Design of Metamaterial Based Microstrip Patch Antenna For Brain Tumor Detection

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April 28, 2021

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Abstract: *To design a microstrip patch antenna loaded with a metamaterial based patch with partial ground plane. The use of metamaterial in Microstrip Patch Antenna helps to enhance the antenna performance and it reduces the size of the antenna. The structure is simulated at 7.3GHz using HFSS software. From this the RF parameters like return loss, VSWR, gain, radiation pattern are calculated. The brain phantom with six layers is designed to represent a realistic human brain model. The proposed antenna is simulated upon brain phantom. The variation in the SAR and E-Field in the brain phantom is measured to detect the brain tumor.*

Keywords— Metamaterial, Brain Phantom, SAR, E-Field

I. Introduction:

Cancer is one of the most dreaded disease of human that even leads to death if it is no identified at the early stage .By 2030, the number of new cases expected to increase more than 13 million. For effective treatment early detection of cancer is an important aspect. The imaging technique to detect the cancer are Magnetic Resonance Imaging (MRI) scan, Computed Tomography (CT) scan, Positron Emission Tomography (PET) scan, Ultrasound and X-ray. Recently microwave imaging technology for brain cancer detection is increased as it offers a secure, quick, inexpensive, noninvasive, and precise system solution. The design using metamaterial based microstrip patch antenna helps to detect the brain tumor in earlier stage. Microstrip patch antenna consists of radiating patch on one side of the dielectric substrate which has a ground plane on other side. The patch is mostly made up conducting material such as copper or gold. It would be easily fabricated on PCB and widely used. Metamaterial is known as the Double Negative Material(DNG).This material performance negative permittivity and negative permeability. Also they have Negative Refractive Index (NRI) and hence they are called Left-Handed Material. However there are many advantages of typical microstrip patch antenna, they also have disadvantage like narrow bandwidth, low gain and relatively large size.

To overcome this disadvantage the hilbert fractal curve is used to reduce the size of patch and it helps to improves the RF performance measures. A Hilbert fractal curve is a space filling curve. This curve is self similar and its basic unit is U-shaped. As per the present research the Hilbert curve will be used as the defected ground structure(DGS).This will helps to reduces the resonance frequency and increases the sensitivity of the sensor.

II. Design of Conventional Microstrip patch antenna

A rectangular microstrip patch antenna is designed conventional rectangular waveguide at 7.3GHz is taken as the resonant frequency. The higher frequency can ensure a convention antenna with small dimension, which is important for any brain imaging system. The antenna is designed with Rogers R03003 substrate with relative permittivity of 3, thickness of substrate is 0.75mm and dimension of substrate is 31.68mm×31.02mm, respectively. RogersR03003 has flexibility for high resonant frequency application than FR4, so RogersR03003 chosen as the substrate material. Substrate thickness affects the performance of an antenna and thicker substrate can enhance the antenna efficiency.

$$W = \frac{C}{2 f_r}\sqrt{\left(\frac{\varepsilon_r + 1}{2}\right)} \quad (1)$$

The width of the patch is identified using this formula, where c is the velocity of light, fr is the resonant frequency.

The formula for find the length of patch .

$f0$, h, $\in r$

$$L = \frac{c}{2 f_r \sqrt{\varepsilon_e}} - 2\Delta L \quad (2)$$

$$L = \boldsymbol{Leff} - 2\Delta L \quad (3)$$

Where,
W= Width of the patch
C=Velocity of the light
F=Resonant frequency
L=Length of the patch
$\in r$=Dielectric constant of the substrate
$Leff$=Effective length, and it is given by,

$$Leff = c / 2f\sqrt{\in reff} \quad (4)$$

The normalized extension in length is given by,

$$\Delta L = 0.412h\frac{(\varepsilon_e + 0.3)(W/h + 0.264)}{(\varepsilon_e - 0.258)(W/h + 0.8)} \quad (5)$$

Where,

$\in reff$=Effective dielectric constant, and the equation for it is given below

$$\varepsilon_e = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(\frac{1}{\sqrt{1 + \frac{12h}{w}}}\right) \quad (6)$$

Substrate length and width are calculated using the below formulas,

$$Lg = L + 6h \quad (7)$$

$$Wg = W + 6h \quad (8)$$

Where, Lg and Wg are length and width of substrate and 'h' is given by

$$h = 0.0606\lambda / \sqrt{\in r} \quad (9)$$

Feed line length is calculated by using below equation $Lf = \lambda g / 4$ (10)

Where, $\lambda g$is guided wavelength and it is given by,

$$\lambda g = \lambda / \sqrt{\in reff} \quad (11)$$

Table .1Dimension of designed microstrip patch antenna

DESIGN PARAMETERS	**DIMENSION IN mm**
Patch width, W	14.53
Patch length, L	11.57
Insert feed, Y_0	3.125
Insert gap, g	1.901
Feed length, Lf	13.202
Feed width, Wf	1.901
Substrate width, W_s	31.02
Substrate length, Ls	31.68
Substrate thickness, h	0.75

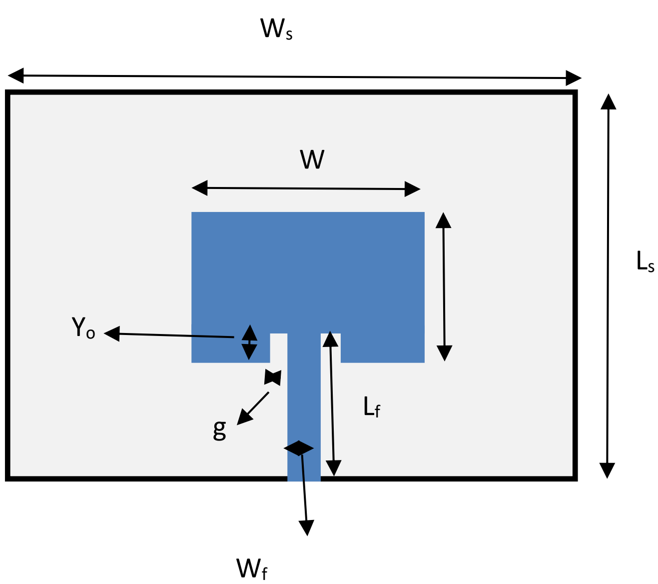


Fig.1a Schematic diagram Microstrip patch antenna

The antenna is designed using the above dimension TABLE.1 and simulated in HFSS software FIG 3. The RF parameters like the return loss FIG 4, VSWR FIG 5, radiation pattern FIG 6.1 and the gain FIG 6 is measured.

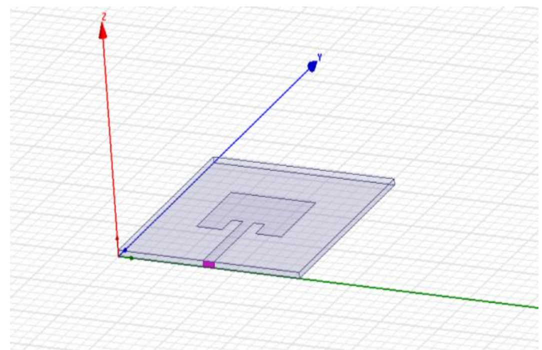


Fig.3 Conventional microstrip patch antenna - 7.3GHz

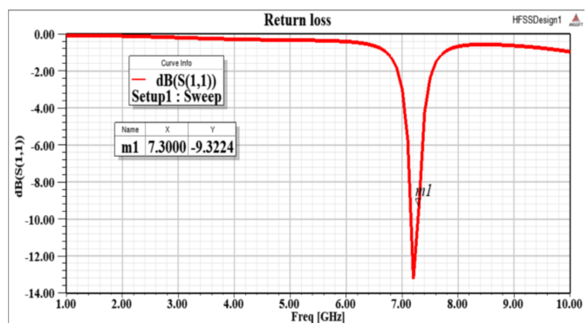


Fig. 4 Return loss of Conventional microstrip patch antenna-7.3GHz

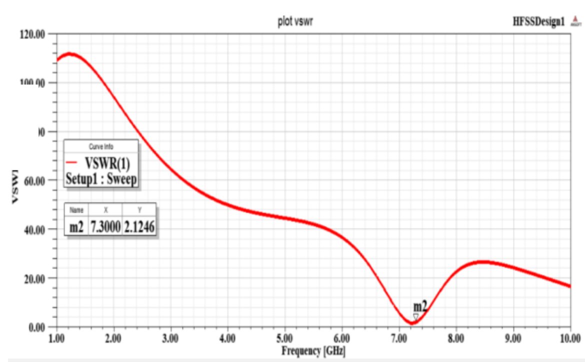


Fig :5 VSWR of Conventional microstrip patch antenna -7.3GHz

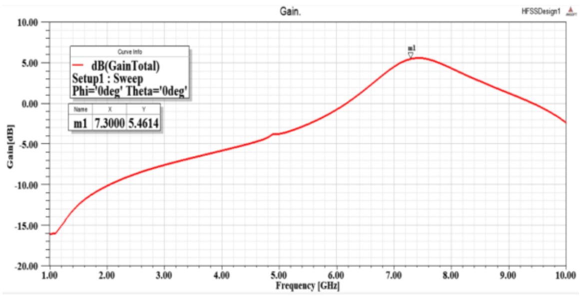


Fig :6 Gain of Conventional microstrip patch antenna-7.3GHz

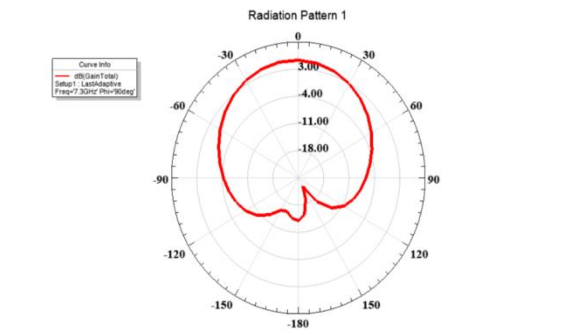


Fig :6.1Radiation Pattern of Conventional microstrip patch antenna-7.3GHz

Design of Hilbert curve based microstrip patch antenna:

$$R_k = 2^{2k+1} - 11 \times 2^{k-1} + 4 \qquad (12)$$

Where k is the size of the square grid.

Grid=2×2, R_k is the number of runs necessary to complete the square grid.

The resulting structure has been slightly modified to include an extra meander structure equivalent to a unit cell[12], such that enough number of unit cells(9 unit cells)can be accommodated , maintaining an overall lateral dimension of 880mm×880mm.The Hilbert based metamaterial FIG.2 is mounted upon the patch to enhance the performance of the antenna. And this is simulated using HFSS software. The RF parameter obtained is compared with the simple Conventional microstrip patch antenna TABLE.2.2.

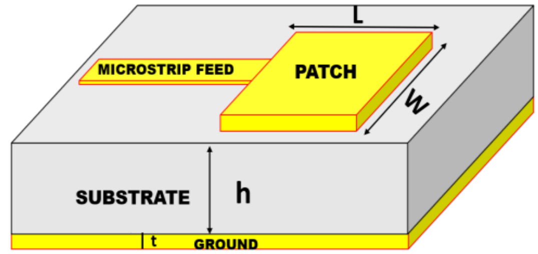


Fig.1 Microstrip patch antenna

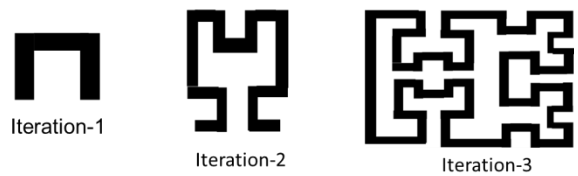


Fig:2 Hilbert curve

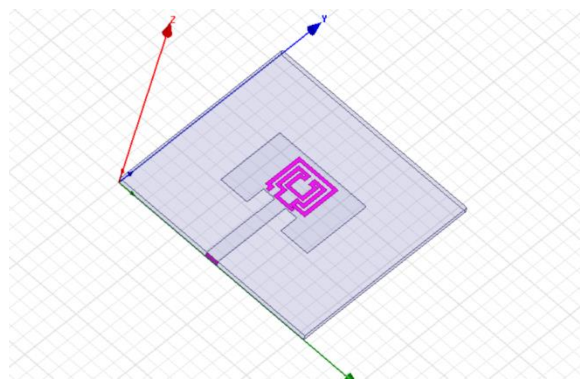


Fig :7 Metamaterial based microstrip patch antenna

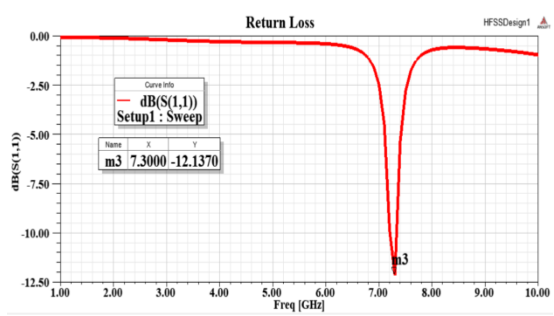


Fig.8 Return loss of metamaterial based microstrip patch antenna-7.3GHz

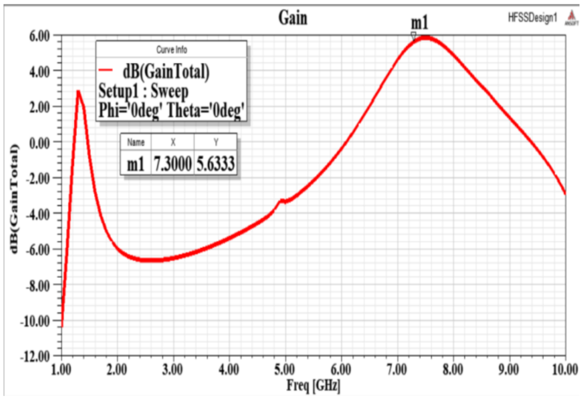


Fig.9 Gain of metamaterial based microstrip patch antenna-7.3GHz

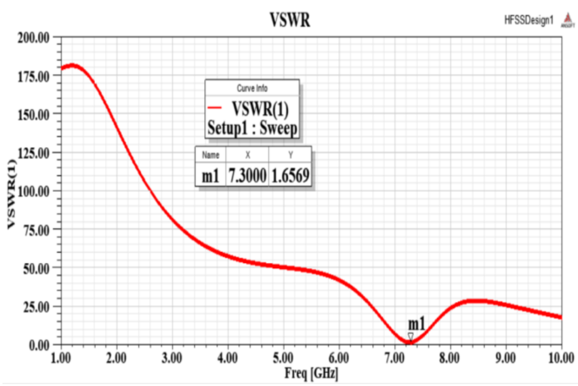


Fig. 10 VSWR of metamaterial based microstrip patch antenna-7.3GHz

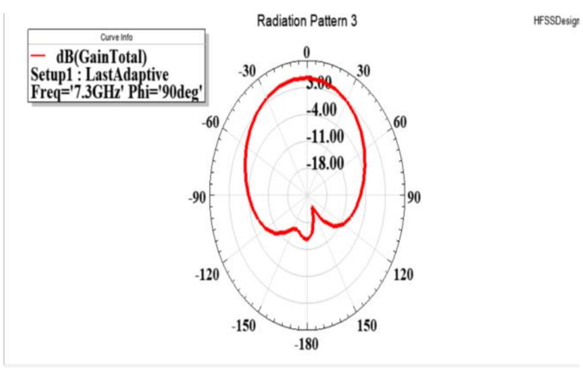


Fig.11 Radiation pattern of metamaterial based microstrip patch antenna-7.3GHz

III. Microstrip patch antenna for brain tumor detection:

Brain phantom design:The brain phantom is made realistic by designing as the six layered model. The permittivity and conductivity of the six layers is given as similar to the real human brain to resemble the same. The CSF, brain, dura, skin, bone, fat forms the six layers[9]. The tumor is placed in the brain for easy detection.

Table:3 Dimension of Brain phantom

TISSUES	**RADIUS (in mm)**	**PERMIT TIVITY (in F/m)**	**CONDUCTIVITY (inS/m)**
BRAIN	3	43.22	1.29
CSF	5	70.1	2.3
DURA	7	46	0.9
BONE	9	5.6	0.03
FAT	11	5.54	0.04
SKIN	13	45	0.73
TUMOR	1.5	55	7

The brain phantom is placed at the distance of 2 to 5 mm from the antenna. The phantom is simulated upon the antenna. The specific absorption rate (SAR) and the current density(E-Field) is measured. The variation of these parameters with and without tumor is measured for the brain tumor detection. It has been found that the SAR and the E-Field has been increased for the phantom with tumor than the phantom without tumor[9].

Fig 12 Conventional microstrip patch antenna with tumor

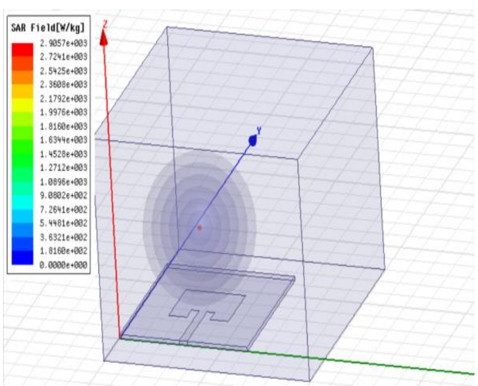


Fig 13 SAR field of Conventional microstrip patch antenna with tumor

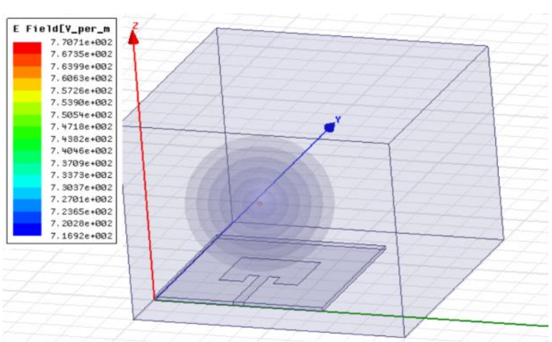
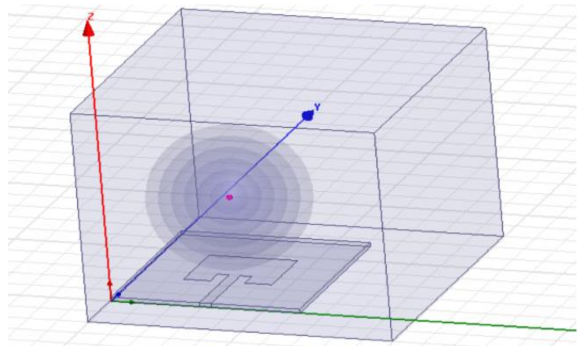


Fig 14 E-Field of Conventional microstrip patch antenna with tumor



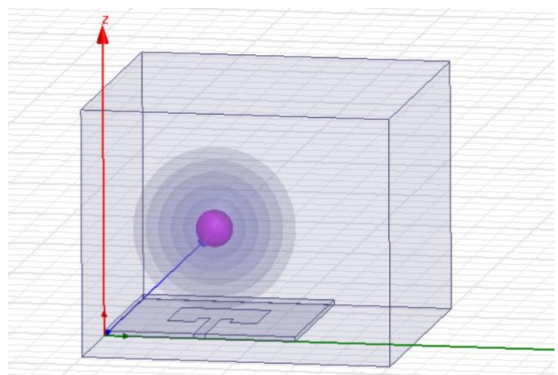


Fig 15 Conventional microstrip patch antenna without tumor

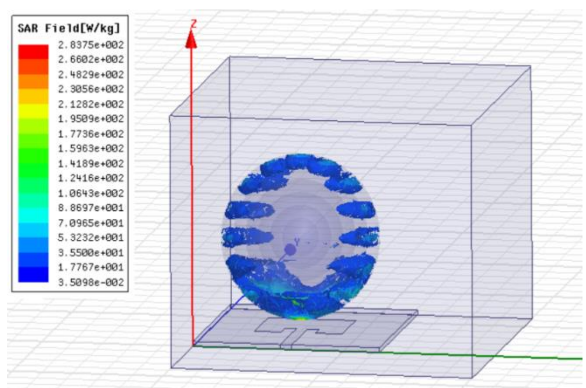


Fig 16 SAR field of Conventional microstrip patch antenna without tumor

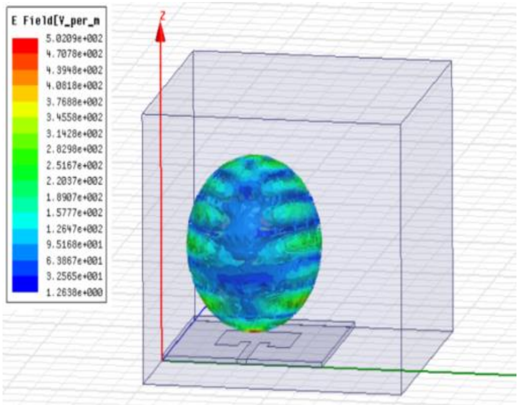


Fig 17 E-Field of Conventional microstrip patch antenna without tumor

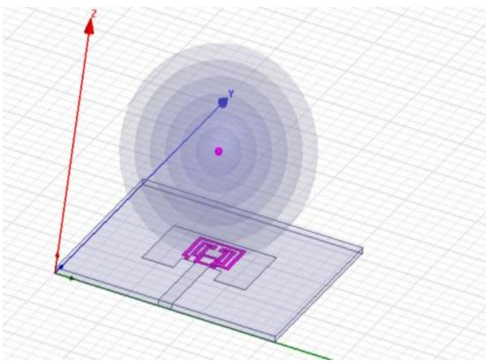


Fig.18 Metamaterial based Microstrip patch antenna for brain tumor detection

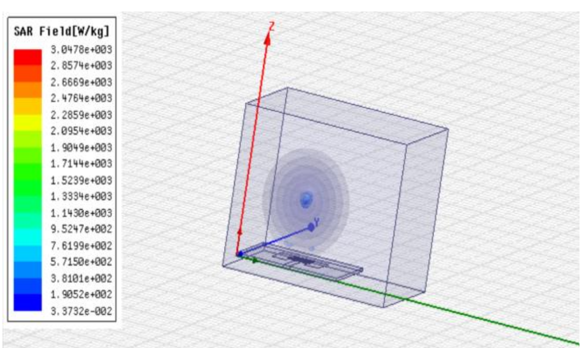


Fig .19 Specific absorption rate of Metamaterial based Microstrip patch antenna for brain tumor detection

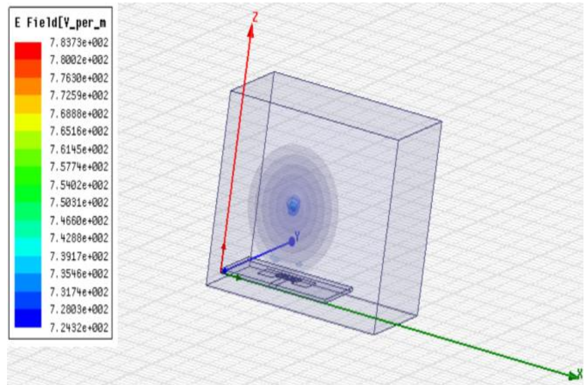


Fig.20 E-Field of Metamaterial based Microstrip patch antenna for brain tumor detection

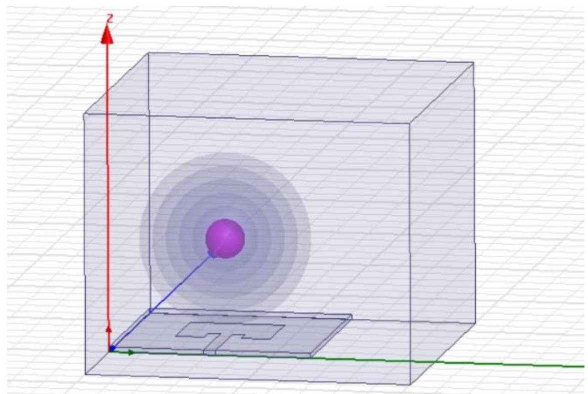


Fig.21 Metamaterial based Microstrip patch antenna for without tumor detection

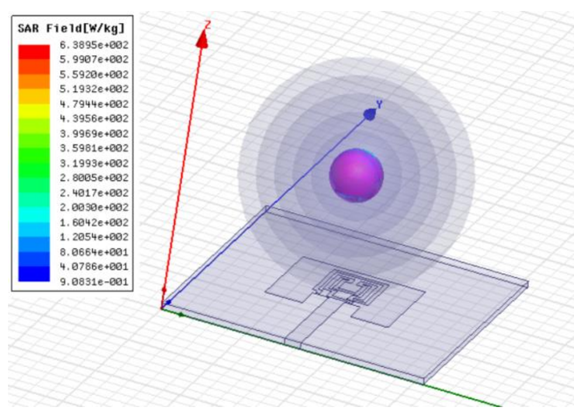


Fig.22 Specific absorption rate for Metamaterial based Microstrip patch antenna for without tumor detection

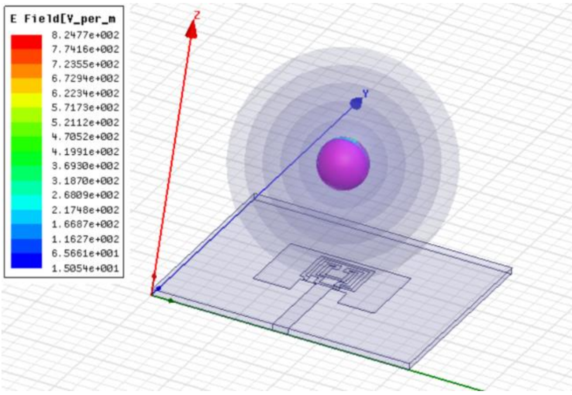


Fig.23 E-Field for Metamaterial based Microstrip patch antenna for without tumor

IV. Tabulated Results

Performance	SAR value (in W/Kg)	E-Field (in V/m)
Conventional microstrip patch antenna with tumor	0.00 - 2.9051 $\times10^3$	7.1692×10^2 - 7.7071×10^2
Conventional microstrip patch antenna without tumor	3.5098×10^{-2}- 2.8375×10^2	1.2638 - 5.00209×10^2
Metamaterial based microstrip patch antenna with tumor	3.3732×10^{-2}- 3.0478×10^3	7.2432×10^2- 7.837×10^2
Metamaterial based microstrip patch antenna without tumor	9.0831×10^{-1}- 6.3895×10^2	1.5054×10^1- 8.2477×10^2

V. Conclusion

The performance of the antenna is initially found without Hilbert curve. The return loss, gain,VSWR are considered as the antenna parameters. Then it has been improved using the Hilbert curve. The phantom is placed at the distance of 2 mm form the antenna and simulated upon the antenna. The results obtained are analyzed.

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