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Design of CPW Feed Complementary Split Ring Resonators Loaded Microstrip Antenna for Brain Tumor Detection

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***Abstract*—The CST programme was used to create a novel and compact Microstrip patch antenna with Complementary Split Ring Resonators (CSRR) to identify and see tumours inside the human brain. To represent the head phantom, appropriate tissue parameters such as permittivity and conductivity at the antenna resonant frequency were used. The antenna will broadcast an equivalent signal and receive backscattering signals from the stratified human head model. To improve performance, a complementary Split Ring Resonator with metamaterial structure was created, and a faulty ground structure was incorporated on the antenna ground plane. To investigate antenna performance, rectangular structures are presented. The CRRs were used in the antenna design, together with a defective ground plane structure, to improve return loss, impedance bandwidth, and antenna gain as compared to a patch antenna without split ring resonators. Tumors of various forms and sizes were studied in this study to detect the presence of tumours at an early stage. Various parameters like Electric field intensity(E), magnetic Field Intensity (H), Current density, Power Loss Density are observed, and simulated results compared with and without tumor in the brain.**

***Index Terms*— Microstrip patch antenna, Complementary Split Ring resonator, Defected Ground Plane, Brain tumor detection, Human head phantom.**

I. INTRODUCTION

The brain is the most important organ in the human neurological system. The proliferation of abnormal cells in our brain causes a brain tumour. Because it affects the most critical organ in the human body, brain cancer is one of the most serious public health issues worldwide. The invasive features of tumours create a high fatality rate, making brain cancer a dangerous condition. But this problem can be easily overcome by detection of the tumor at the early stages. Because it is far easier to provide efficient and successful treatment at an early stage of development than it is to provide treatment at a later time. Microwave transmissions, with their nonionizing electromagnetic waves, can easily permeate human body tissues without causing health problems [1]. The main concept behind this antenna design is the variation in electrical characteristics between healthy and cancerous tissues.

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The antennas are a crucial component of any brain imaging system for determining the quality of tumour detection. The antenna utilised in such a system must meet certain criteria, including ease of integration, compactness, simplicity of geometric construction, small dimensions, increased bandwidth, gain, and directionality [2–6].

Micro strip patch antennas, according to several researchers, can meet these requirements since they have various advantages such as low profile, light weight, low volume, planar configuration, low fabrication cost, and so on [7]. However, Traditional patch antennas must be modified for accurate measurements and detection in microwave imaging systems, as well as for dependable pulse transmission and collection of backscattered signals. To ensure the safety of the patient under test, accuracy in the SAR analysis, which is highly dependent on the accurate head phantom model, is a necessary by providing similar electrical parameters and exact specifications.This research study is divided into two sections: (1) Design of a microstrip patch antenna with complementary split ring resonators using CST software, and (2) Tumor detection in a human head phantom.

A malignant phantom was created by putting a tumour model into a typical six-layered spherical human head phantom. The dimensions and electrical properties of head and tumour models are chosen to mimic the real ones as closely as possible. The values of the reflection coefficient -parameters derived using a head phantom with and without a tumour mode.

II. Antenna Design

The antenna is designed on a Rogers RT 5880 which has a dielectric constant of 2.2 substrate having dimensions of 35mm× 26mm × 1 mm as shown in figure 1. The defected ground plane dimensions are 10mm × 26mm as shown in figure 2. The actual size of the antenna is 20 mm × 14 mm. Because of the antenna dimensions are small which makes it practically wearable on human head. In the antenna design, the square shaped Complementary split Ring resonators with the dimensions of 4.5mm × 4.5mm × 1mm were incorporated along with defected ground plane structure to provide an improvement in return loss, in impedance bandwidth, and in antenna gain.

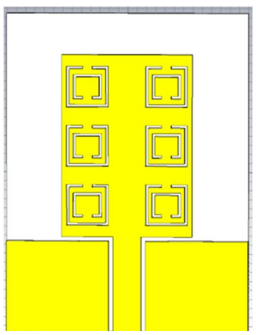


Figure 1. Geometry of Patch Antenna with Square shaped CRRs

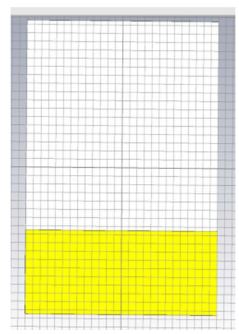


Figure 2. Back View of antenna with CPW feed Defected Ground Structure

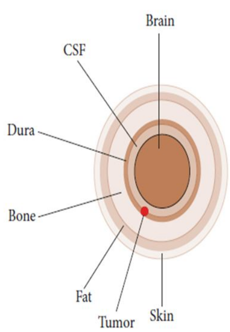


Figure 3. Six layered Phantom Model

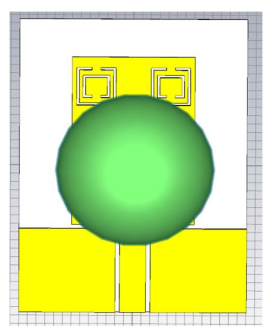


Figure 4.Antenna with sphere shaped phantom without tumor

The normal six-layered tumorous human head phantom model is created by inserting a tumour model into the head, and the proposed microstrip patch antenna is used to detect tumour inside the human head phantom, as illustrated in figure 3. The human head phantom model is shaped like a spherical and consists of six layers of the

brain phantom, including Skin, Fat, Skull, Dura, CSF, Brain, and tumour on which the antenna is mounted, as illustrated in figure 4. The tumour model's dimensions and electrical properties are generated at random to resemble the real ones.
The figure 2.5 shows the steps for proposed antenna design and procedure for tumor detection in human brain. The active devices can be put on top of the circuit, similar to microstrip, and it has broadband performance, low dispersion, easy mode suppression, and can provide extremely high frequency response.

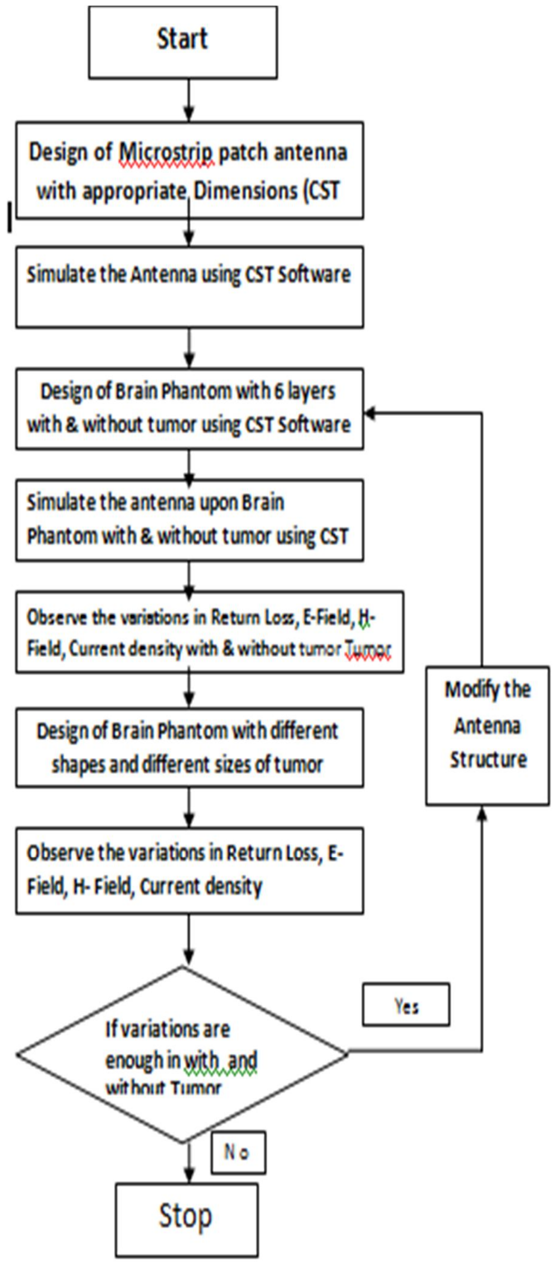


Figure 5. Steps for the proposed antenna design & procedure

A phantom is a mass of material that resembles human tissue and has a mass density of 1030 kg/m3 that is used to study the effects of radiation beams on humans. The different brain phantom specifications are described in table I.

TABLE I. BRAIN PHANTOM SPECIFICATIONS

Tissues of head	Radius (mm)	Permittivity (F/m)	Conductivity (S/m)	Density (Kg/m^3)
Brain	8.10	43.22	1.29	1030
CSF	8.30	70.10	2.30	1005.9
Dura	8.35	46.00	0.90	1130
Skull	8.76	5.60	0.03	1850
Fat	8.90	5.54	0.04	910
Skin	9.00	45.00	0.73	1090
Tumour	5.00	55.00	7.0	1040

III. SIMULATION RESULTS & ANALYSIS

A. Figure Phantom without tumour

Important parameters like reflection coefficient, E- Field Density, current density, H- Field Density and Power loss density are shown in figure 6 to 11. S-parameter analysis is performed to determine whether a brain tumour is present. At the resonance frequency of 2.33 GHz, the S-parameter findings of a Human Head Phantom Model with a 5 mm tumour inside the Human Brain (-38.788 dB) deviate from the S11 values of a normal head (-22.87 dB), as shown in figure 6. Various other performance parameters are also analyzed like E- Field Density, H- Field density, Current Density and Power Density for the tumor detection and observed through simulation.

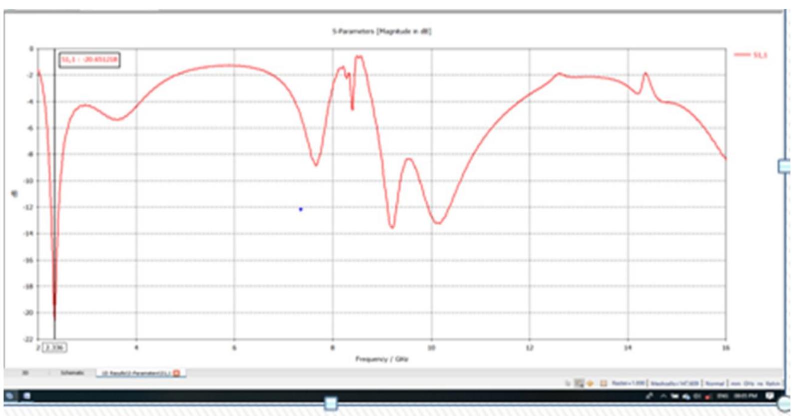


Figure 6. Variation of S- Parameters, - 22dB, antenna resonates at 2.33 GHz

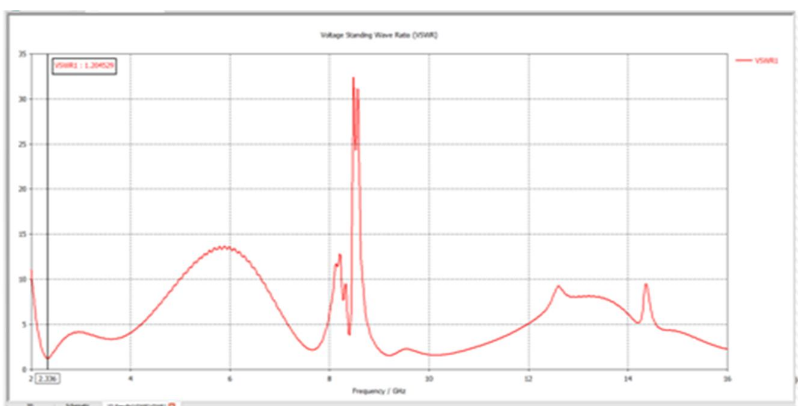


Figure 7. Variation of VSWR of 1.13. at 2.33 GHz

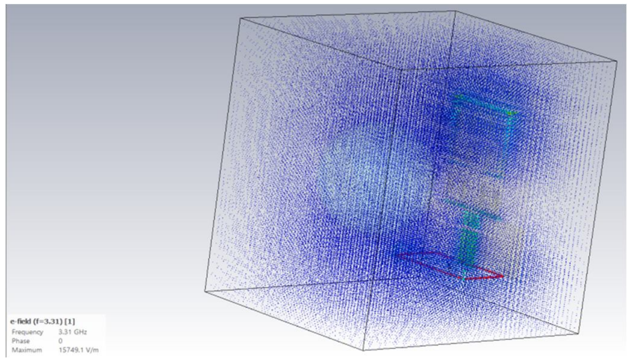


Figure 8. Variation of Electric field e-field maximum=52728.5 V/m

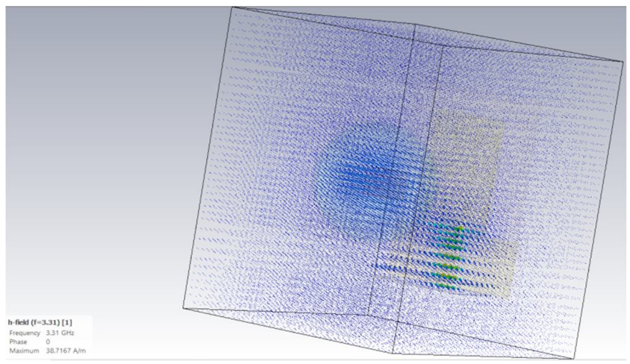


Figure 9. Variation of Magnetic fieldh-field maximum=357.585 A/m

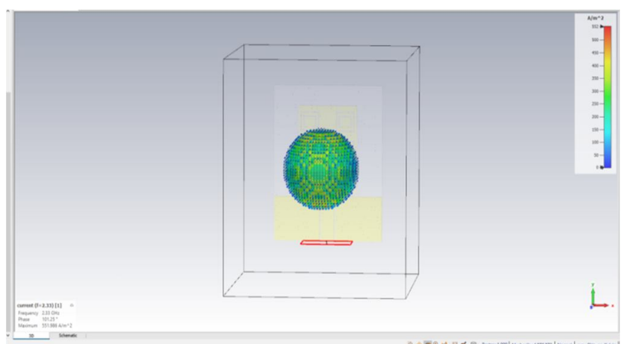


Figure 10. Variation of Current Density Maximum=551.98A/m ^2

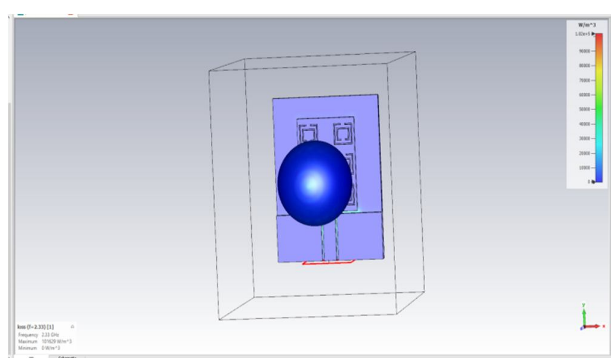
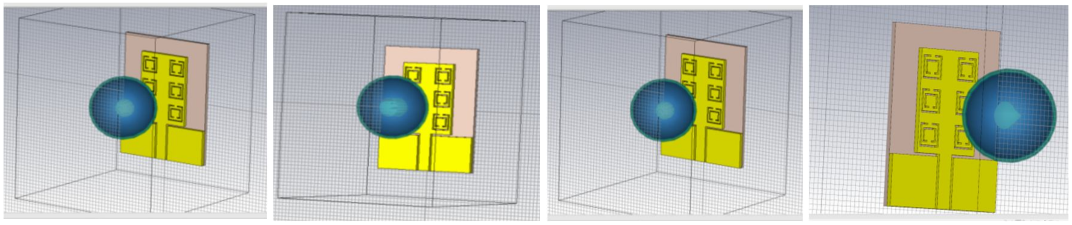


Figure 11. Variation of Power loss Density Maximum=101629 W/m^3

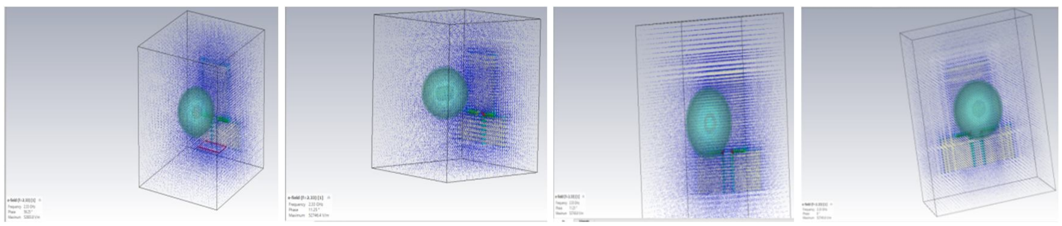
B. Design of phantom with tumour shapes

The tumour can be in any shape and size, keeping that point, in this paper the work was carried out in such a way that antenna was designed with sphere shaped brain phantom along with the presence of tumour in different shapes like cube, cylindrical, cone and torus.



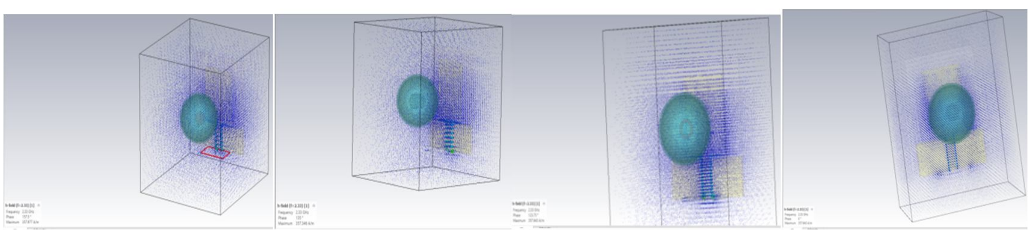
(a)Cube Shape (b) Cylindrical shape (c) Conical Shape (d) Torus shape

Figure 12. Different shapes of tumor



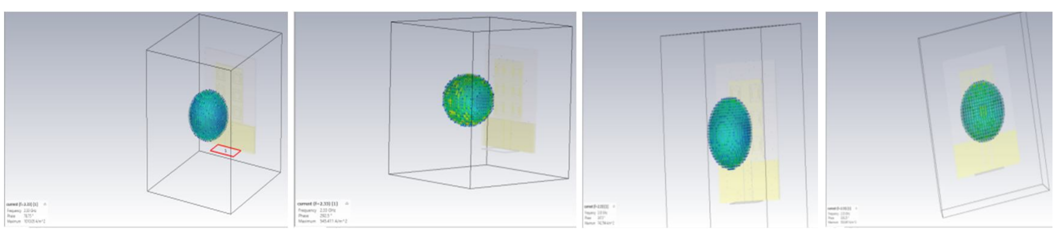
(a)Cube Shape (b) Cylindrical shape (c) Conical Shape (d) Torus shape

Figure 13. E- Field Density for different tumour structures



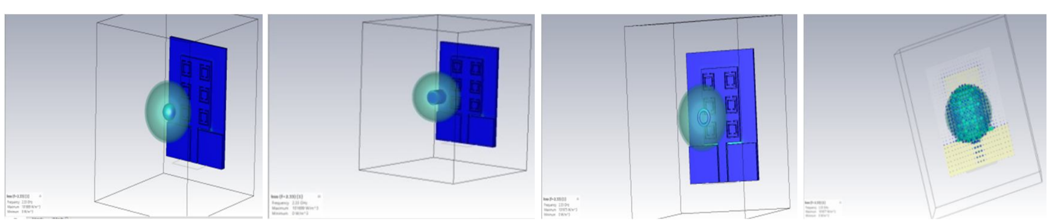
(a)Cube Shape (b) Cylindrical shape (c) Conical Shape (d) Torus shape

Figure 14. H- Field Density for different tumour structures



(a)Cube Shape (b) Cylindrical shape (c) Conical Shape (d) Torus shape

Figure 15. Current Density for different tumour structures



(a)Cube Shape (b) Cylindrical shape (c) Conical Shape (d) Torus shape

Figure 16. Power Loss Density different tumour structures

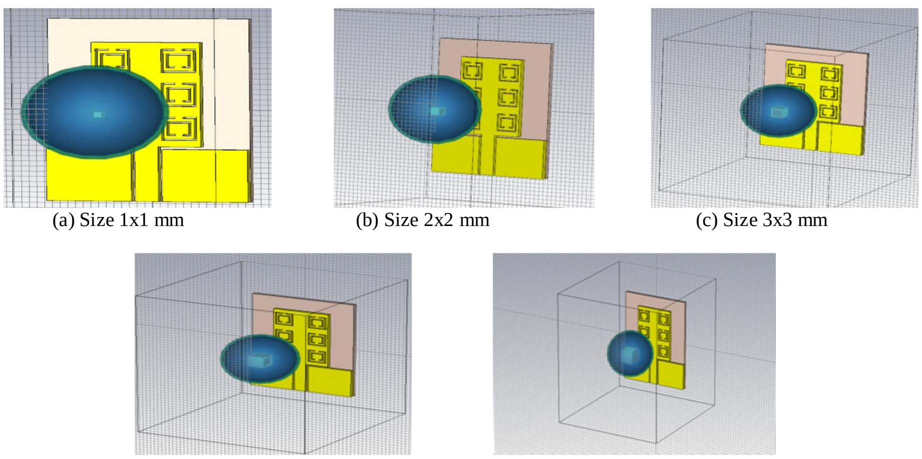
Finally, a comparison between the values of electrical properties of the tumor has been observed as shown in table II. The simulated results without cancerous tumor is illustrated which verifies the prototype of proposed antenna.

TABLE II. COMPARISON OF ALL PARAMETERS FOR DESIGN OF PHANTOM WITH DIFFERENT SHAPES

Parameters	Without Tumor	Cube	Sphere	Cone	Cylinder	Torus
H-Field(A/m)	357.585	358.834	357.977	357.643	357.634	357.643
E-field(V/m)	52728.5	52921.1	52803.8	52745.6	52746.4	52743.8
Current Density (A/m^2)	551.986	1043.18	1010.05	1011.47	1034.41	1042.79
Power loss Density (W/m^3)	101629	102306	102267	102599	103145	102175

C. Simulation Results for various tumor sizes

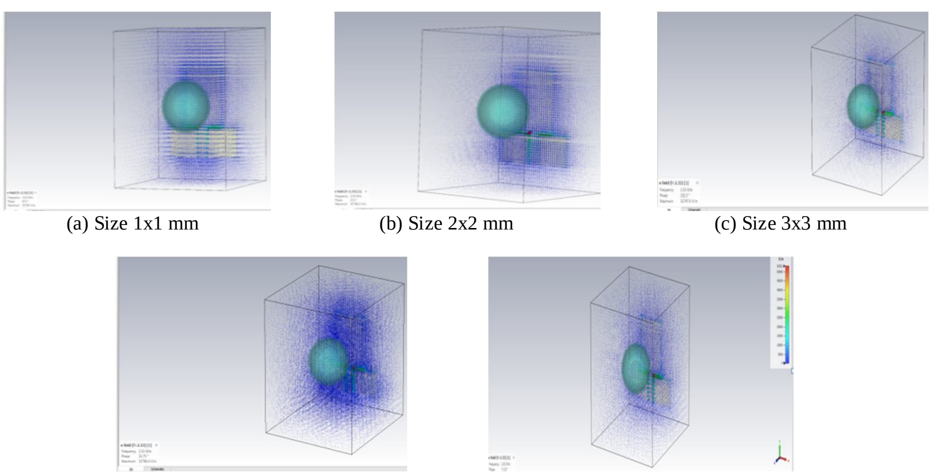
The main aim behind consideration of different sizes of tumour is, what can be the minimum size of the tumour can be detected by observing variation in its parameters. So that the disease can be detected at the early stage itself. Also the table III describes the different simulated parameters with different size of tumor.



(a) Size 1x1 mm (b) Size 2x2 mm (c) Size 3x3 mm

(d) Size 4x4mm (e) Size 5x5 mm

Figure 17. Various Tumor Sizes



(a) Size 1x1 mm (b) Size 2x2 mm (c) Size 3x3 mm

(d) Size 4x4mm (e) Size 5x5 mm

Figure 18. E Field -Density of different tumour sizes

TABLE III. TUMOUR SIZES & ITS VARIATION IN PARAMETERS

Parameters	5x5mm	4x4mm	3x3mm	2x2mm	1x1mm
E-Field (V/m)	52921.1	52780.4	52747.6	52748.2	52740
H-Field (A/m)	358.834	357.906	357.653	357.684	357.597
Current Density (A/m^2)	1043.18	926.989	870.769	808.586	753.748
Power Loss Density (W/m^3)	102306	101822	101700	101688	101663

From the above two tables table 2 & 3, it is clearly observed that there is a clear variation in the electrical parameters of the tumour in both the cases i.e. tumour with different structures and tumour with different sizes. This variation in parameters was obtained when the tumour is presented in the brain phantom model, because of more current signals reflected from tumour. So that losses are increased. Also it has been observed from the tables that current density of the brain phantom model having tumour is increased approximately more than two times as compared to the brain phantom model not having tumour. The remaining Parameters E- Field Density, H-Field Density, Power Loss Density are also shown significant variation in the Brain phantom model with tumour to without tumour.

IV. CONCLUSION

The identification of brain tumours using a microstrip patch antenna is investigated in this work. Modeling of a human head phantom and an effective microstrip patch antenna are two crucial components of the brain imaging system. To represent the head phantom, appropriate tissue parameters such as permittivity and conductivity at the antenna resonant frequency were used. A spherical shape with six layers, including the brain, CSF, dura, bone, fat, and skin, is also being investigated as a realistic human head model. To improve the performance of an antenna, complementary split ring Resonators were inserted in the design. Thus the patch antenna with CRRs is accepted as a perfect antenna for the brain scanning system. It is clearly observed that there is a clear variation in the electrical parameters of the tumour in both the cases i.e. tumour with different structures and tumour with different sizes. Also it has been observed from the tables that current density of the brain phantom model having tumour is increased approximately more than two times as compared to the brain phantom model not having tumour. The remaining Parameters E- Field Density, H-Field Density, Power Loss Density are also shown significant variation in the Brain phantom model with tumour to without tumour.

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