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DESIGN OF MICROSTRIP PATCH ANTENNA FOR BRAIN CANCER DETECTION

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Abstract

A microstrip patch antenna is a metallic strip or patch mounted on a dielectric layer over a ground plane. An antenna is a transducer that converts electrical signals to electromagnetic waves and radiates into free space.FR-4 substrate is used because it is low- cost and easily available in the market. At first, a compact rectangular shaped microstrip patch antenna which operates at ISM band (2.4-2.4835GHz) is designed for without slot and with slots (center slot, vertical slot and four vertical and center slot). Next the antenna is surfaced on the human head phantom model which consists of six homogeneous layers that are Skin, Fat, Skull, Dura, Cerebrospinal Fluid and Brain. In human head phantom model the tumor is placed at the four different locations (Left side-top and bottom and Right side-top and bottom). The tumor location can be determined by rotating the antenna array to scan the head. Then the antenna is simulated upon the human head phantom for without slot and with slot and the variations in the electric field, magnetic field, return loss and specific absorption rate are measured. It is simulated using the CST Microwave Studio.

Keywords:

Gain, VSWR, Return Loss, SAR

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 death of cancer are expected in 2030 [2]. There are number of brain diseases which if not detected at the early stage, might end up resulting in premature death. Detection of brain cancer can be done in various ways and usually depends on the stage in which the cancerous tumors are traced. Basic method like x-ray mammography, ultrasound, computed tomography (CT) scan, magnetic resonance imaging (MRI) scan and biopsy are used in detecting tumors in the initial stages. These limitations have motivated researches to develop a more effective, low-cost diagnostic method and involving lower ionization for cancer detection. In this proposed work, first the micro strip path antenna is designed and simulated over the computer simulation technology [7]. Next the brain phantom with tumor at six different location & without tumor at six locations are designed with appropriate dimensions using computer simulation technology. Brain tumors are abnormal growth of cells in the brain. Although such growths are popularly called brain tumors, not all brain tumors are cancer. Cancer is a term reserved for malignant tumors. Malignant tumors can grow and spread aggressively, overpowering healthy cells by taking their space, blood, and nutrients. They can also spread to distant parts of the body. Like all cells of the body, tumor cells need blood and nutrients to survive [5]. Tumors that do not invade nearby tissue or spread to distant areas are called benign. In general, a benign tumor is less serious than a malignant tumor. But a benign tumor can still cause many problems in the brain by pressing on nearby tissue. Tumors that start in the brain are called primary brain tumors. A tumor that starts in another part of the body and spreads to the brain is called a metastatic brain tumor.

The below literature survey specifies the antenna design to detect brain cancer and it provides high VSWR, high Return loss and also low gain. In order to improve the performance of human brain cancer detection, rectangular shaped microstrip patch antenna which operates at ISM band (2.4-2.4835GHz) for brain cancer detection is designed. The antenna is surfaced on the human head phantom model which consists of six homogeneous layers that are skin, fat, skull, Dura, cerebrospinal fluid (CSF) and brain and which provides improvement in Gain, VSWR, E-field for detecting the human brain cancer. The permittivity, conductivity, return loss, SAR, VSWR E-field and H-field are measured using CST software.

2. LITERATURE REVIEW

Shokry et al. [5] reported that the antenna is operating at a band from 3.3568-12.604GHz in free space and from 3.818 to 9.16GHz on the normal head model. The antenna has dimensions of $44\times30\text{mm}^2$. It is fabricated on FR4-substrate with relative permittivity 4.4 and thickness 1.5mm. It is simulated using the CST Microwave Studio. The simulated antenna shows -10dB for 4.031GHz.

Zulkifli et al. [1], an ultra-wide band (UWB) antenna is proposed as a transceiver of microwave imaging on brain tumors, which it operates in UWB range (i.e. 3.1-10.6GHz). The antenna is designed and fabricated on a low cost FR-4 substrate with 1.6mm thickness. The antenna provides low gain

Zhang et al. [2], an Ultra wide-Band (UWB) Vivaldi Antenna array is used for microwave imaging based brain cancer detection is designed. A cancerous brain model which consists of a 5mm tumor is simulated with CST Microwave Studio. It provides maximum return loss and four layers is simulated.

Riouch et al. [9], a novel design of an antenna array structure which is a crucial part in a radiometer system is designed. The flexible compact antenna array is composed of two elements coupled with a T-junction, fed by a coplanar waveguide (CPW).

Suriya et al. [10], a compact wearable micro strip patch antenna is used for the determination of brain tumor. This antenna is designed at a lower frequency since it is used at a very sensitive part of the body. The SAR value in this paper for with tumor is low.

From the above literature review it is found that the proposed antenna provides maximum return loss, high electric field with tumor and low SAR value. Our antenna is miniaturized size with covering the entire desired working frequency band by adding some perturbation structure on the antenna structure and it provides minimum return loss, with tumor it provides low electric field, high magnetic field and high SAR value.

3. PROPOSED METHOD

The rectangular shaped microstrip patch antenna with slot and without slot is designed. Then the design of human head phantom model for cancerous tumor and for without cancerous tumor is also designed. The proposed antenna is kept at a distance of 20mm from the brain phantom and simulated over CST for brain tumor detection. Substrate of the antenna is FR-4. Patch, ground, feed of the antenna are Copper (annealed).

3.1 ANTENNA DESIGN

The microstrip patch antenna has ground, substrate, patch and feeding techniques. The substrate of the antenna is FR-4. The ground and patch of the antenna is copper annealed. The slot of the antenna is nickel. The length of the substrate is mm and the width of the substrate is mm and the thickness of the substrate is 1mm. The back side of the substrate contains the partial ground plane. The length of the ground is mm and the width of the ground is mm and the thickness of the ground is mm. The other side of the substrate contains the patch. The length of the patch is mm and the width of the patch is mm and the thickness of the patch is 1mm. The proposed antenna is fed with the microstrip line feed. The length of the feed is mm and the width of the feed is mm and the dimensions of the proposed antenna are shown in Table.1.

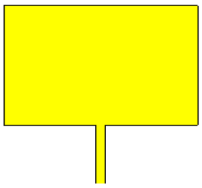


Fig.1.Without slot

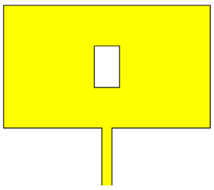


Fig.2. Center slot

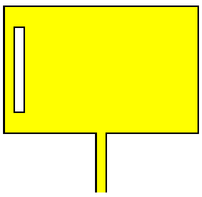


Fig.3.Vertical slot

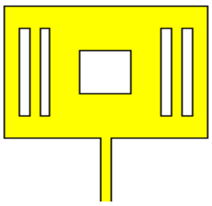


Fig.4. Four vertical and center slot

Table.1. Dimensions of RMSPA

Antenna Specifications	**Dimensions in mm**
Thickness of the ground	0.03
Width of the ground	60
Height of the ground	60
Thickness of the substrate	1.56
Width of the substrate	60
Height of the substrate	60
Thickness of the patch	0.03
Width of the patch	40
Height of the patch	30
Width of the feed	1
Height of the feed	15
Width of the center slot	10
Height of the center slot	10
Width of the vertical slot	2
Height of the vertical slot	20

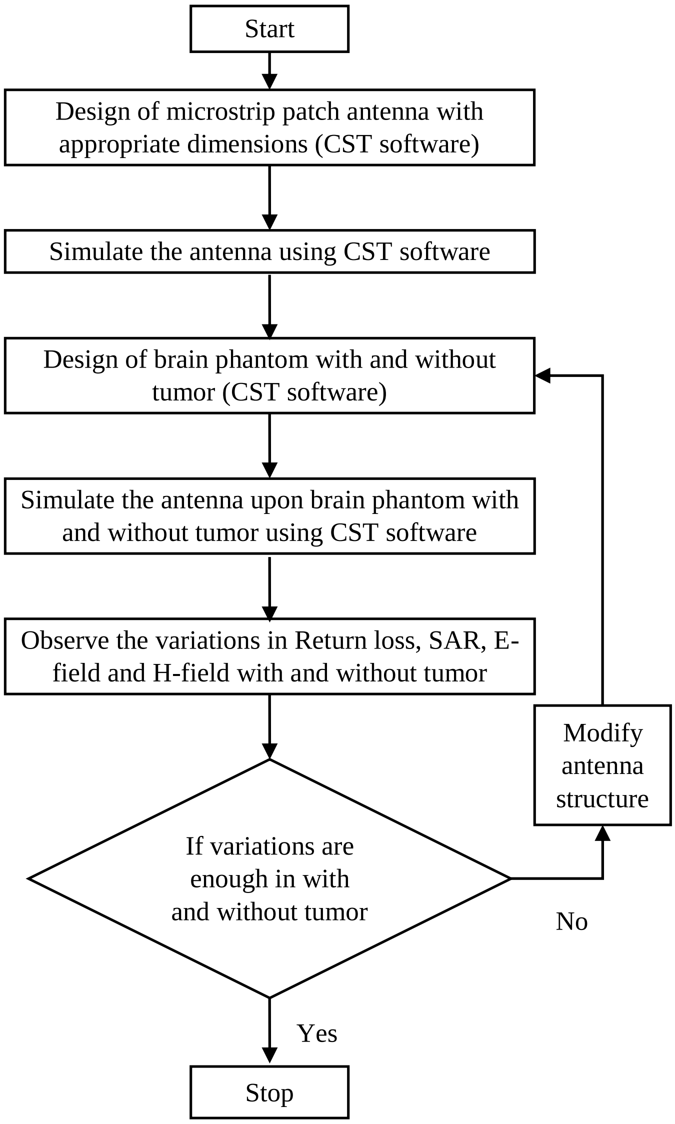
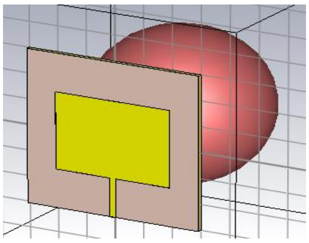


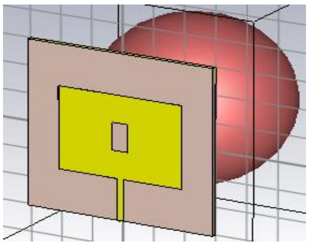
Fig.5. Steps involved in proposed work

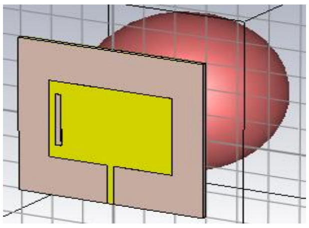
3.2 BRAIN PHANTOM DESIGN

A brain phantom is designed by considering a sphere as a brain and a tumor. The permittivity of the brain is 43.22F/m and its conductivity is 1.29S/m. The permittivity of the tumor is 54.2F/m and its conductivity is 2.62S/m.

In our proposed work, first the antenna is designed and simulated over computer simulation technology. Next the brain phantom is designed with the appropriate dimensions using the computer simulation technology. Then the proposed antenna is simulated upon the brain phantom with and without tumor separately and it is found that the return loss, 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.5


(a)


(b)


(c)

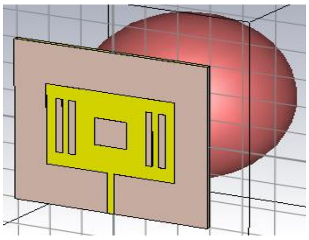
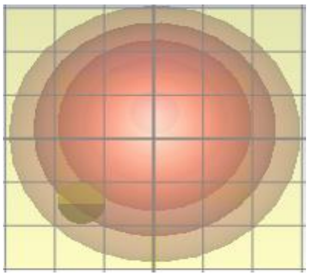

(d)

Fig.6. Brain phantom without tumor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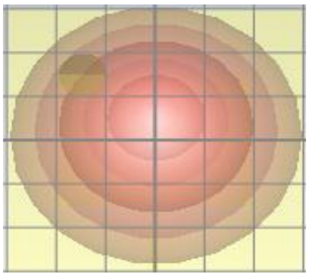
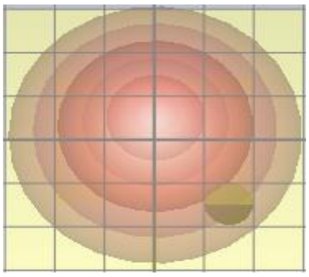

(b)


(c)

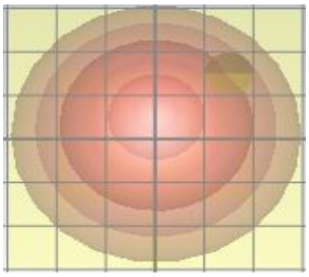

(d)

Fig.6. Brain phantom with tumors

Table.2. Geometrical measurement of antenna

Tissue	Permittivity	Conductivity	Density
Skin	45	0.73	1090
Fat	5.54	0.04	910
Skull	5.6	0.03	1850
Dura	46	0.9	1130
CSF	70.1	2.3	1005.9
Brain	43.22	1.29	1030

4. RESULTS

4.1 BRAIN PHANTOM WITHOUT TUMOR-WITHOUT SLOT

A brain phantom model is designed by considering a sphere as a brain. The permittivity of the brain is 43.22F/m and its conductivity is 1.29S/m and it is placed at a distance of 20mm from the antenna and simulated. The simulation results of Return loss, E-field, H- field and specific absorption rate are given below.

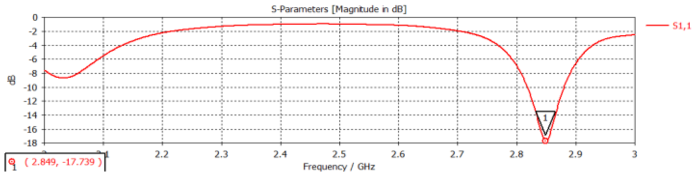


Fig.7. Return loss at 2.84GHz - without tumor

The Fig.7 shows the return loss value of -17.739 at 2.84GHz in the absence of tumor.

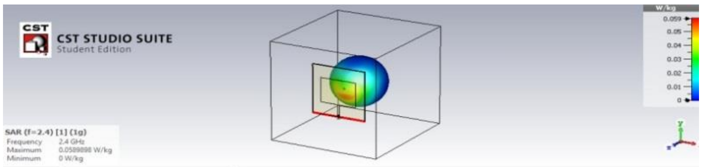


Fig.8. SAR at 2.4GHz - without tumor

The Fig.8 shows the SAR value of 0.059W/kg at 2.4GHz for 1 gram tissue in the absence of tumor.

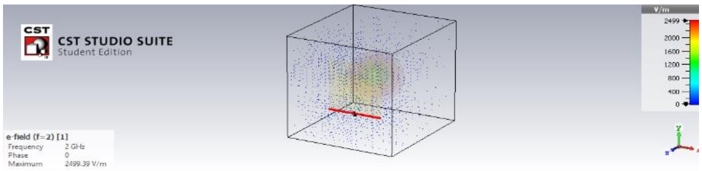


Fig.9. E-field at 2.4GHz - without tumor

The Fig.9 shows the E-field value of 2560V/m at 2.4GHz in the absence of tumor.

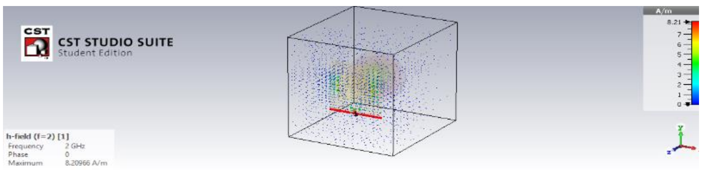


Fig.10. H-field at 2.4GHz - without tumor

The Fig.10 shows the H-field value of 8.20A/m at 2.4GHz in the absence of tumor.

4.2 BRAIN PHANTOM WITHOUT TUMOR-CENTER SLOT

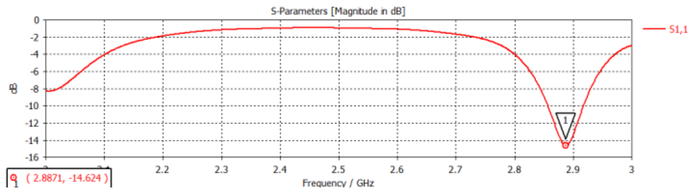


Fig.11. Return loss at 2.88GHz - without tumor

The Fig.11 shows the Return loss value of -14.62GHz at 2.88GHz in the absence of tumor.

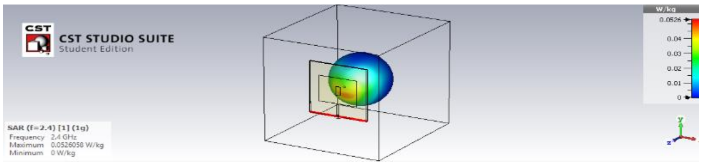


Fig.12. SAR at 2.4GHz – without tumor

The Fig.12 shows the SAR value of 0.0526W/kg at 2.4GHz for 1 gram tissue in the absence of tumor.

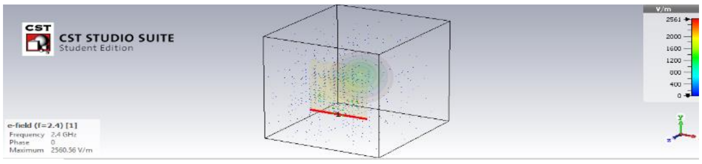


Fig.13. E-field at 2.4GHz - without tumor

The Fig.13 shows the E-field value of 2560V/m at 2.4GHz in the absence of tumor.

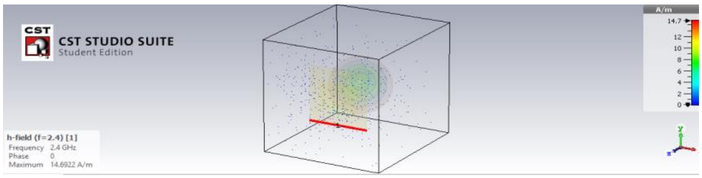


Fig.14. H-field at 2.4GHz - without tumor

The Fig.14 shows the H-field value of 8.20A/m at 2.4GHz in the absence of tumor.

4.3 BRAIN PHANTOM WITHOUT TUMOR-VERTICAL SLOT

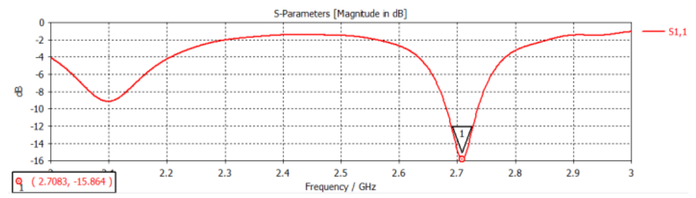


Fig.15. Return loss at 2.88GHz - without tumor

The Fig.15 shows the Return loss value of -15.864GHz at 2.7083GHz in the absence of tumor.

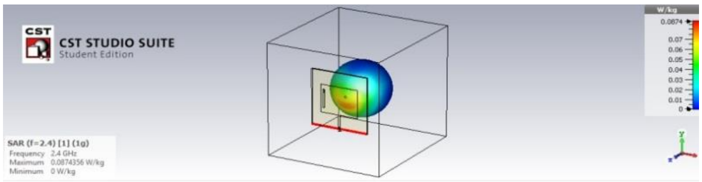


Fig.16. SAR at 2.4GHz - without tumor

The Fig.16 shows the SAR value of 0.0874W/kg at 2.4GHz for 1gm tissue in the absence of tumor.

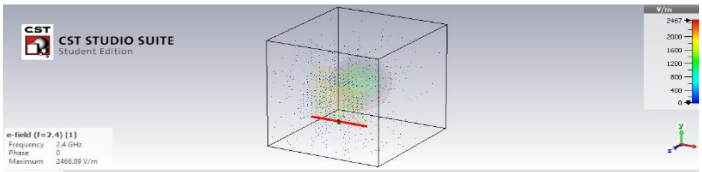


Fig.17. E-field at 2.4GHz - without tumor

The Fig.17 shows the E-field value of 2466V/m at 2.4GHz in the absence of tumor.

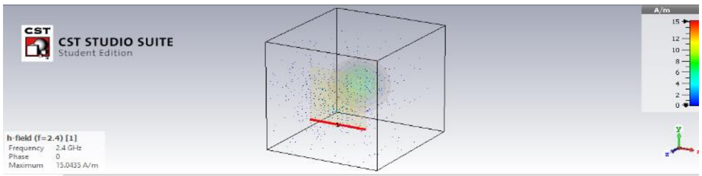


Fig.18. H-field at 2.4GHz - without tumor

The Fig.18 shows the H-field value of 15.04A/m at 2.4GHz in the absence of tumor.

4.4 BRAIN PHANTOM WITHOUT TUMOR-VERTICAL AND CENTER SLOT

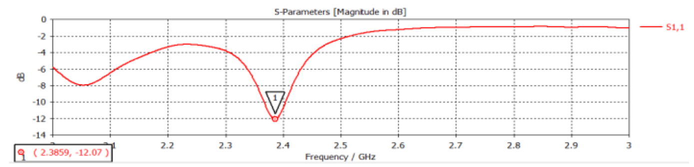


Fig.19. Return loss at 2.88GHz - without tumor

The Fig.19 shows the Return loss value of -12.07GHz at 2.38GHz in the absence of tumor.

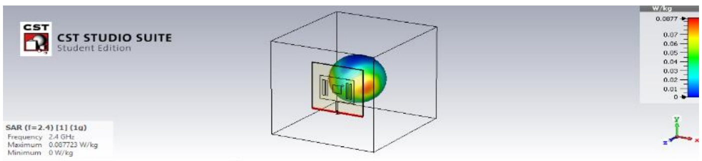


Fig.20. E-field at 2.4GHz - without tumor

The Fig.20 shows the E-field value of 4431V/m at 2.4GHz in the absence of tumor.

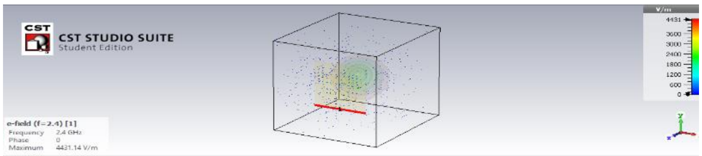


Fig.21. H-field at 2.4GHz - without tumor

The Fig.21 shows the H-field value of 33.2A/m at 2.4GHz in the absence of tumor.

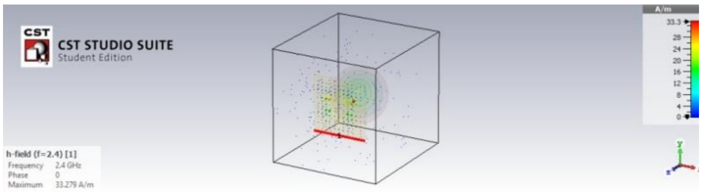


Fig.22. Return loss at 2.838GHz - with tumor

The Fig.22 shows the Return loss value of -28.002GHz at 2.838GHz in the presence of tumor.

4.5 BRAIN PHANTOM WITH TUMOR-WITHOUT SLOT

A small sphere with permittivity 64F/m and conductivity 3S/m is considered as a tumor and kept at four different locations over the brain and simulated separately for each locations to ensure the performance of the proposed antenna. The simulation results are given below.

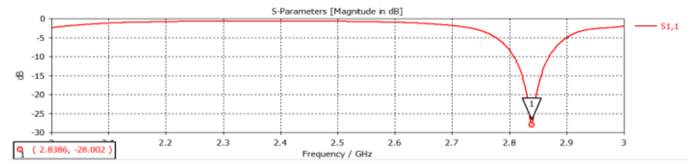


Fig.23. Return loss at 2.838GHz - with tumor

The Fig.23 shows the Return loss value of -28.002GHz at 2.838GHz in the presence of tumor.

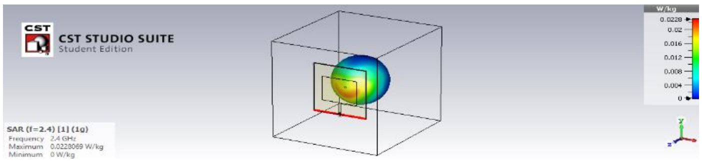


Fig.24. SAR at 2.4GHz - with tumor

The Fig.24 shows the SAR value of 0.0228W/kg at 2.4GHz for 1gm tissue in the presence of tumor.

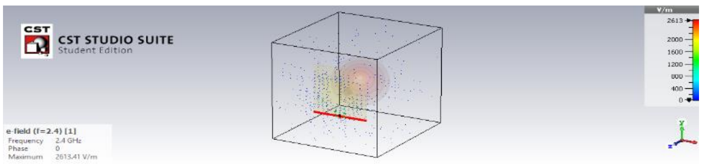


Fig.25. E-field at 2.4GHz - with tumor

The Fig.25 shows the E-field value of 2618.41V/m at 2.4GHz in the presence of tumor.

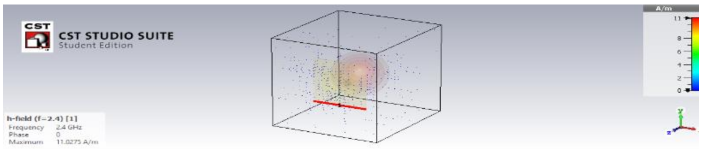


Fig.26. H-field at 2.4GHz - with tumor

The Fig.26 shows the H-field value of 11.02A/m at 2.4GHz in the presence of tumor.

4.6 BRAIN PHANTOM WITH TUMOR-CENTER SLOT

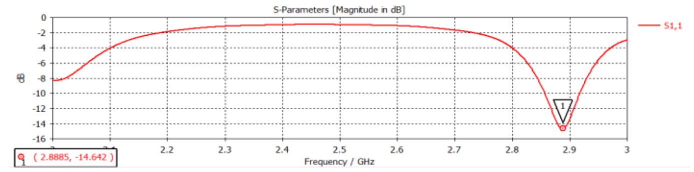


Fig.27. Return loss at 2.88GHz - with tumor

The Fig.27 shows the Return loss value of -14.62GHz at 2.88GHz in the presence of tumor.

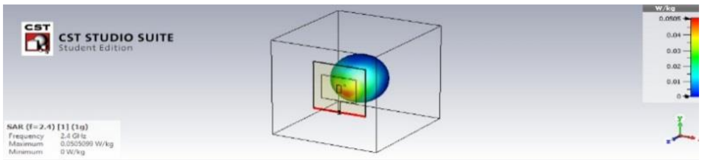


Fig.28. SAR at 2.4GHz - with tumor

The Fig.28 shows the SAR value of 0.0505W/kg at 2.4GHz for 1gm tissue in the presence of tumor.

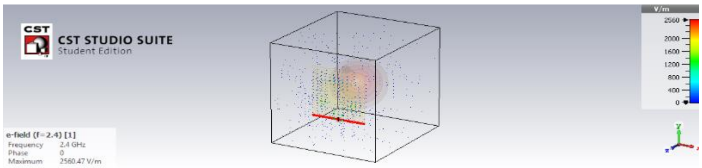


Fig.29. E-field at 2.4GHz - with tumor

The Fig.29 shows the E-field value of 2560.47V/m at 2.4GHz in the presence of tumor.

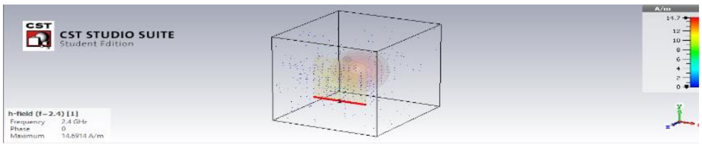


Fig.30. H-field at 2.4GHz - with tumor

The Fig.30 shows the H-field value of 14.69A/m at 2.4GHz in the presence of tumor.

4.7 BRAIN PHANTOM WITH TUMOR- VERTICAL SLOT

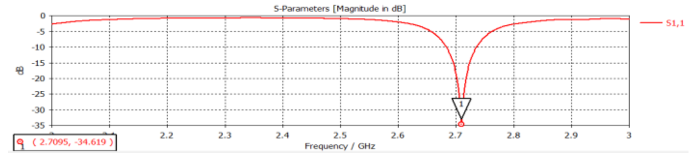


Fig.31. Return loss at 2.70GHz - with tumor

The Fig.31 shows the Return loss value of -34.61GHz at 2.70GHz in the presence of tumor.

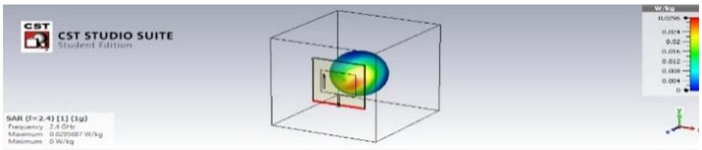


Fig.32. SAR at 2.4GHz - with tumor

The Fig.32 shows the SAR value of 0.029W/kg at 2.4GHz for 1gm tissue in the presence of tumor.

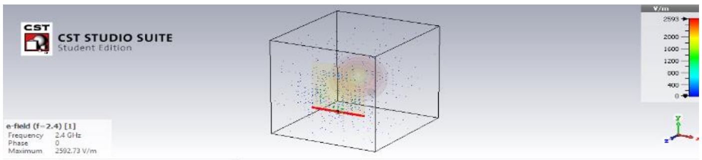


Fig.33. E-field at 2.4GHz - with tumor

The Fig.33 shows the E-field value of 2592.73V/m at 2.4GHz in the presence of tumor.

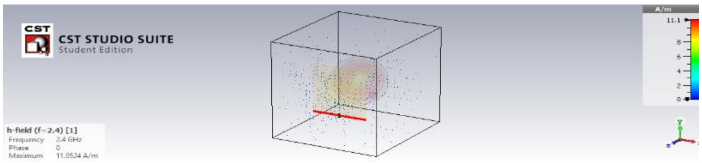


Fig.34. H-field at 2.4GHz - with tumor

The Fig.34 shows the H-field value of 11.05A/m at 2.4GHz in the presence of tumor.

4.8 BRAIN PHANTOM WITH TUMOR- VERTICAL AND CENTER SLOT

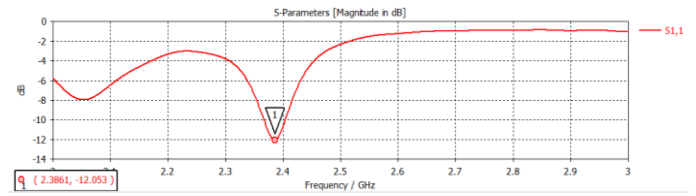


Fig.35. Return loss at 2.38GHz - with tumor

The Fig.35 shows the Return loss value of -12.053GHz at 2.38GHz in the presence of tumor.

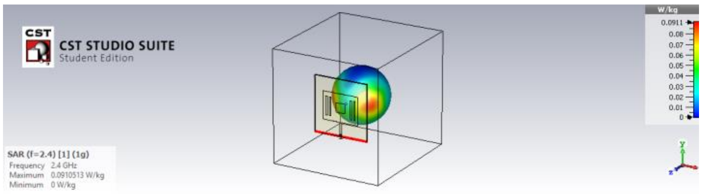


Fig.36. SAR at 2.4GHz - with tumor

The Fig.36 shows the SAR value of 0.091W/kg at 2.4GHz for 1gm tissue in the presence of tumor.

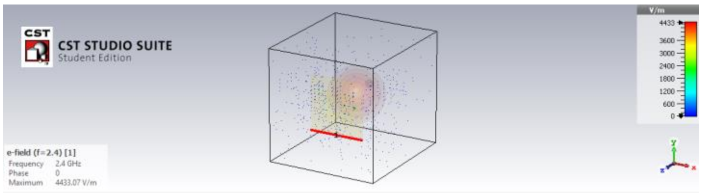


Fig.37. E-field at 2.4GHz - with tumor

The Fig.37 shows the E-field value of 4422.07V/m at 2.4GHz in the presence of tumor.

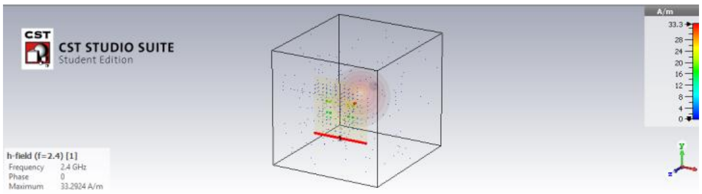


Fig.38. H-field at 2.4GHz - with tumor

The Fig.38 shows the H-field value of 33.2A/m at 2.4GHz in the presence of tumor.

The Table.3 shows the return loss, field variations and specific absorption rate in the absence and presence of tumor over the brain. It is found that the antenna provides minimum return loss of -34.61dBi, minimum E-field of 2592V/m, minimum H- field of 11.05A/m and maximum specific absorption rate of 0.029(W/m^3) for with tumor and maximum return loss of -12.07dBi, maximum E-field of 4431V/m, maximum H- field of 33.2A/m and minimum specific absorption rate of 0.059(W/m^3) for without tumor.

Table.3. Observed field distribution for brain tumor detection

Tumor Status	Return Loss (dBi)	E-Field (V/m)	H-Field (A/m)	SAR (W/m^3)
Without tumor 1	-17.739	2560	8.20	0.059
Without tumor 2	-14.62	2560	8.20	0.052
Without tumor 3	-15.86	2466	15.04	0.087
Without tumor 4	**-12.07**	**4431**	**33.2**	**0.059**
With tumor 1	-28.002	2618	11.02	0.022
With tumor 2	-14.62	2560	14.69	0.050
With tumor 3	**-34.61**	**2592**	**11.05**	**0.029**
With tumor 4	-12.05	4422	33.2	0.091

5. CONCLUSION

The conception and simulation of rectangular microstrip patch antenna was successfully designed using the computer simulation tools. The frequency band used for the antenna is 2- 2.483GHz. The performance of the proposed antenna is evaluated based on the variations in magnetic field, electric field, return loss and SAR of the antenna after simulated upon the brain phantom with and without tumor. It is found that the antenna when simulated upon the brain phantom with tumor has a return loss of -34.61GHz which is higher than that of the brain without tumor. The specific absorption rate of 0.0505W/kg for 1gm tissue which is higher than that of the brain without tumor.

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