Brain Tumor Detection Using Metamaterial Based Microstrip Patch Antenna

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Abstract - *A compact metamaterial based microstrip patch antenna is designed and analysed in this paper for efficient detection of brain tumor. At first, a compact patch antenna is designed with metamaterials loaded over patch and with partial ground plane. Next a brain phantom is developed with tumor & without tumor. Then the antenna is simulated upon brain phantom and the variations in magnetic field, current density & specific absorption rate are measured. It is found that the current density value has been increased twice than that of the brain without tumor and the specific absorption rate is also drastically increased compared to the brain having no tumor.*

Key Words: **Microstrip patch antenna, Specific absorption rate, Current density.**

1. INTRODUCTION

Cancer is one of the most complicated disease that even leads to death if it is not identified at the earlier stage. Statistics reveal that around 13.2 million deaths of cancer are expected in 2030 [1]. Early detection of cancer is an important aspect for effective treatment. Detection of cancer can be done in various ways and usually depends on the stage in which the cancerous tumors are traced. Basic methods like x-rays, ultrasound, computed tomography (CT) scan, magnetic resonance imaging (MRI) scan and biopsy are used in detecting tumors in the initial stages. Microwave tomography [2-5] and radar based microwave imaging techniques have been investigated in cancer detection [6]. In microwave tomography, the electric field distribution is reconstructed by solving the inverse non-linear function problem. Using radar based microwave imaging techniques, ultra-wideband pulses are transmitted from antenna array that surrounds the human head and it is an expensive technique. Microwave imaging has been evolved from older detection techniques in which hidden objects can be detected using electromagnetic waves in microwave region (300 MHz - 300 GHz). Here, detection is based on the variations in electrical properties of the tumorous cells from the surrounding healthy tissues [7-12]. Recent technologies, particularly the use of ultra-wideband (UWB) systems allow resolution enhancement in the detection. In paper [13] an ultra-wideband antenna was used for brain tumor detection by analyzing the variations in current density and specific absorption rate. Detection was also done by analyzing the variations in return loss of the antenna by simulating the antenna upon brain phantom with and without tumor [14]. In paper [15] detection of tumor was done by measuring the amount of energy scattered from the antenna. If the antenna was focused on the tumor, then more energy gets scattered than that of the antenna that is kept away from the tumor .

In this paper, a compact metamaterial based microstrip patch antenna for efficient brain tumor detection is proposed. This proposed antenna is designed and simulated over computer simulation technology (CST) microwave studio (MWS), which is based on finite integration technique. The proposed antenna is simulated upon brain phantom with and without tumor separately and the variations in current density, specific absorption rate and h-field in the presence of tumor shows the efficient performance of the antenna and the front view of the proposed antenna is shown in Fig-2.

2. PROPOSED METHOD

2.1 Antenna design

The Microstrip patch antenna has a substrate made of Rogers RT 5880 which has a dielectric constant of 2.2 and thermal conductivity value 0.2 (W/K/m). The length of the substrate is 35 mm and the width of the substrate is 26 mm and the thickness of the substrate is 1 mm from the ground plane. The back side of the substrate contains the partial ground plane. The ground plane is made up of copper which is a lossy metal. The length of the ground plane is 10 mm and the width of the ground plane is 26 mm and it is of zero thickness. The other side of the substrate contains the patch that is made up of copper which is a lossy metal. The length of the patch is 20 mm and the width of the patch is 14 mm and the thickness of the patch is 1 mm. The patch is loaded with six complementary split-ring resonators. The proposed antenna is fed with microstrip line feed. The width of the feed line is 3 mm and the length of the feed line is 10.5

mm and the dimensions of the proposed antenna are shown in Table 1.

2.2 Brain phantom design

A brain phantom is designed by considering a sphere as a brain and a cube as a tumor. The permittivity of the brain is 45.8 F/m and its conductivity is 0.77 S/m. A cube with dimensions 5 x 5 x 5 mm^3 is considered as a tumor with permittivity 54.2 F/m and conductivity 2.62 S/m. Tumors will have very high conductivity and different dielectric properties than that of healthy tissues.

In this proposed work, first the antenna is designed and simulated over computer simulation technology. Next the brain phantom is designed with appropriate dimensions using computer simulation technology. Then the proposed antenna is simulated upon brain phantom with and without tumor separately and it is found that the current density and specific absorption rate has been drastically increased in the presence of tumor within the brain. The steps involved in proposed method is shown in Fig -1.

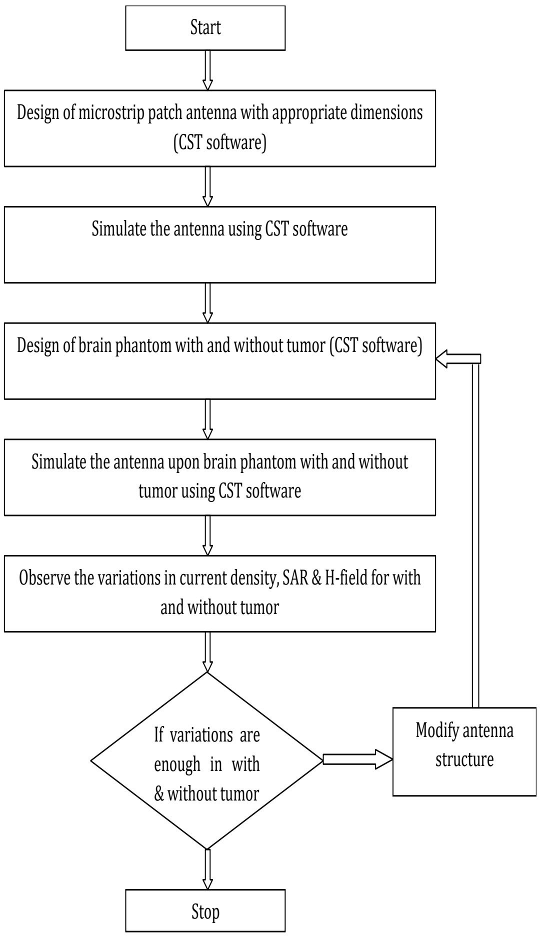

Fig -1: Steps involved in proposed work

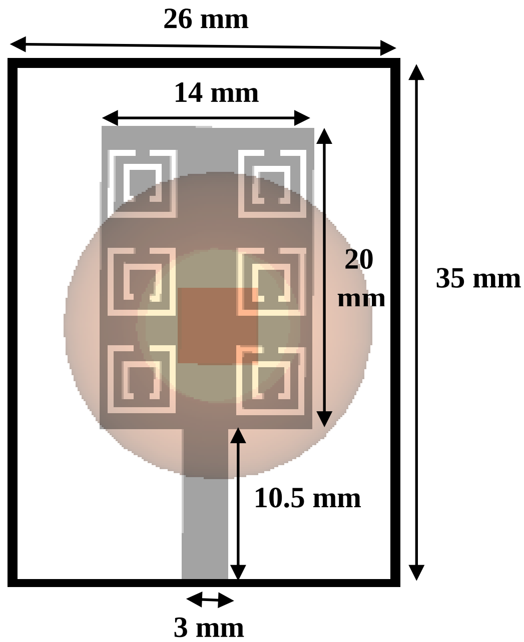

Fig -2: Structure of Proposed Antenna (Front View)

Table -1: Antenna Design Specifications

Sl. No	Antenna Specifications	Dimensions
1.	Length of Patch	20 mm
2.	Width of Patch	14 mm
3.	Length of Substrate	35 mm
4.	Width of Substrate &Ground	26 mm
5.	Length of Ground	10 mm
6.	Substrate Height	1 mm
7.	Dielectric Constant of substrate	2.2
8.	Feed	Microstrip line feed
9.	Width of Feed	3 mm
10.	Length of Feed	10.5 mm
11.	Length of CSRR	4.5 mm
12.	Width of CSRR	4.5 mm

3. METAMATERIAL SPECIFICATIONS

The patch is loaded with six complementary split-ring resonators of dimensions 4.5 x 4.5 mm^2. The length of each complementary split ring resonator is 4.5 mm and the width of each complementary split ring resonator is 4.5 mm and the thickness of each complementary split resonator is 1 mm from the substrate. The spacing between the rings are 0.4 mm and 0.6 mm respectively. Each ring has a slit of dimensions 1 mm in opposite directions. The back view of the proposed antenna is shown in Fig -3.

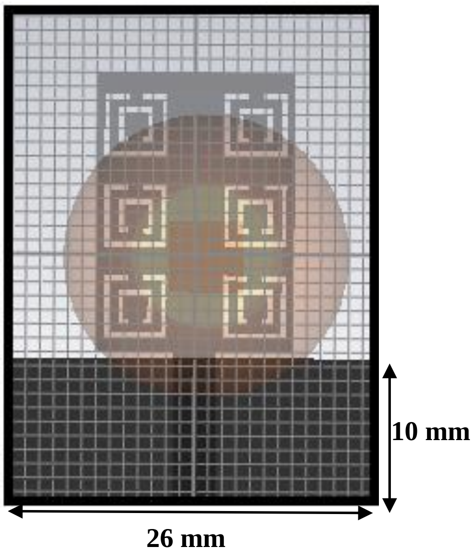

Fig -3: Structure of Proposed Antenna (Back View)

The return loss can be calculated using the formula,

RL= 10 log (Pout/Pin)

Current density can be calculated by,

J=I/A

Specific absorption rate can be calculated by,

$$\mathrm{SAR} = \int_{\mathrm{sample}} \frac{\sigma(\mathbf{r})|\mathbf{E}(\mathbf{r})|^2}{\rho(\mathbf{r})} d\mathbf{r}$$

4. RESULTS AND DISCUSSION

The performance of the proposed antenna is found by simulating the antenna with computer simulation technology (CST) microwave studio which is based on finite integration technique . The proposed antenna is kept at a distance of 20 mm from the brain phantom and simulated over CST for brain tumor detection.

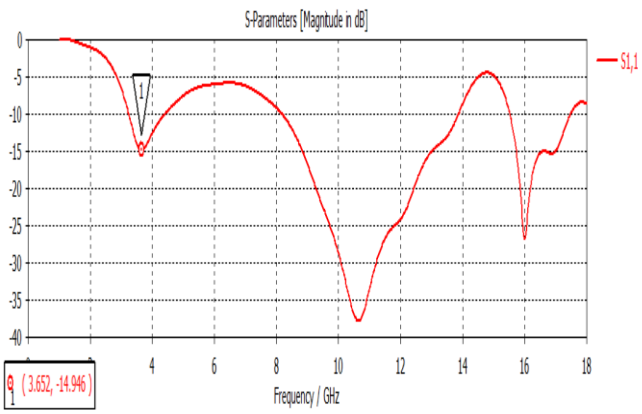

Fig -4: Simulated return loss (S11) curve versus frequency of proposed antenna

Fig-4 shows the return loss (S11) curve of the designed antenna obtained by CST simulator. The proposed antenna resonates at three different frequencies and here 3.652 GHz alone is considered for brain tumor detection.

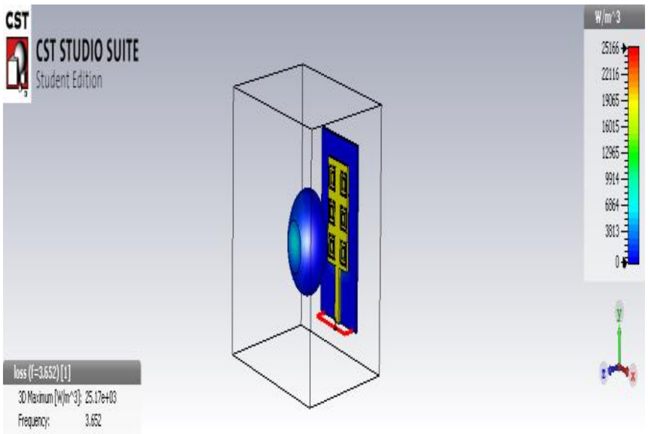

Fig -5: Specific absorption rate at 3.652 GHz-without tumor

From Fig-5, it was observed that the antenna has a specific absorption rate of 25166 W/m^3 at 3.652 GHz in the absence of tumour.

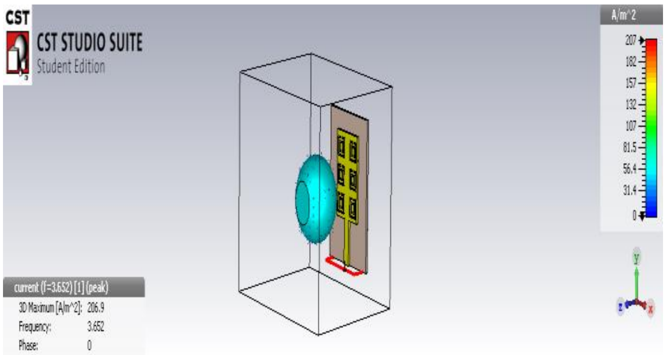

Fig -6: Current density at 3.652 GHz-without tumor

From Fig-6, it was observed that the antenna has a current density of 207 A/m^2 at 3.652 GHz in the absence of tumor.

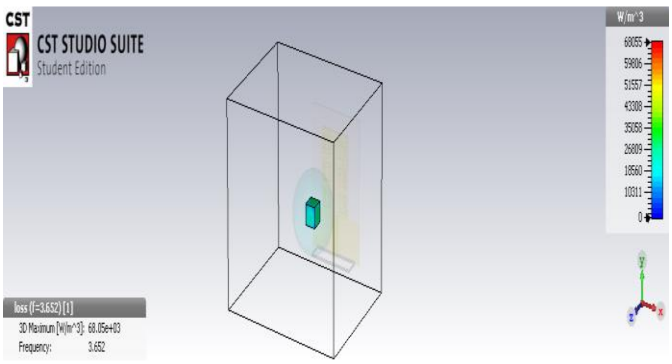

Fig -7: Specific absorption rate at 3.652 GHz-with tumor

From Fig-7, it was observed that the antenna has a SAR of 68055 W/m^3 at 3.652 GHz in the presence of tumor. This implies that the specific absorption rate is drastically increased when the antenna is simulated upon brain phantom having tumor.

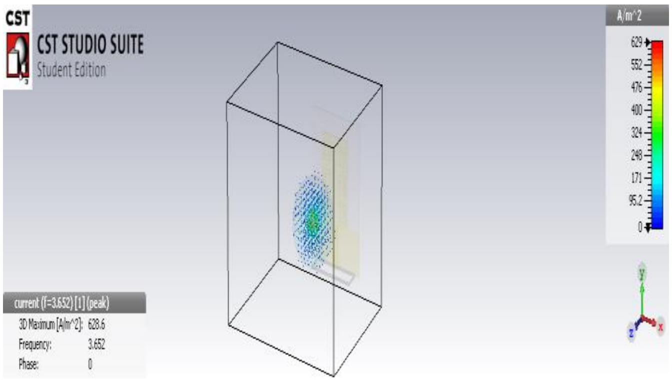

Fig -8: Current density at 3.652 GHz-with tumor

From Fig-8, it was observed that the antenna has a current density of 629 A/m^2 at 3.652 GHz in the presence of tumor. This shows that the current density has been increased twice than that of the brain having no tumor.

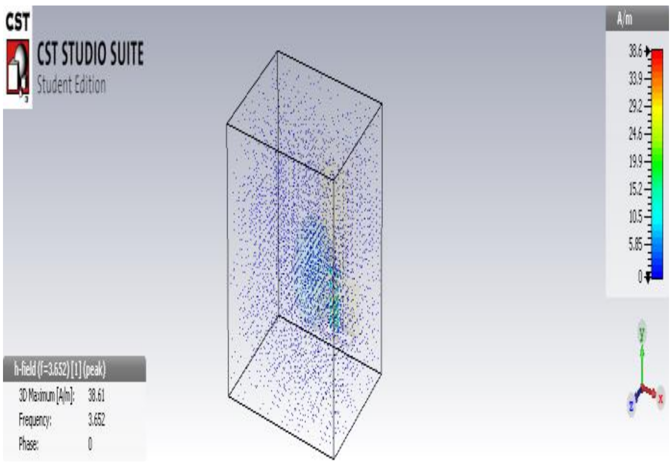

Fig -9: H-field at 3.652 GHz-without tumor

Fig-9 shows the H-field value of 38.6 A/m at 3.652 GHz in the absence of tumor.

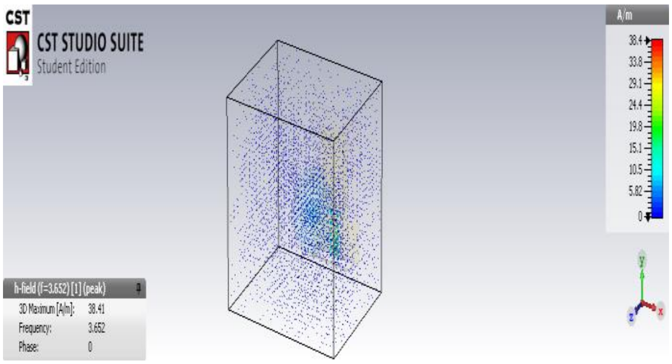

Fig -10: H-field at 3.652 GHz-with tumor

Fig-10 shows the H-field value of 38.4 A/m at 3.652 GHz in the presence of tumor. This shows that the H-field value is reduced than that of the brain without having tumor.

5. CONCLUSION

In this paper, a compact metamaterial based microstrip patch antenna is designed and optimized over CST simulator for efficient brain tumor detection. The performance of the proposed antenna is evaluated based on the variations in SAR, magnetic field and current density of the antenna after simulated upon brain phantom with & without tumor. It is found that the antenna when simulated upon brain phantom with tumor has a current density value of 629 A/m^2 which is twice than that of the brain without tumor and the specific absorption rate of 68055 W/m^3 which is much greater than that of the brain having no tumor.

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