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CUP SHAPED DUAL BAND MICROSTRIP ANTENNA WITH DGS FOR BIO-TELEMETRY

Sumita Shekhawat[1], Deepti Chauhan[1], Poonam Tiwari[2], Kuldeep S Rathore[3] and Deepak Bhatnagar[4]

[1]*Department of Physics, Kanoria PG Mahila Mahavidyalaya,Rajasthan, Jaipur, India*
[2]*Department of Physical Sciences, Banasthali Vidyapith, Banasthali, Rajasthan, India*
[3]*Department of Physics, Arya College of Engineering and IT, Rajasthan, Jaipur, India*
[4]*Department of Physics, University of Rajasthan, Rajasthan, Jaipur, India*

ABSTRACT

Advancement of technology in the field of communication has made it possible to send biological information of human body to external intensive care systems and Biotelemetry is one such advance area of research. Being planar patch antennas are finding attention for RF biotelemetry due to their specific properties. In this paper we have proposed a compact cup shaped planar microstrip antenna with dual band performance. The proposed antenna is fabricated and measured. It operates efficiently in ISM, LTE and WLAN band and offers impedance bandwidth of 81.59 %(1.72-4.1 GHz) in S-band and 17.12% (4.7-5.58 GH) in C-band. The fabricated antenna is also analyzed on body phantom gel and hence performance is optimized to get best possible matching between them. When antenna is measured on phantom gel its bandwidth degraded from 81.58% to 33.47% in S band and in C-band impedance bandwidth decreases from 17.12% to 7.5% but still antenna is covering ISM, LTE and 5.2 GHz Wi-Fi bands used in biotelemetry application.

Keywords - Biotelemetry, Planar antenna, ISM (Industrial, Scientific Medical) Band, Body phantom

[1] INTRODUCTION

Today is the era of advance technology and is extending in all fields including medical devices. Loads of people are suffering from serious diseases because of today's unhealthy smart living and needs regular check-ups for early detection of problems. Biotelemetry made it possible as it transmits biological signals from body to long distances. Movassaghi et.al[1] illustrated that antennas plays vital role in wireless biotelemetry. When used for health care monitoring antenna should communicate in dual mode i.e. with devices located on the body and also establishes the communication link with the off body monitoring devices.

Designing antennas for human body is not an easy task as the biological environment drastically changes the performance of antenna. Many researcher all around the world worked on the effect of performance of antenna when operated in close proximity [2]-[4]. Due to exposure of Electromagnetic radiations towards human body energy is absorbed with in the body which gives rise to SAR (Specific Absorption Rate) [5]-[7]. S. Obayashi .et.al [8] & K.

Ziri-Castro .et.al [9] investigated antenna used in cell-phone and pager systems for on and off the body radiation propagation. A novel antenna for body-centric application has been proposed by Bright Yeboah-Akowuah et.al [10] by introducing a circular slot on the patch to control the antenna's resonance and input impedance. The antenna shows very good performance when used close to human tissues but it is having very low bandwidth. A. Gupta et.al [11] designed a square ring shaped patch antenna for on-off dual mode communication covering ISM, LTE, and WLAN band and also shown that when antenna is placed in body environment, at optimized location shows low SAR at the three frequencies.

In this paper a dual band cup shaped patch with defected ground configuration has been discussed for use in dual mode on /off body communication. This antenna has wide bandwidth of 58.7% (2.02-3.7 GHz) which covers ISM (2.41-2.48 GHz), LTE (2.6 GHz) and 5% (5.06-5.32) covering 5.2 GHz WLAN band. The performance of antenna is validated on multilayer phantom model designed using the equivalent dielectric properties of human body layer.

[2] DESIGNING OF PROPOSED ANTENNA

When antenna is designed to be used in close proximity of human body several conditions must be satisfied like low profile, easily integrated with the monitoring devices, having wide impedance bandwidth, omnidirectional radiation pattern. Patch antennas being planar are finding research interest in wireless biotelemetry but having low impedance bandwidth. So in this paper we have tried to improve the bandwidth by cutting slots in conventional narrow band elliptical patch at optimized position. FR4 substrate having permittivity εr = 4.4, thickness =1.59mm and loss tangent = 0.025 is used to design antenna. Ansoft's electromagnetic simulation software HFSS [12] is used for design, simulation and optimization process. Elliptical patch shape is considered initially as they are having more degree of freedom and gives larger bandwidth as compared to other conventional designs found in literature. The overall size of antenna is 40x40x1.6 mm3. The patch size considered has semi major axis 13.5 mm with eccentricity 0.66 antenna is feed along minor axis. Geometrical layout of proposed antenna is shown in fig.1. The final geometry is fabricated using lithography technique. The photograph of fabricated antenna's upper patch and lower ground layer is shown in fig.2. The fabricated antenna is measured using Agilent vector network analyzer.

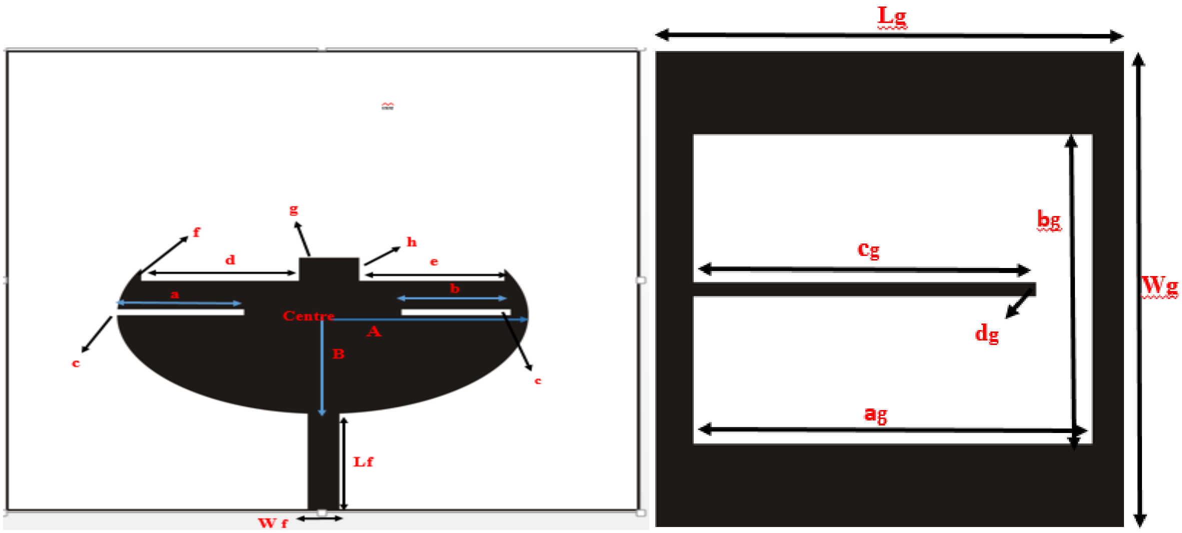


Fig 1. Geometrical layout (a) lower ground plane (b) upper patch

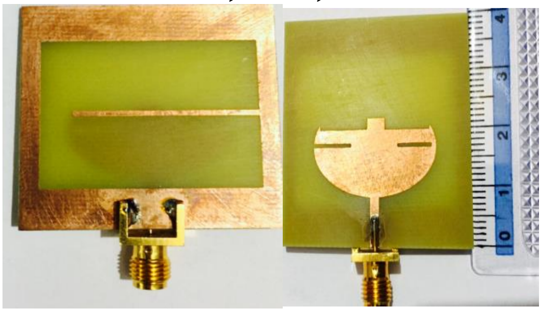


Fig.2 Photograph of Fabricated antenna (a) bottom ground layer (b) upper ground patch

The optimized parameters of proposed antenna pointed in fig1 are shown below in table I.

TABLE I

PARAMETERS OF PROPOSED ANTENNA

Optimized upper patch parameter	**Value in mm**	**Optimized lower ground Parameter**	**Value in mm**
A X B	13.5x8.91	L_gx W_g	40 x 40
axc	7 x 0.5	a_gxb_g	33.7 x 25
bxc	6.9 x 0.5	c_g x d_g	29 x 1
d	10.5		
e	9.7		
f	1.08		
gxh	3.8 x 2		
L_f x W_f	18.12 x 2		

Effect of Rectangular Ground Cut on Frequency of Operation of Elliptical Geometry

The resonant frequency for the conventional elliptical patch is given by Pawan.et.al [13].

$$f_r = \frac{ck_{nm}}{2\pi r_e \sqrt{\varepsilon_{eff}}} \qquad (1)$$

c represent velocity of light, k_{nm} shows the m^{th} root of Bessel function of order n ; ε_{eff} is the effective dielectric constant of the substrate material. This formulae is given assuming ellipse as a circle of radius r_e. and is calculated using relation 2.

$$r_e = \sqrt{\frac{a_{eff}^2 + b_{eff}^2}{2}} \qquad (2)$$

Where $$a_{eff} = \left(a^2 + \frac{2ha}{\pi\varepsilon_{eff}} \left[\ln\left(\frac{a}{2h}\right) + (1.41\varepsilon_{eff} + 1.77) + \frac{h}{b}(0.268\varepsilon_{eff} + 1.65) \right] \right)^{1/2} \quad (3)$$

$$b_{eff} = \left(b^2 + \frac{2hb}{\pi\varepsilon_{eff}} \left[\ln\left(\frac{b}{2h}\right) + (1.41\varepsilon_{eff} + 1.77) + \frac{h}{b}(0.268\varepsilon_{eff} + 1.65) \right] \right)^{1/2} \quad (4)$$

a and b represents major and minor axis of ellipse, h represents height of substrate, ε_{eff} is the effective dielectric constant which incorporate fringing field effect and is calculated using relation 5.

$$\varepsilon_{eff} = \varepsilon_r - \frac{0.35\varepsilon_r}{2}\left[\frac{h}{a} + \frac{h}{b} + \frac{h^2}{ab}\right] \quad \textbf{(5)}$$

For the given ellipse (a= 13.4 mm, b= 8.91 mm, h=1.6, ε_r=4.4) putting k_{nm} equals to 1.8412 calculated dominating mode frequency is 4.10 GHz. Simulating the same elliptical shape patch having full ground plane using HFSS simulation software found that it is resonating at 4.26 GHz frequency as shown in fig 4 so there is minute variation in calculated and simulated frequencies. Thus simple elliptical patch is having narrow bandwidth and it does not meet our requirement so we have defected ground with rectangular slot at centre because on minutely analysing the magnitude of surface current plot on ground given in fig 3 we found that most of the current is flowing at this position. Cutting rectangular slot at centre of ground plane increases the current path greatly due to which resonating frequency shifts toward lower side. Fig 4 shows the variation of reflection coefficient with frequency for the two cases. It illustrates that on cutting rectangular ground slot in simple elliptical patch antennas the resonating frequency shifts towards lower side, also matching improves and it operate over large band width from 2.46 GHz- 4.04GHz with centre frequency 3.66 GHz. but we need an antenna with dual band one band to be operate in ISM band and other in WLAN band so further modification in patch is required.

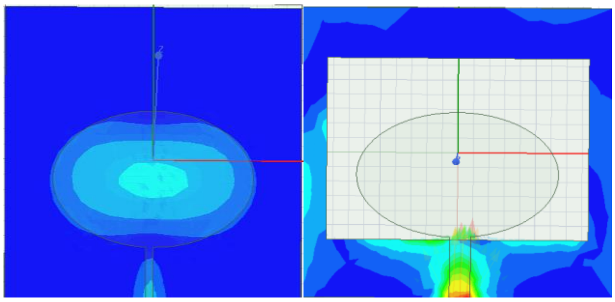


Fig.3 Current density plot on (a) Elliptical patch without ground slot (b) Elliptical patch with rectangular slot in ground

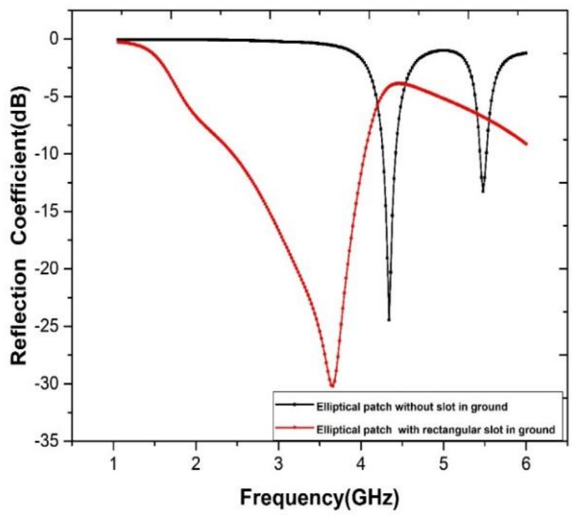
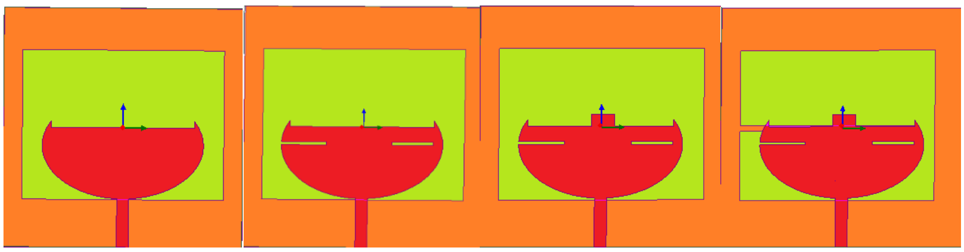


Fig 4. Variation of reflection coefficient versus frequency for patch with and without slot in ground

Step by Step Generation of Proposed Geometry

To reach the final geometry of our interest several modifications are done in previously discussed simple elliptical patch geometry with rectangular ground slot and these phases are shown in fig .5. For better understanding of different alterations done in antenna structure and their effects on performance the variation of reflection coefficient versus frequency for all antenna geometries are given in fig.6.



(a) Antenna Geometry 1 (b) Antenna Geometry 2(c) Antenna Geometry 3 (d) Antenna Geometry 4

Fig.5 various stages to reach the final geometry

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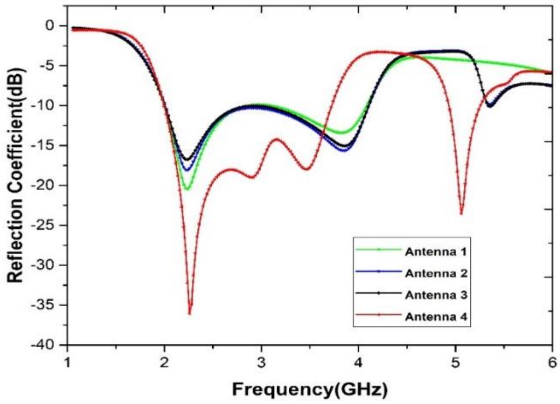

Fig.6 Reflection coefficient versus frequency variation for various antenna geometry

As can be clearly seen the final antenna is resonating in dual band from frequency 2.0 GHz-3.72 GHz in S-band and 4.92-5.26 GHz in C-band covering ISM band(2.41-2.48 GHz) , LTE band(2.5-2.69) , WLAN (5.150-5.250 GHz) thus antenna can be used as a dual mode antenna in biotelemetry.

Other important parameters which shows that antenna is having good performance when it is practically used are gain and efficiency. For the final antenna design gain and efficiency are shown in fig.7. The gain for the final antenna is positive and almost constant in the whole impedance bandwidth range for both bands. As can be clearly seen efficiency in impedance bandwidth range of S band is nearly 98% and C band is nearly 80 % but is almost uniform throughout the range in both bands. Thus antenna will efficiently radiate at both bands.

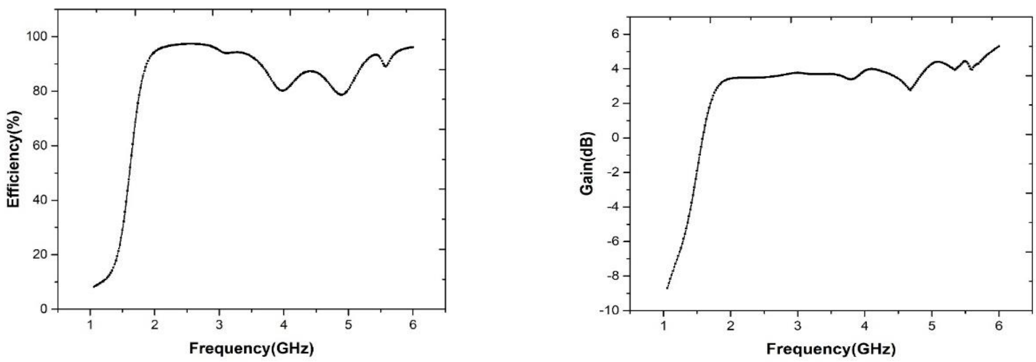

Fig. 7 Variation of (a) Gain and (b) Radiation efficiency with frequency

Simulated Radiation pattern for the proposed antenna at frequency 2.45/2.6/5.2 are given in fig 8. As can be clearly seen patterns are omnidirectional at lower frequency 2.4 and 2.6 which is required when antennas are being used for on body application but at higher frequency patterns are slightly distorted and are broadside.

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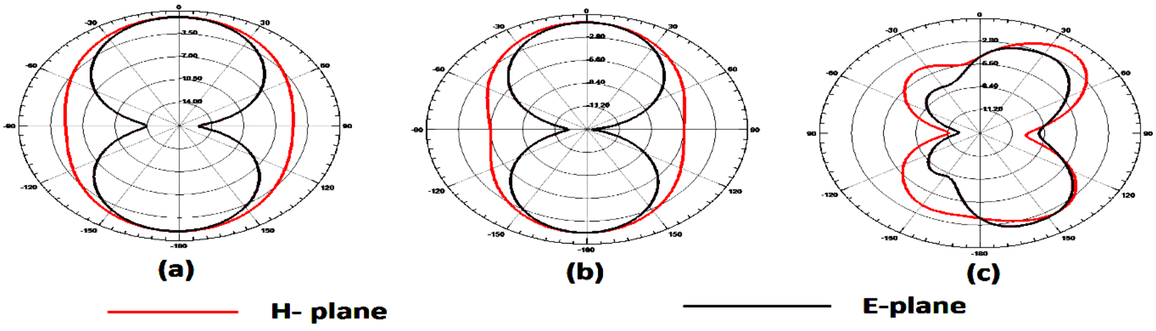

Fig.8 Simulated E & H plane radiation pattern at frequency (a) 2.45GHz (b) 2.6 GHz (c) 5.2 GHz

[3] ON BODY PERFORMANCE OF FINAL ANTENNA GEOMETRY

Human Phantom

A human body equivalent phantom model in the shape of cuboid of dimension 60x60x25 mm^3 was designed in HFSS software to carry out simulation study of proposed antenna. This model is having layers of varying thickness with dielectric properties of skin(2mm), fat(5mm), muscle(8mm) and bone(10mm).The dielectric properties of different layers are given by Karthik et.al[14] and are listed in table II . For experimental verification of simulated result a gel having 2/3 properties of muscle phantom [15] is prepared following method presented in [16], ingredients with quantity used are given in Table III.

TABLE II.

DIELECTRIC PROPERTIES OF DIFFERENT TISSUES OF HUMAN BODY

Tissue	Permittivity	Conductivity(S/m)	Loss tangent
Skin	38.8	1.18	0.30
Fat	5.30	0.07	0.14
Muscle	53.5	1.34	0.25
Bone	18.6	0.78	0.31

TABLE III.

INGREDIENTS REQUIRED TO PREPARE HUMAN PHANTOM

Ingredient	Quantity(gm)
Deionized Water	3373
Agar	104.6
Sodium Chloride	37.6
Sodium azide	2.0
TX-151	84.4
Polyethylene powder	337.5

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Radiation Properties of Designed Antenna on Human Phantom

When designed antenna placed on human body model its performance changes drastically due to the presence of high conductivity medium so varying gap between the antenna and human model gain versus frequency studies are done and result shown in fig 9.

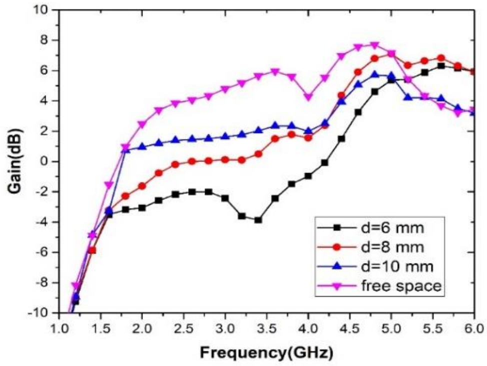

Fig 9 Variation of gain versus frequency with varying gap d

Minutely analysing the fig.9 we found that when antenna is placed at separation d=10mm from body, gain is 1.38 dB , 1.40 dB and 4.20 dB at frequency 2.45 GHz , 2.6 GHz and 5.2 GHz which is lower than values in free space but at this separation antenna is having positive gain so it can efficiently radiate.

The proposed antenna performance is tested through simulation as well as experimentally in free space as well as on human body at a separation of 10 mm. To validate its performance, the simulated and measured reflection coefficient versus frequency plot for free space as well as on human phantom gel are given in fig.10. As shown in figure the measured impedance bandwidth for antenna when placed on human phantom is 33.47%(1.94 -2.72 GHz) in S band whereas in C-band impedance bandwidth is 7.5% (5.1-5.5 GHz). The measured impedance bandwidth in free space is 81.59 %(1.72-4.1 GHz) in S-band and 17.12% (4.7-5.58 GHz). As can be seen clearly when antenna is brought near body its bandwidth is degraded. This is due to high dielectric properties of human phantom model. But still the ISM, LTE and 5.2 GHz WLAN bands are covered.

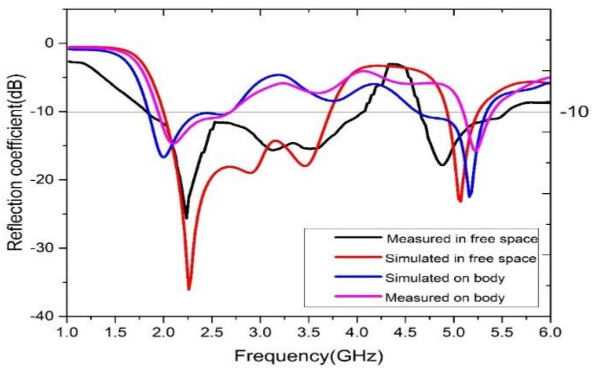

Fig 10. Comparison of simulated and measured reflection coefficient with frequency for proposed antenna in free space and on human phantom

[4] ANALYSIS OF SPECIFIC ABSORPTION RATE (SAR) FOR SAFETY PURPOSE

On placing an antenna near human body, the near-field radiations of the antenna affect the body and continuous contact of this radiation may affect the proper functioning of sensitive organs, also causes heating effect so it is necessary to check the power absorbed by the human body. SAR represents specific absorption rate with in human tissue. SAR value should not be larger than 2 W/kg averaged over 10 g of tissue as per the IEEE C95.1-2005 standard [19]. So SAR measurement are done using HFSS simulator keeping power at 0.1 watt and placing antenna at a distance of 10mm from human phantom. As shown in fig 13 the peak SAR at frequency 2.45 GHz/2.6 GHz/5.2 GHz is 0.695/1.08/0.425 which is well below the standard value.

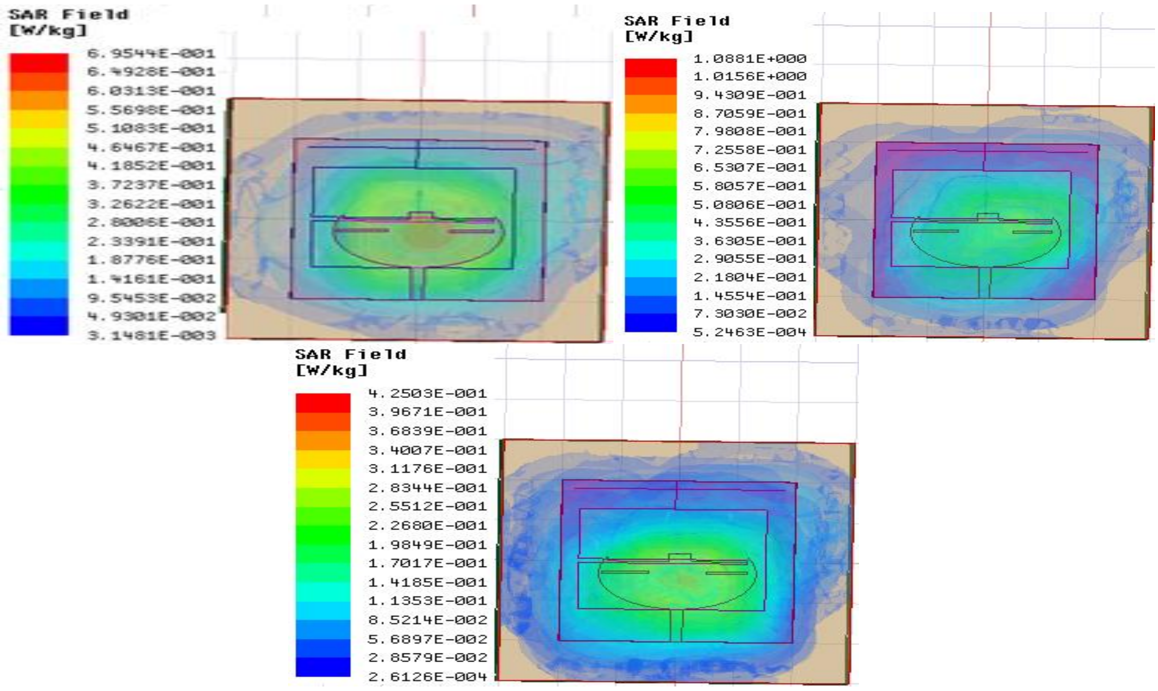

Fig. 11 Simulated SAR value at frequency (a) 2.45 GHz (b) 2.6 GHz (c) 5.2 GHz

[5]CONCLUSION

In this article a novel dual band Microstrip antenna is designed and fabricated for bio-telemetry covering ISM band, LTE band and Wi-Fi 5GHz band. A human phantom gel is also prepared to validate antenna performance for on/off body communication and for safety measurement. The study of gain of antenna varying its separation from human body phantom is also done and found that the optimized minimum separation between two where antenna works efficiently is 10 mm. Comparative study is done to validate antenna performance in free space and on human phantom so that it can be used practically. The measured results are showing that when used on human phantom gel impedance bandwidth decreases from 81.58% to 33.47% in S band and in C-band impedance bandwidth decreases from 17.12% to 7.5% but still antenna is covering ISM, LTE and 5.2 GHz Wi-Fi bands of our interest i.e biotelemetry application. The SAR measurements of antenna shows that at frequency 2.45 GHz/2.6 GHz/5.2 GHz is 0.695/1.08/0.425 which is considerably lower than the standard peak value of 2 W/kg. The radiation patterns are omnidirectional at lower frequency 2.4 and 2.6 a necessary condition for on body antenna but at higher frequency patterns are slightly distorted and are broadside. Thus proposed antenna is an attractive applicator for on/off body communication.

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