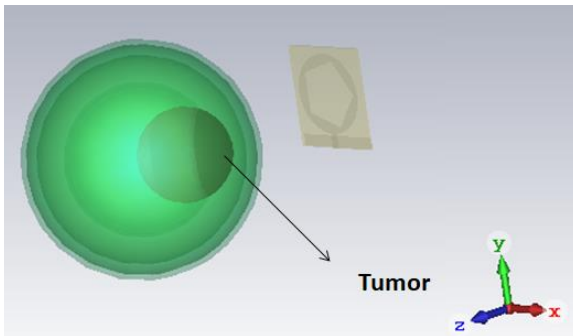

Figure 3: single-layer spherical stroke model (Tumor)

4. RESULTS AND DISCUSSION

The simulated return loss (dB) of the proposed antenna is about −38.44 dB at 2.448 GHz. It exhibits a −10 dB return loss bandwidth of around 857 MHz (2.14 to 2.99 GHz) and the simulated s-parameter graph shows in Figure 4.

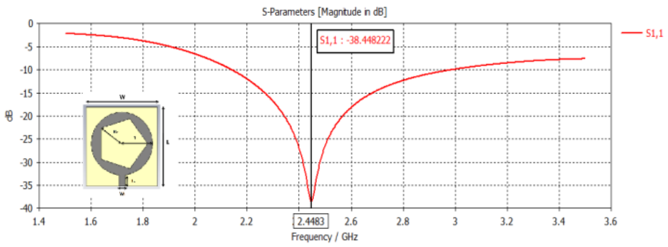

Figure 4: S-parameter plot of the proposed antenna.

The simulated return loss (dB) of the proposed antenna with head model is about −31.14 dB at 2.444 GHz. It exhibits a −10 dB return loss bandwidth of around 857 MHz (2.14 to 2.99 GHz) and the simulated s-parameter graph shows in Figure 5.

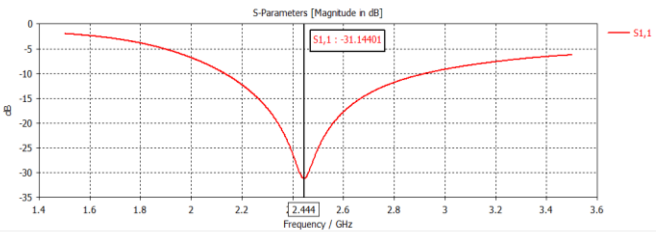

Figure 5: S-parameter plot of the proposed antenna with Phantom.

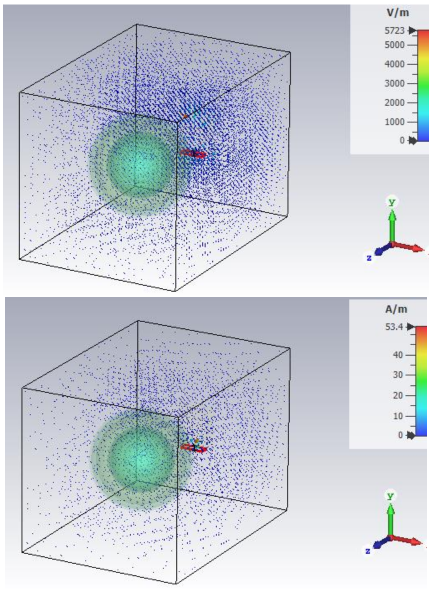

Figure 6: Electric and Magnetic Field of the proposed antenna with Phantom.

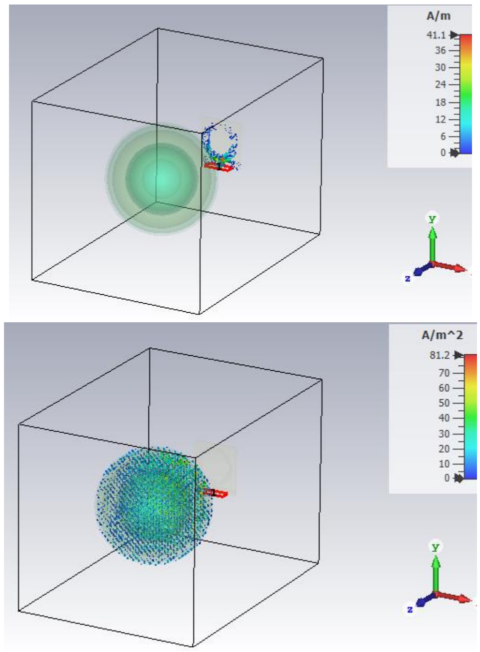

Figure 7: Surface current and current density of the proposed antenna with Phantom.

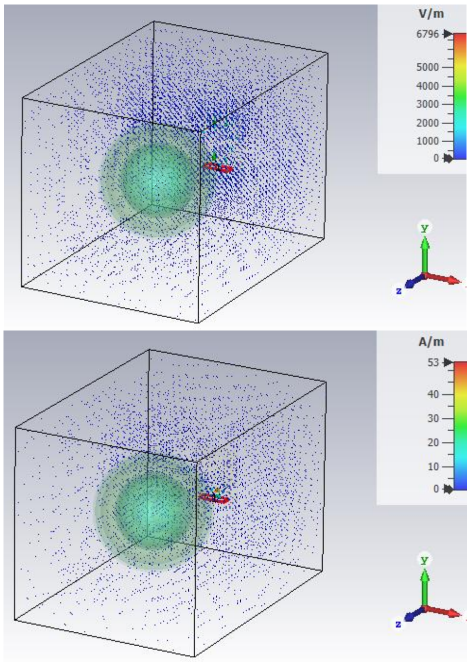

Figure 8: Electric and Magnetic Field of the proposed antenna with Phantom.

Table 2 shows the comparison among the proposed antenna without tumor and with tumor. From the above table, electric field, magnetic field, surface current and current density values for without tumor and with tumor are different, with help these threshold values and also using the variation in Reflected time signals with and without tumor model (shown in figure 8), we can able to detect tumor in head. The proposed antenna shows an efficiency of 72.5% in a flat position when being simulated in free space. The proposed antenna has a peak gain of 1.49 dB at 2.45GHz in free space at the flat position.

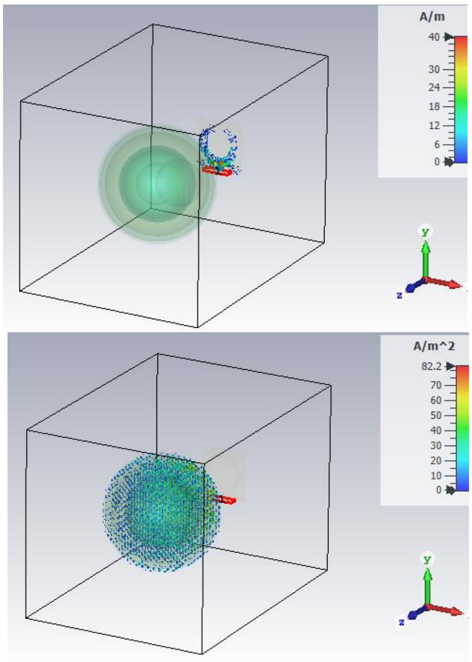

Figure 9: Surface current and current density of the proposed antenna with Phantom.

Table 2: The result comparison among the proposed antenna without tumor and with tumor

Model	Electric Field (V/m)	Magnetic Field (A/m)	Surface current (A/m)	current density (A/m^2)
For proposed antenna with Phantom without tumor	5723	53.4	41.1	81.2
For proposed antenna with Phantom with tumor	6796	53	40	82.2

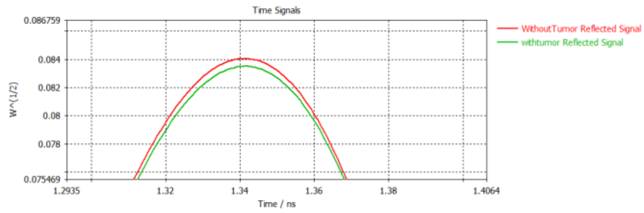

Figure 10: Variation in Reflected time signals with and without tumor model.

5. CONCLUSIONS

A Flexible Monopole Antenna on a FR-4 substrate is presented for early brain stroke detection application. This Monopole Antenna exhibits a bandwidth of 857 MHz, along with a realized gain of 1.49 dB. The performance of this antenna is adequate in flat and cylindrical head proximity conditions for ISM band applications. Also, the SAR distribution shows that the values are well within the safety limits. This study serves as a proof of concept validation of stroke detection this technique. With sufficient controls in place and in-depth study of various critical factors such as temperature and pulse of the patient, a point of care device could come into fruition. The magnitude of the variation in reflected signals can be significantly enhanced by using the antenna array.

In future, an antenna array will be placed on the head, and reflected signals will be collated and processed by digital signal processing algorithms. The signature can then be visualized as a 2D image using digital image processing algorithms. This antenna might be a basis for a futuristic diagnostic tool for point-of-care stroke detection by the first responders. The flexible and compact nature of this Flexible monopole antenna enables the feasibility of a future surrogate device for early brain stroke detection.

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