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Design and Performance Analysis of Body Wearable Antenna

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Abstract: In this paper an inset feed, rectangular microstrip textile patch antenna operating at 2.4 GHz has been proposed. The designed antenna is analyzed under bend and normal condition. For design of this antenna, 2.85 mm thick polyester fabric with dielectric constant of 1.44 is used as a substrate and 0.04 mm thick copper is used as conductive part of antenna. The designed antenna is tuned at desired frequency with return loss of -32.5 dB and an impedance bandwidth of 90 MHz is observed. Then same antenna is simulated on a three layer body phantom model (containing properties of muscles, skin and fat) for flat and bending conditions. A SAR (specific absorption rate) analysis is also done on the basis of 1 g and 10 g tissue of human body. Variations in performance parameters like return loss, gain and SAR due to lossy nature of human body are observed and analyzed. Further EBG (electromagnetic band gap) material is used to reduce SAR.

Keywords: - Body wearable patch antenna, SAR (specific absorption rate), EBG (electromagnetic band gap)

I. INTRODUCTION

A wearable antenna is an integral part of cloth wear by the user. Body wearable antenna is used to measure respiration, heart beat and temperature of the body. For this purpose a wearable and flexible antenna is required to transmit and receive the data [1]-[3]. Dual band antenna operating in frequency range 2.45 and 5-6 GHz are also used in airwave, mobile telephone and network communication systems [4]-[5]. Now days, a wearable antenna become the unobtrusive part of wearable textile system due to the availability of conductive textile [6]-[8]. An antenna has to be worn on body so antenna should perform in better way even in bending and crumpling conditions [9]. Due to crumpling in textile, performance of antenna is changed, and the radiated power is transmitted in other than desired directions. The efficiency and resonance frequency also degraded due to crumpled surface [10]. As human body is losy medium, when antenna is placed on body, dielectric constant is subjected to change and other performance parameter may also change [11]. An important parameter for wearable antenna considered is specific absorption rate (SAR). SAR is measure of back radiation absorbed by the human body when antenna is place near to body. Maximum SAR limit specified by US standard is 1.6 W/Kg for 1 g of tissue and for 10 g of tissue 2W/Kg is limited by International Commission of Non Ionization Radiation Protection (ICNIRP) of Europe [base paper]. For body wearable antennas various techniques have been discussed in literature to reduce the SAR. Using electromagnetic band gap (EBG) [12]-[13] is one of the effective techniques used to reduce SAR of antenna. In this method a high impedance surface is designed at resonance frequency. In addition to ground plane this EBG surface provides the high impedance to the back radiation and directs these radiations in desired direction [14]. For more comfort and security purpose body wearable antenna can be used as button antenna made from conductive threads on textile substrate [15]. Providing good bandwidth and gain, body wearable antennas are used in off body/ on body communication systems [16]. Overall paper is organized in four sections. Introduction of the paper is covered in section I. Design methodology is explained in section II. In section III results and discussions are given. Conclusion of paper is given in section IV of the paper.

II. DESIGN METHODOLOGY

A body wearable textile antenna shown in fig.1 is designed using an insulating textile substrate bonded with conducting thin copper plate as a ground and patch of antenna. The dimensions of antenna are calculated using the transmission line model [17]. The length and width of the proposed antenna are 49.20 mm and 56.50 mm respectively.

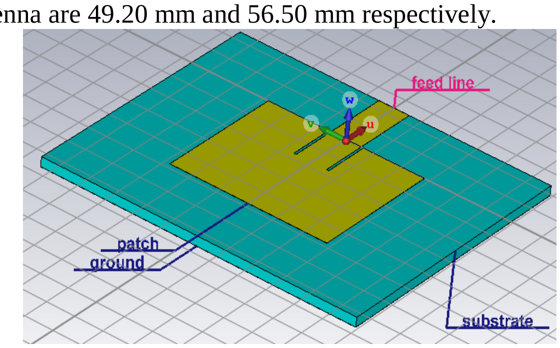

Fig.1 Antenna without body phantom

The size of ground plane is 160x180 mm^2. To energize the antenna an inset feed is used, instead of co-axial cable. Coaxial feed line is not suitable for body wearable antenna due its complexity, and mounting requirement. For inset feeding line, length and width of feed line 41.23 mm and 11mm respectively. The designed antenna is simulated using CST STUDIO 2018 on a three layer body phantom model (containing properties of muscles, skin and fat) for flat and bending conditions. In fig. 1 antenna is shown without phantom and fig 2 shows the antenna with phantom model.

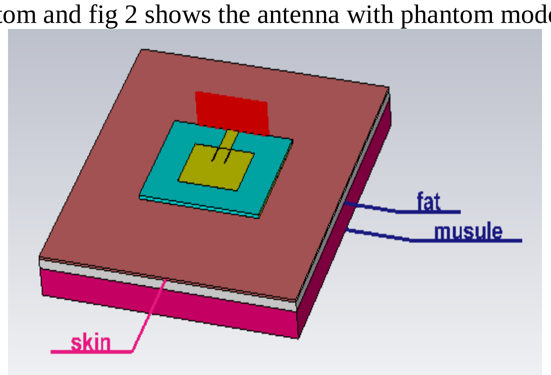

Fig.2 Antenna on body phantom

The simulated results of antennas without body and on body are given as below.

III. RESULTS & DISCUSSIONS

Return loss: Return loss measures the reflection due to mismatching. The return loss of designed antenna is given in fig. 3a and 3b.

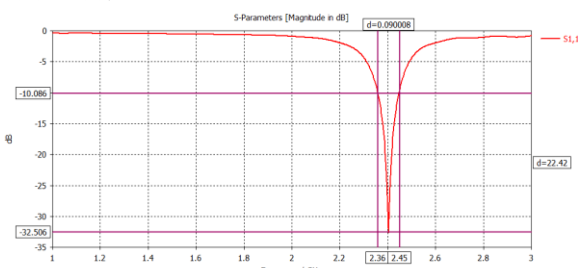

Fig.3a. Return loss for antenna with body phantom

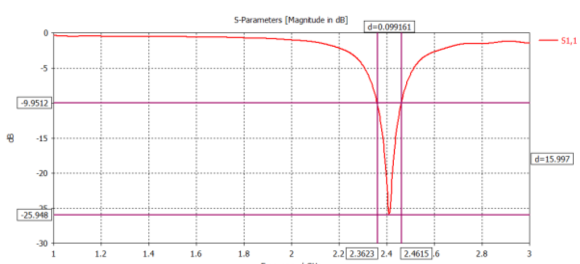

Fig.3b. Return loss for antenna on body phantom

Discussion: From the fig. 3a and 3b it is observed that return loss is more when antenna is tested without phantom as compared to antenna on body phantom. Without body return loss is -32.5 and on body phantom it is -25.9 dB. Due to lossy nature of human body dielectric constant is changed, which decreases the return loss of antenna on body phantom as compared to without phantom. But impedance bandwidth has been improved in case of antenna with body phantom which is 99 MHz as compared to 90 MHz in case of without body phantom.

Radiation Pattern: Radiation pattern is diagrammatical representation of radiated power in different direction. Radiation pattern of designed antenna with and without body phantom is given in fig.4a and fig.4b.

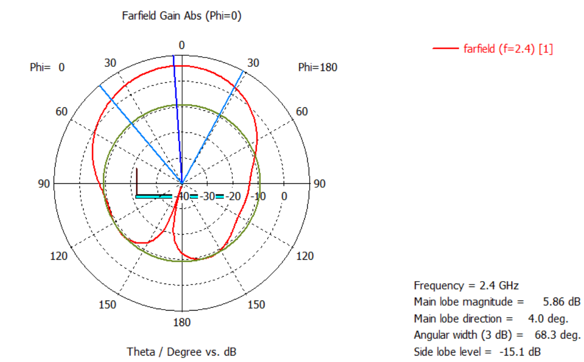

Fig.4.a Radiation pattern of Antenna without body phantom

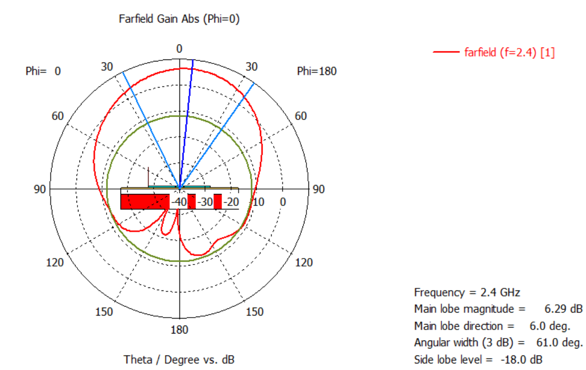

Fig.4.b Radiation pattern with body phantom

Discussion: From fig 4a and 4b it is observed that the gain of antenna with body phantom is 6.29 dB and without phantom it is 5.86 dB. Antenna with phantom gave high gain due to high conductivity of body. A ground plane along with body directs the power in desired direction and increase the gain of antenna.

SAR (Specific Absorption Rate): The absorbed power in body is measured in term of specific absorption rate (SAR). As per US standard 1.6 W/Kg for 1 gm of tissue is limited. For 10 gm of tissue 2W/kg is specified by the International Commission of Non Ionization Radiation Protection (ICNIRP). The back lobe radiations are due to lossy conductor and skin of human body. SAR simulated for flat phantom is given in fig. 5a (1 g tissue) and 5b (10 g tissue).

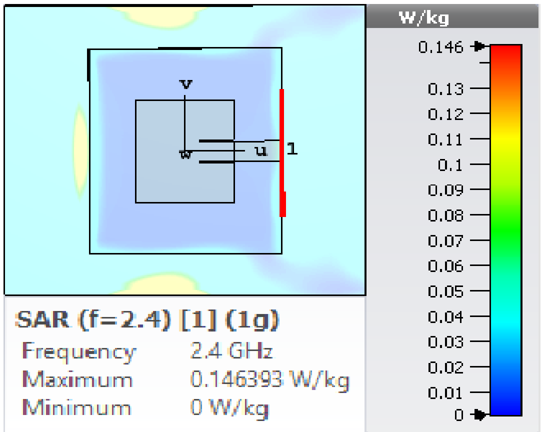

Fig.5a. SAR for 1 g tissue

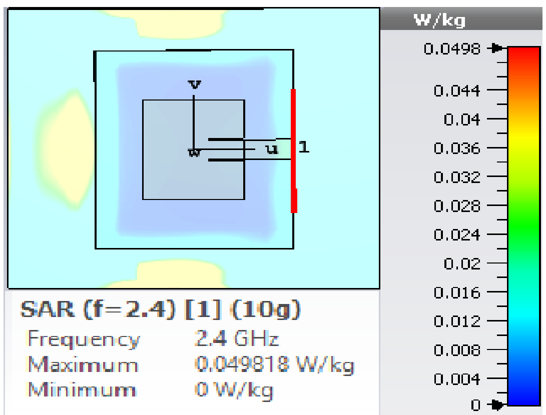

Fig.5b. SAR for 10 g tissue

Discussion: From fig 5a and 5b it is clear that SAR value is in safe range as per international standards. For 1 g tissue, SAR of proposed antenna is 0.146 W/kg which is much less than 1.6W/kg required for US standard. For 10 g of tissue observed value of SAR is 0.05W/kg which also in the safe range of radiation as per International Commission of Non Ionization Radiation Protection (ICNIRP) Europe.

Bending Antenna: For a body wearable antenna it is not possible to provide the flat surface for all applications.

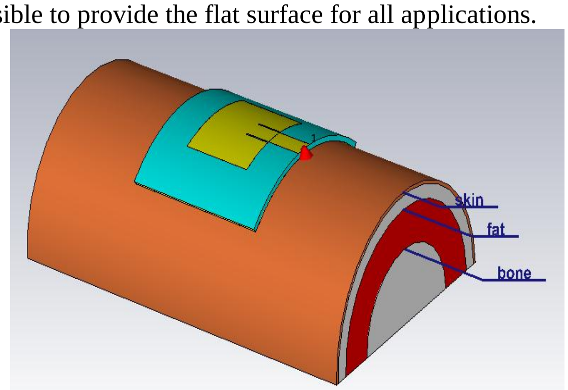

Fig.6 Bent antenna on phantom

So the antenna should efficiently work in bending condition also without affecting the performance parameters. An antenna on bending phantom is shown in fig. 6.

Return loss: Return loss of antenna under bending condition is shown in fig 7. Return loss of antenna is reduced for the bending condition but bandwidth is increased. Despite low return loss, this antenna is useful for wearable application because of high bandwidth within -10 dB of return loss.

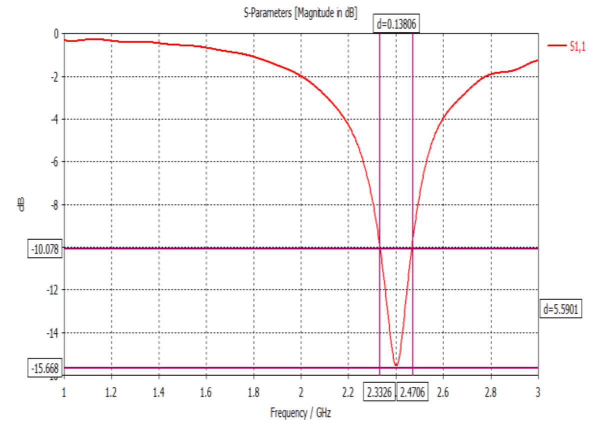

Fig.7. Return loss of bent antenna with phantom

From fig.7 bandwidth of 138 MHz is observed, which is more than ISM band (85 MHz) bandwidth.

Radiation pattern: Radiation pattern of antenna in bending case is shown in fig.8. When antenna is bent on the body phantom, more area of antenna come in contact with the body and more back radiated power is absorbed by body. If more power is absorbed by body very less power is directed in the desired direction and gain of antenna is decreased. So gain of 5.23 db is achieved in bending case as compared to flat body phantom which is 6.29 dB.

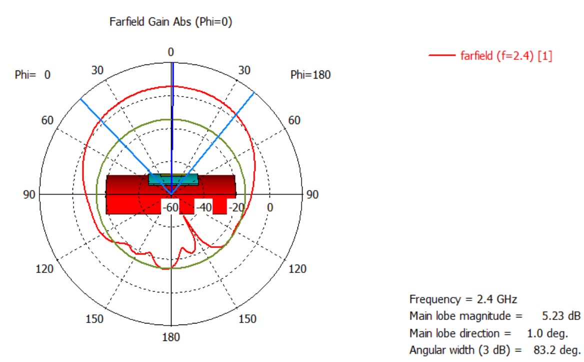

Fig.8 Gain of Antenna with body phantom

SAR (specific absorption rate): When antenna is tested for bending antenna on body phantom, SAR value is increased. From fig 9.(a,b) the SAR value for 1 g tissue is 2.5 W/kg and 0.596 W/kg for 10 g tissue. 1 g tissue is more immune to SAR as compared to 10 g tissue of body. So this antenna is suitable for 10 g of tissue in bending condition, and for 1 gm of tissue, SAR value have to be reduced. In literature various techniques have been proposed to reduce SAR value.

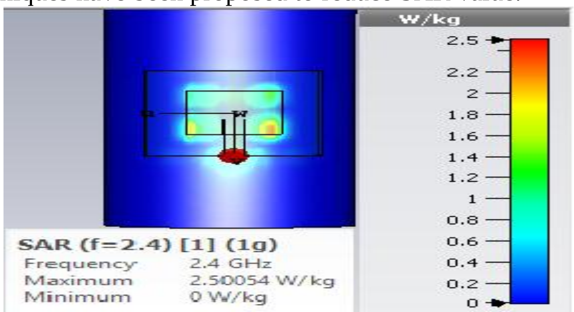

Fig. 9a SAR for 1g tissue

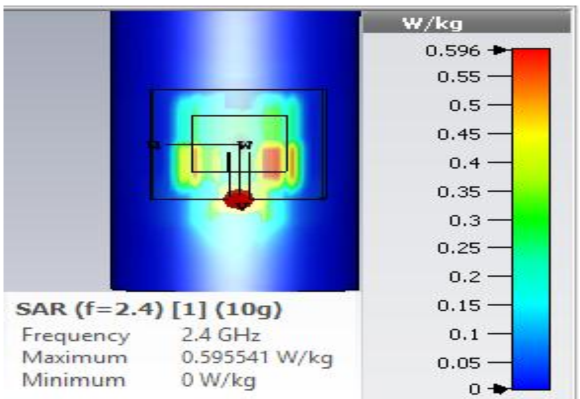

Fig.9b. SAR for 10g tissue

SAR value for 1 g of tissue is shown in Fig.9a and SAR value for 10 g of tissue is shown in fig. 9b.

Antenna with EBG: High impedance surface or electromagnetic band gap (EBG) is used to decrease the back radiation and SAR of antenna. It is having a property to provide high impedance in a designed frequency band [18]. For design of this material an array of 5x5 cells is used. The length, width and gap between cells are calculated using the Sievenpiper's surface equation [19]. The antenna with EBG is shown in fig.10

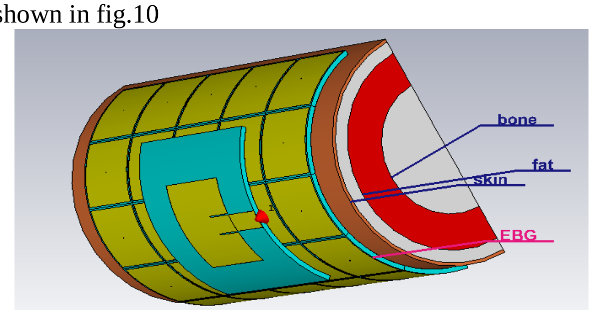

Fig. 10 Bent antenna on EBG surface with phantom

The antenna using EBG material shown in fig 10 is simulated using 0.5 W power and SAR observed for 1 g and 10 g of tissue is shown in fig 11a and fig. 11 b. Using the EBG material along with conductive ground plane maximum radiation is directed away from the body and back radiations are reduced. After using EBG the value of SAR for 1 g tissue is 0.0471 W/kg and for 10 g tissue is 0.0225 W/kg. Now the designed antenna is suitable for body wearable application.

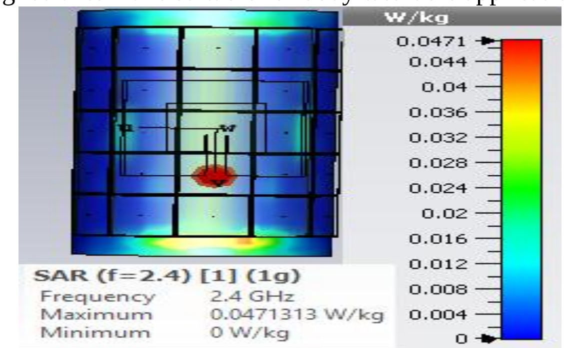

Fig.11. a) SAR on bending phantom with EBG 1g

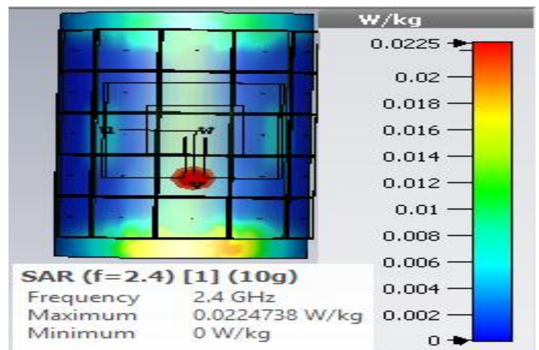

Fig.11 b) SAR of bending phantom with EBG 10g

IV. CONCLUSION

In this paper a body wearable antenna operating at 2.4 GHz is presented. The designed antenna is simulated on a body phantom and without body phantom model, and results are found satisfactory even for bending condition of antenna also. Important parameters like, return loss, bandwidth, gain and SAR of antenna are observed and analyzed. SAR in case of bending antenna for 1 g of tissue is 2.5 W/kg which is more than 1.6 W/kg as per US standard. Then EBG structure is employed along with conductive ground plane to reduce back radiation and SAR of antenna. After using EBG, SAR value observed for antenna is 0.047 W/Kg for 1 g tissue and 0.0225 for 10 g of tissue which are much less than the required standard and safe values. So antenna is suitable for wearable and wireless communication systems.

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Authors Profile

Mr Jaget Singh is working as an assistant professor in Department of Electronics and Communication Engineering of University Institute of Engineering and Technology, Panjab University Chandigarh, since last 13 years. His research area is electromagnetic field theory, microwave engineering and antennas.

Prof. B.S. Sohi is currently holding the position of pro-vice chancellor in Chandigarh University. He has done incredible contribution to the field of research and served as the Director of the UIET, Panjab University Chandigarh. His research interests are electromagnetics, image processing, wireless communication and basic electronics.

