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Detection of Kidney Tumor Using UWB Patch Antenna

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Abstract - *It is proposed to design and utilize a strip line inset fed Ultra-Wide Band (UWB) patch antenna having a bandwidth of 7GHz resonating from 23GHz to 30GHz in order to identify the existence of tumor inside a human kidney. A two layered healthy kidney model has been designed and a 3mm radius tumor is positioned inside the kidney model. A comparative analysis of radiation properties of patch antenna for a normal healthy and a tumor induced kidney model has been done. The comparative analysis of performance metrics of the proposed patch antenna viz. bandwidth, directivity, gain, return loss, voltage standing wave ratio and electric field intensity for the kidney models has been done. According to the results, a kidney model with a tumor has a greater SAR than a kidney model with a healthy kidney. Based on the obtained results, the proposed patch antenna could potentially be utilized for detection of tumor in human kidney.*

Key Words: Inset fed antenna, UWB, detection of tumor in the kidney

1.INTRODUCTION

In today's world, cancer disease is considered to be among the most complex diseases suffered by human beings, with an estimate of approximately 13.2 million people likely to be affected and die worldwide by the year 2030. Microwave imaging has evolved as a novel alternative tool for detecting tumors to traditional detection methods such as X-ray, magnetic resonance imaging (MRI), computed tomography (CT scan), and ultrasound. The microwave imaging approach is based on the principle of a large variation in the dielectric characteristics of normal and cancer tissue. Microwave tumor detection is thought to be rapid, cost efficient, ethical, painless, and offers precise results. However, a trade-off always exists between the image resolution and energy penetration, since an improved image resolution and a reduced energy penetration is observed at high operating frequencies. An antenna designed in the Ultra-Wide Band (UWB) frequency range, allows for an increase in penetration depth and simultaneously minimizes the transmitted signals attenuation levels. A high-directional antenna is necessary to locate the tumor at a precise spot. While low frequencies are necessary to detect deeper level tumors, high frequencies are needed to detect tumors at the skin's surface.

Designing body-worn antennas is intrinsically multidisciplinary because the human body is an electromagnetically lossy, dispersive medium that perturbs antenna resonance, reduces radiation efficiency, and alters near-field coupling. Mechanical deformation from bending, stretching, and twisting causes detuning, bandwidth shifts, and radiation pattern distortion, while sweat, temperature, and laundering introduce further variability in textile and polymer properties over time. Robust designs therefore require co-optimization of materials, geometry, and electromagnetic boundaries, including ground planes, artificial magnetic conductors, electromagnetic bandgap backings, and impedance-matching or coupling layers that stabilize on-skin performance. Ensuring biosafety adds additional constraints: SAR compliance, thermal comfort, and mechanical breathability, all without compromising gain, bandwidth, or battery life.

Against this backdrop, kidney tumor detection presents a focused biomedical sensing opportunity for wearable antennas. Kidney tumors possess dielectric properties different from those of the surrounding renal tissue and fluids, thereby producing measurable perturbations in reflected or transmitted microwave fields. Operating within carefully chosen frequency ranges, balancing depth of penetration with spatial resolution, a conformal wearable microstrip antenna-or indeed a small on-body array-can interrogate the abdomen and sense contrast-driven signatures associated with tumors. This represents a pathway toward low-cost, non-invasive adjuncts to conventional imaging, enabling preliminary screening, at-home follow-up after treatment, or triage in resource-limited settings. Realizing this vision places several tightly coupled demands. First, substrate and encapsulation choices must be flexible, biocompatible, and low-loss, with stable dielectric properties under bending and moisture exposure. Second, the radiator and ground configuration should mitigate body loading and back radiation while preserving forward coupling into deep tissue; metamaterial inspired surfaces can miniaturize the footprint and control near field.

2. LITERATURE SURVEY

The antenna is designed with an elliptical slot inserted in a rectangular patch by utilizing the coplanar waveguide (CPW) feeding technique on a polyimide substrate. The proposed antenna operates within 7–14 GHz (S11 < − 10 dB) with a minimum return loss is observed as low as – 58 dB by simulation.[1]

The antenna, 35 × 20 mm, is fed using the well- known Co-Planar Waveguide (CPW) configuration, where it operates at 2.44 GHz and 5.8 GHz of the Industrial Scientific and Medical (ISM) radio band. By employing the flexible Rogers Ultralow 3850 as the antenna substrate, the proposed antenna exhibited high flexibility.[2]

A meandering technique is employed to reduce the electrical size of the antenna. The operational band of the proposed antenna is 0.5-4.5 GHz, while its dimensions are as small as 21×19.25×0.025 mm. The antenna is simulated using a commercial full-wave simulator (CST Microwave Studio), fabricated on Polyethylene terephthalate (PET), and tested in realistic scenarios.[3]

The antenna presented in this paper is designed to operate in the Industrial, Scientific and medical (ISM) band, (2.4- 2.4835 GHz). The thickness of the antenna is only 0.887mm, meaning this antenna can easily be subjected to bent conditions.[4]
A wideband UWB patch antenna is designed and tested on healthy and tumour-affected brain models, showing higher SAR in tumour cases, enabling potential tumour detection.[5]

3.METHODOLOGY

Figure 1 depicts the construction of a micro strip line fed microstrip patch antenna. CST Design Studio was used to develop the microstrip patch antenna. The antenna is 7 x 8 x 1.6 mm3 in size. As an antenna substrate, a Rogers RT5880 dielectric lossy material with a tangent loss of 0.0009 and a dielectric constant of 2.2 has been employed. The core objective of work done is to make use of the proposed antenna for determining the existence of tumor in human kidney. Table I shows the antenna's planned dimensions.

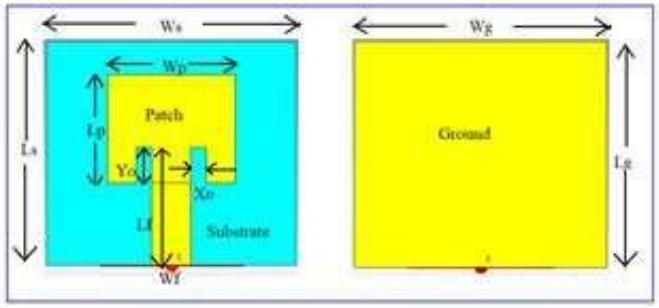

Fig. 3.1. Proposed Patch Antenna Structure

Table I – Antenna Dimensions

Antenna Dimension in mm	Ls=7=Lg	Lp=3.4	Y0=1.1	Lf=2.66
	Wf=8=Wg	Wf=1.26	X =0.5	Wp=4.1

Table II – Electrical Properties and Dimensions of Human Kidney and Tumor

Layer	Thickness (t) or Radius(r) (mm)	Permittivity (y)	Electrical Conductivity (S/m)	Thermal Conductivity (w/k-m)	Density (Rho) (Kg/m)
Kidney Skin	5.5	58.67	1.392	0.26	1050
Kidney medulla	5	58.67	1.392	0.22	1040
Tumor	3	27	2.39	0.55-0.70	1050

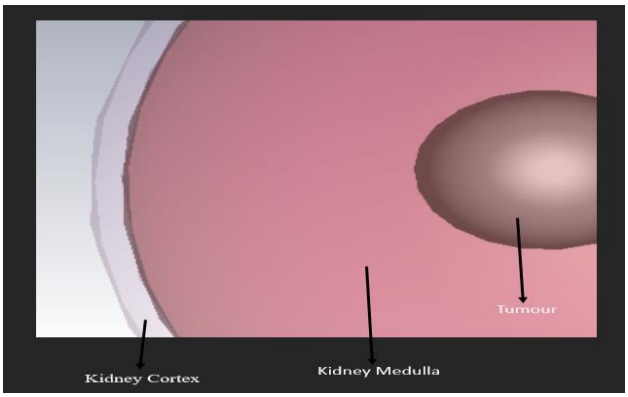

Fig.3.2 Layers of kidney and Tumor

4.RESULTS AND DISCUSSION

- Case 1: Antenna in free space.

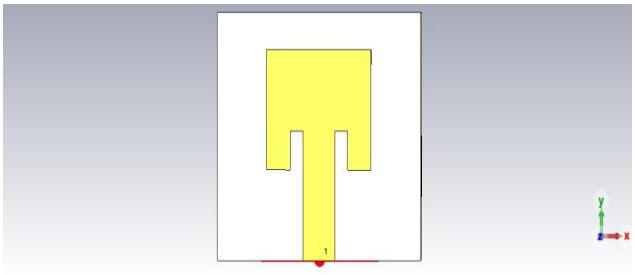

Fig.4 Antenna in free space.

The proposed antenna is a patch antenna designed and simulated in CST Microwave Studio for free-space operation. The antenna is 7 x 8 x 1.6 mm3 in size. As an antenna substrate, a Rogers RT5880 dielectric lossy material with a tangent loss of 0.0009 and a dielectric constant of 2.2 has been employed. The antenna here is used to calculate S11, VSWR, Gain, Directivity, Electrical field intensity.

REFLECTION COEFFICIENT: The S11 for the proposed antenna design is shown in Fig 5. The antenna has a resonant frequency at f = 24.1 GHz and 27.6GHz with a bandwidth of 6.2GHz.

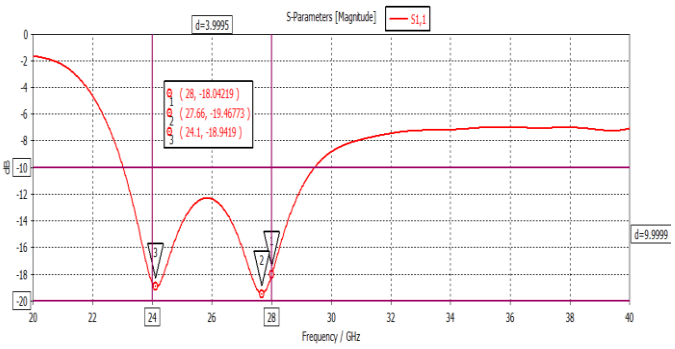

Fig.5 S11 graph for proposed antenna design.

VOLTAGE STANDING WAVE RATIO (VSWR): The VSWR for the proposed antenna design is shown in Fig 6. The VSWR at f = 24 GHz is 1.263 and at 27 GHz is 1.379.

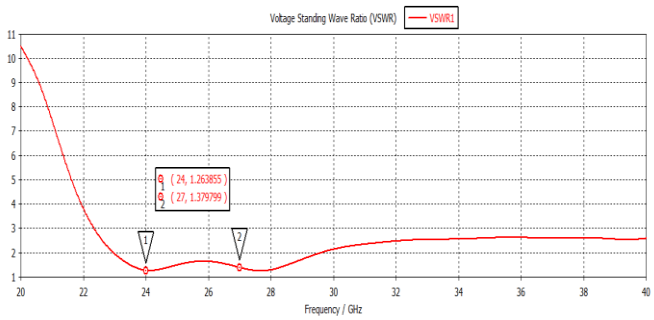

Fig.6 VSWR graph for proposed antenna design.

GAIN AND DIRECTIVITY OF EXISTING ANTENNA DESIGN: The obtained gain for the proposed antenna design is 6.01 dBi. The directivity obtained is 6.083. The gain, directivity, Electric field intensity is calculated for the resonant frequency at f = 28 GHz are as shown in figures 7,8.

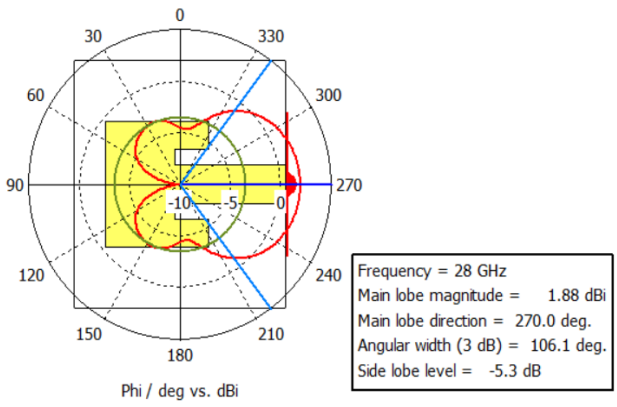

Fig.7 Gain measured without kidney layers and tumor.

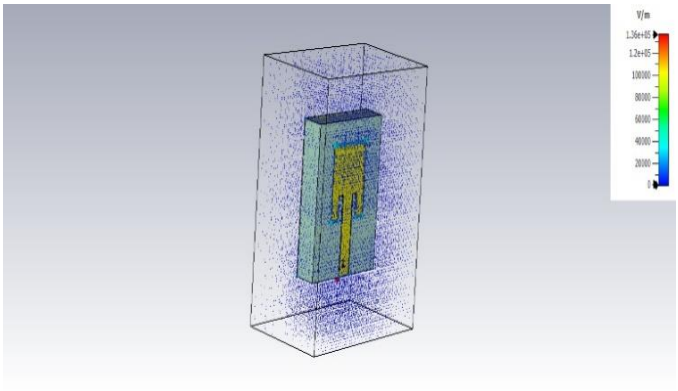

Fig.8 Electric field measured for proposed antenna design.

- Case 2: Kidney layers placed in front the proposed antenna design.

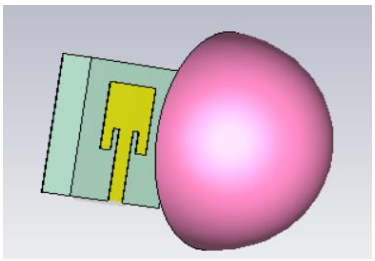

Fig.9.1 Front view of the Antenna only with the kidney skin and medulla layer.

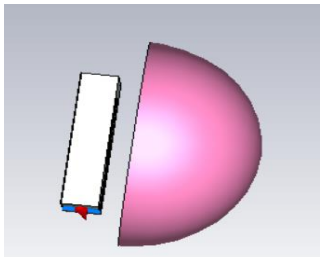

Fig.9.2 Side view of the Antenna only with the kidney skin and medulla layer.

In the antenna shown in the figures 9.1 and 9.2 the kidney layers (skin and medulla) are placed in front of the antenna design with the distance of 1mm of which the layers of kidney have a density of 1050kg/m^3 and 1040kg/m^3 respectively. The kidney skin is of radius 5.5mm and medulla of 5mm.

REFLECTION COEFFICIENT: The S11 for the proposed antenna design with only kidney layers is shown in Fig 10. The antenna has a resonant frequency at f = 28 GHz and 30 GHz.

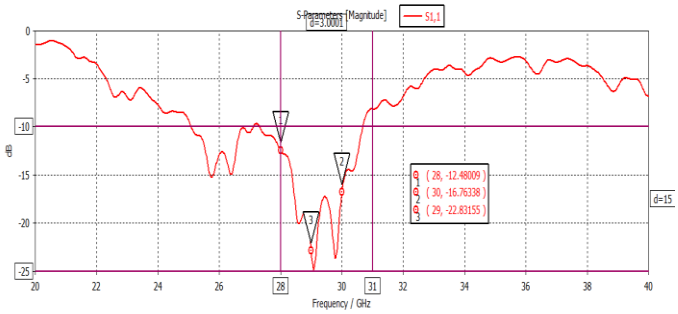

Fig.10 S11 graph for proposed antenna design with only kidney layers.

VOLTAGE STANDING WAVE RATIO (VSWR): The VSWR graph for the proposed antenna design with only kidney layers is shown in Fig.11. The VSWR at f = 24 GHz is 2.403 and at 27 GHz is 1.84029.

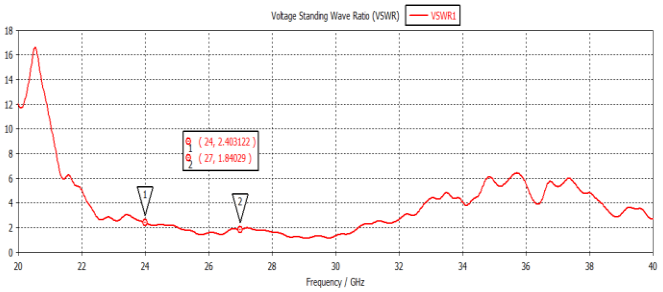

Fig.11 VSWR graph for proposed antenna design with only kidney layers.

GAIN AND DIRECTIVITY OF EXISTING ANTENNA DESIGN: The obtained gain for the proposed antenna design is 3.008 dBi. The gain, directivity, SAR, Electric field intensity is calculated for the resonant frequency at f = 28 GHz are as shown in figures 12,13,14.

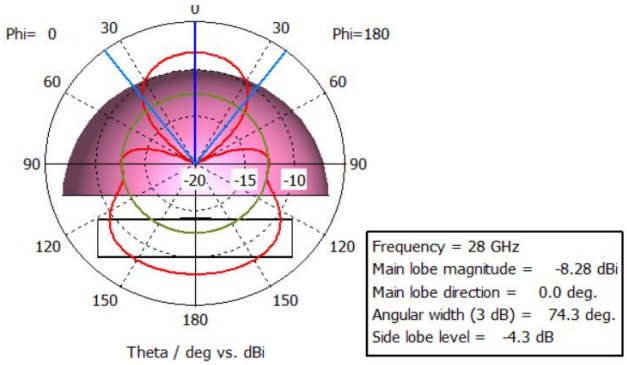

Fig.12 Gain measured only with kidney layers

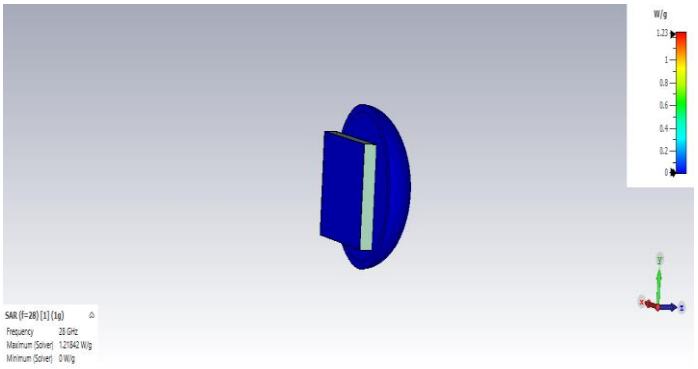

Fig.13 SAR of proposed antenna design with only Kidney layers

The Specific Absorption Rate, which is expressed as W/g, is the rate at which energy is absorbed by human body tissue. The SAR is simulated at 28GHz for a 0.1g mass of tissue in a human kidney model without kidney tumor as illustrated in Fig. 13. Table III summarizes the SAR at 28GHz, which is 1.22 W/g.

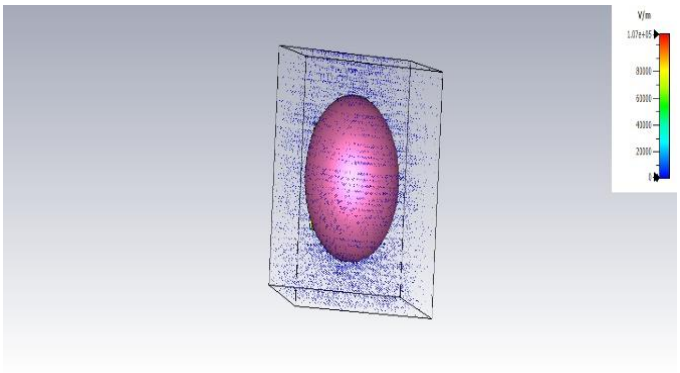

Fig.14 Electric field measured for proposed antenna design with only kidney layers.

- Case 3: Kidney layers and the tumor placed in front of the antenna design.

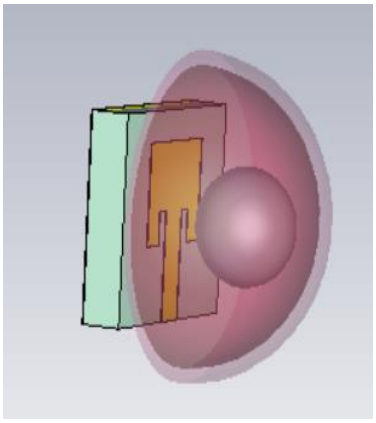

Fig.15.1 Front view of kidney layers and the tumor placed in front of the antenna design

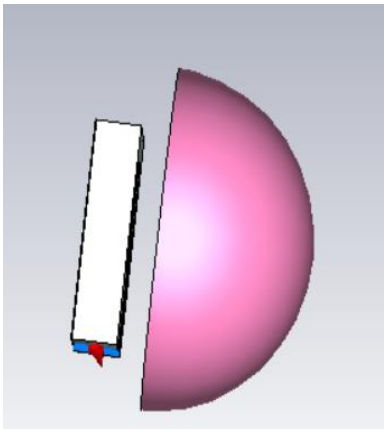

Fig.15.2 Side view of kidney layers and the tumor placed in front of the antenna design

In the figures 15.1 and 15.2 the kidney layers (skin and medulla) are placed in front of the antenna design with a distance of 1mm of which the layers of kidney and tumor having a density of 1050kg/m^3, 1040kg/m^3 and 1040kg/m^3 respectively. The kidney skin is of radius 5.5mm, medulla of 5mm and tumor of radius 3mm.

REFLECTION COEFFICIENT: The S11 graph for the proposed antenna design with kidney layers and tumor is shown in Fig 16. The antenna has a resonant frequency at f = 26 GHz and 30GHz

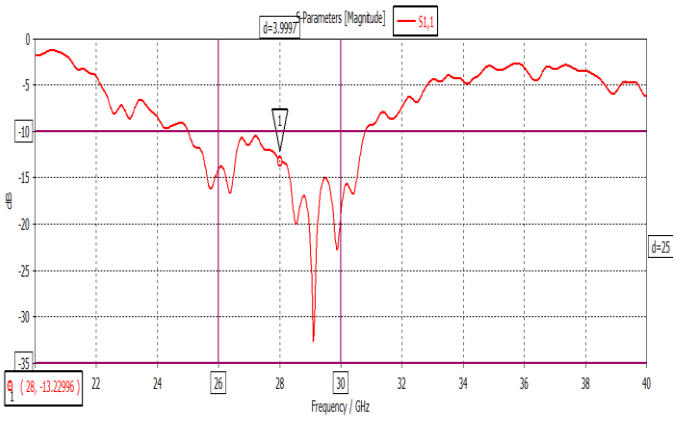

Fig.16 S11 graph for proposed antenna design with kidney layers and tumor

VOLTAGE STANDING WAVE RATIO (VSWR): The VSWR graph for the proposed antenna design with kidney layers and tumor is shown in Fig 17. The VSWR at f = 24 GHz is 2.36 and at 27 GHz is 1.799.

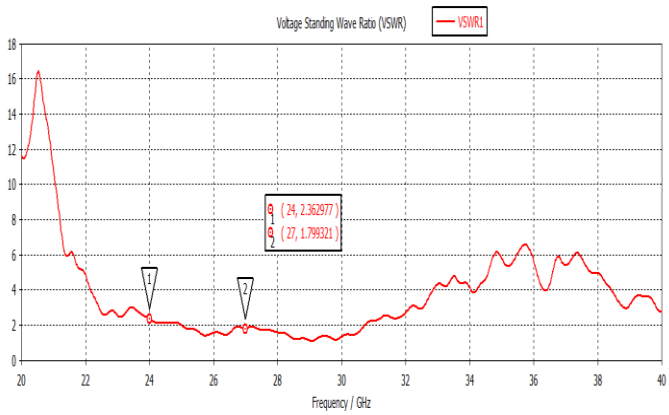

Fig.17 VSWR graph for proposed antenna design with kidney layers and tumor

GAIN AND DIRECTIVITY OF EXISTING ANTENNA DESIGN: The obtained gain for the proposed antenna design is 3.94 dBi the gain, directivity, SAR, Electric field intensity is calculated for the resonant frequency at f = 28 GHz are as shown in figures 18,19,20.

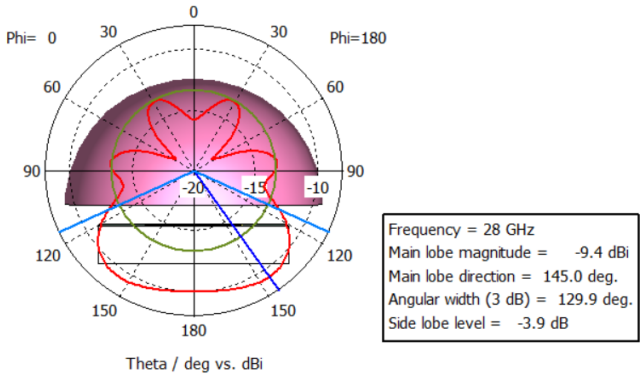

Fig.18 Gain measured with kidney layers and tumor

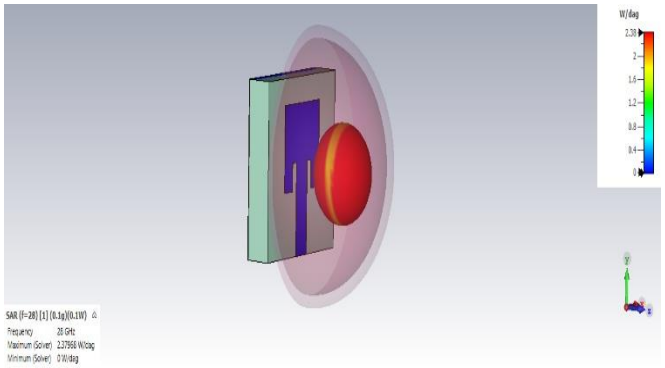

Fig.19 SAR of proposed antenna design with kidney layers and tumor

The Specific Absorption Rate, which is expressed as W/g, is the rate at which energy is absorbed by human body tissue. The SAR is simulated at 28GHz for a 0.1g mass of tissue in a human kidney model without kidney tumor as illustrated in

Fig. 19. Table III summarizes the SAR at 28GHz, which is 2.38 W/g. According to the safety standards the SAR value must be below 2W/g for a human body tissue here it is clearly visible that the value is greater than 2 so the presence of kidney tumor is detected.

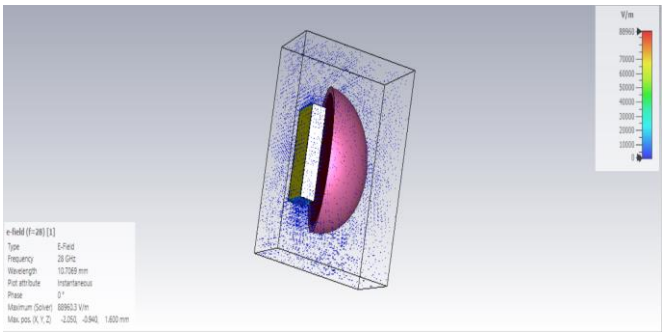

Fig.20 Electric field measured for proposed antenna design with kidney layers and tumor

Table III – Comparison of characteristics at 28GHz Frequency

Parameter	Antenna in free space	Antenna with kidney layers	Antenna with kidney layers and tumor
Electric field intensity (V/m)	1.35e+05	1.07e+05	89619
Return loss (dB)	-19.46	-12.48009	-13.2299
VSWR	1.286	1.623	1.557
Gain (dB)	6.01083	3.008	3.9477
Directivity (dBi)	6.083	6.072	6.6211
SAR	-	1.22 with 0.1W input power	2.3 with 0.1W input power

After inserting the tumor tissue into the kidney, the kidney model is positioned approximately 1 mm from the inset fed antenna. To develop and simulate, computer simulation technology (CST) microwave studio (MS) was employed. Figure 16 displays the reflection coefficient curve for the presence of tumor in the kidney. The presence of a kidney tumor in the kidney has resulted in a shift in gain and directivity. Gain and directivity at 28 GHz have changed from 3.008dBi to 3.947dBi as shown in Table III respectively. As shown in Fig.19, the SAR at 28Ghz has increased for the presence of kidney tumor in the kidney model. When the kidney tumor is of size 2mm the SAR value measured was 1.19W/g and when the size of the tumor was 5mm it was 4.76W/g so by this it can be understood that when the size of tumor is small it is not detectable and on increasing the size the SAR value gradually increases and the presence of kidney tumor is detected Table III is a summary of all three cases.

5. CONCLUSION

Kidney tumor detection is detected using the suggested inset fed UWB patch antenna. For the investigation of kidney tumor identification, a model of the two layers of the human kidney with an internal tumor with a radius of 3 mm is utilized. Analysis is done on the specific absorption rate (SAR), return loss, electric field intensity, and antennas with and without tumors. As can be shown from the findings, the proposed antenna design is capable of identifying the presence of kidney tumor in the human kidney. In this study by placing the kidney tumor in the center of the kidney or anywhere inside the kidney area, more research may be done. The planned miniature antenna has been manufactured to comply with the SAR level advised by the ICNIRP and FCC, assuring the protection of human health.

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