International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-1, November 2019

Dual Band Wearable Antenna for IOT Applications

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Abstract: ***A dual band wearable antenna operating on 2.6 GHz (2570-2620 MHz FDD/TDD) and 5.2 GHz (802.11a) bands for Body Area Network (BAN) application is presented. The stack substrates of Felt and ethylene-vinyl acetate (EVA) foam are used to make the structure flexible. Maximum gain of 2.75 and front to back ratio of 8.35 is achieved on industrial scientific and medical (ISM) band. Additional bandwidth enhancement has been achieved by creating slots on partial ground plane. The calculated specific absorption rate (SAR) value is 1.33 W/kg for 1 g of body tissue. Simulated and measured results are presented for the proposed structure.***

Keywords: ***BAN, EVA, Gain, ISM, Multiband, SAR, Wearable***

I. INTRODUCTION

Wireless body centric communication provides various applications in the areas such as patient's health monitoring, defense security and public entertainment. The antennas integrated with wearing cloths and being in close proximity to the body are more suitable for personal wireless devices required for maintaining quality of service regardless of body movements. Because of the available large space on body, the wearable electronic devices do not have any limitation of size and shape [1,2]. In comparison to traditional antennas, body-worn antennas are to be flexible and better suited for integration with wireless communication devices. These applications motivate the design of antennas using materials with flexibility [3]. In the past, various textiles materials have been used to design various wearable devices [4-6]. Small printed antennas are widely reported in literature during last decade as referred in [7-9]. Small size printed antennas have low efficiency. Various configurations have been studied over the past years. The structures designed with Meta-material and fractal techniques help in reducing the size of microstrip antennas that show better efficiency [10]. A coplanar waveguide fed ring strip with stubs are proposed for UWB operation [11]. Biomedical implantable antenna for stimulation and neural signal recording devices is presented in [12] for providing power supply by inductive coupling. A printed circuit board based metal frame antenna [13] is proposed for health monitoring with wrist band wearable devices. An implantable loop antenna with circular polarization is proposed for ISM band operation in [14]. Implantable on chip antenna using CMOS technology is proposed in [15]. Biomedical printed MIMO antenna is designed for telemetry applications in [16].

Revised Manuscript Received on November 30, 2019.
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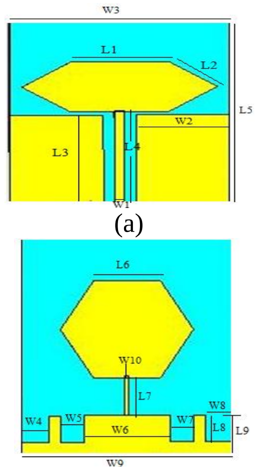
In this work we have proposed a dual band wearable antenna with flexible substrate for the application of short range wireless communication in body area networks.

II. ANTENNA DESIGN

The simulated structure is displayed in fig.1. The ground plane of antenna is made up of copper tape of thickness 0.05 mm. The partial ground plane of rectangular shape (W9 x L9= 44x12 mm²) with symmetrical slots at left and right sides of ground plane is realized at one end of substrate. The two slots (W4 x L8= 7 mm x 8 mm) and (W5 x L8= 6 mm x 8 mm) are at left side and similar slots are at right side of the partial ground plane. A hexagonal shape parasitic element is connected with very thin strip (W10 x L7=01 x 12 mm) to rectangular ground plane. Each side (L6) of the hexagonal is of 15 mm. First substrate of felt material with relative permittivity (ε_r) of 1.38, loss tangent (δ) of 0.044, W3=54 mm, L5=66 mm and thickness of 01 mm is placed above partial ground plane. Second substrate of EVA foam with relative permittivity (ε_r) of 1.20, loss tangent (δ) of 0.02, W3=54 mm, L5=66 mm and height of 1.65 mm is stacked on first substrate with acrylic glue. The coplanar ground planes, feed and radiating patch consist of copper tape placed on second substrate. The size of each coplanar ground (W2 x L3) is 23 x 33.5 mm². The radiating patch is elliptical in shape with six segments. The lengths of major axis and minor axis of patch are 48 mm and 20 mm respectively. The lengths of sides are L1=24 mm and L2=14.14 mm. The length of microstrip feed (L4) is 35 mm and width (W1) is 2.5 mm. The gap between feed and coplanar ground is of 2.75 mm. The gap between coplanar ground and patch is of 1.5 mm. The partial ground plane and coplanar ground planes are connected with two shorting strips on either sides of feed to keep them on same potential. The different dimensions of antenna are shown in fig.1and table-I.



(a)

(b)

Fig.1 Structure of Antenna: (a) Top view (b) Bottom View

Table-I: Different Parameters of Structure

Structure	Dimensions (mm)
Substrate	Length (L5)=66
	Width (W3)=54
Patch	Side (L1)=24
	Side (L2)=14.14
Coplanar Grounds	Length (L3)=33.5
	Width (W2)=23
Feed	Width(W1)=2.5
	Length(L4)=35
Parasitic Hexagonal Monopole	Each side(L6)=15
Thin connecting line to parasitic element	Width (W10)=01
	Length (L7)=12
Partial ground	Length (L9)=12
	Width (W9)=54
Left/Right side slots in partial ground plane	Width (W4)=07
	Length(L8)=08
	Width (W5)=06
	Width (W7)=06
	Width (W8)=07
	Width (W6)=20

III. DESIGN ANALYSIS

The proposed antenna has been designed and simulated with CST software. The felt substrate (Ɛr=1.38) with thickness of 1 mm is at bottom side of structure and EVA foam substrate (Ɛr=1.2) with a thickness of 1.65 mm is placed on top of first substrate layer. The use of two stacked layers of substrates where top layer is with low relative permittivity and bottom layer is with slightly higher relative permittivity, is to achieve enhanced bandwidth. The width and length of micro-strip feed provide impedance matching. The parasitic hexagonal monopole below the coplanar ground also helps in increasing the bandwidth at operating bands.

IV.RESULTS AND DISCUSSION

The return loss graph in fig.2 shows that S11 is -13 dB on 2.6 GHz and -11 dB on 5.2 GHz. The bandwidth of first resonance on 2.6 GHz is 160 MHz and 75 MHz on 5.2 GHz. The radiation patterns on 2.6 and 5.2 GHz are shown in fig.3. The 3 dB beam widths of major lobes on 2.6 GHz and on 5.2 GHz are 163 degree and 49 degree respectively. The 3-D radiation pattern with structure transparent is shown in fig.4. The top and bottom view of hardware design of antenna is presented in fig.5. The comparison of simulated and measured return loss is shown in fig.6. The measurement of S11 was done with the help of VNA of Rohde & Schwarz.

A cubic human body equivalent model has been designed for finding SAR value due to radiation of antenna when placed on body. The size of cubic model is 100 x 96 x 70 mm^3 with 60 mm thickness of muscle, 7 mm thickness of fat and 3 mm thickness of skin. The simulation for SAR was done with different gaps between body model and antenna to find an optimum gap where SAR value is within the limit described by IEEE/FCC. In this design, the SAR value of 1.33 W/Kg for 1g of body tissue was observed when antenna was placed at a distance of 11 mm from the body model. The body model and simulated SAR is shown in fig.7.

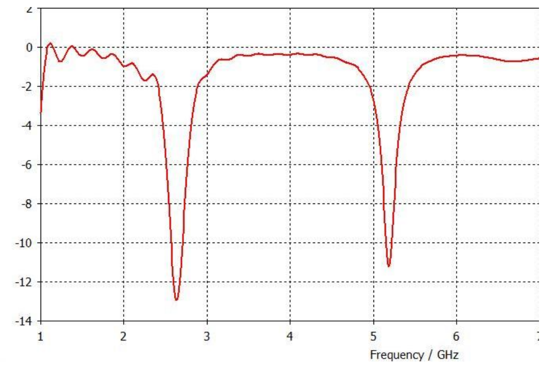
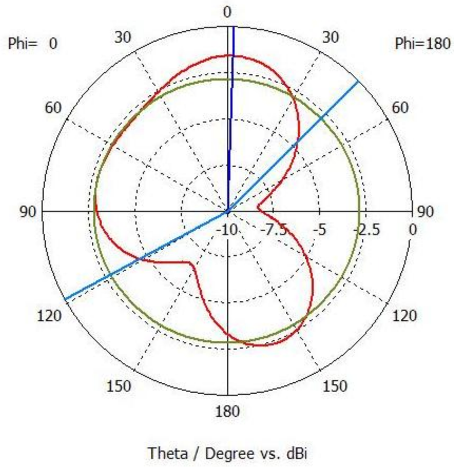
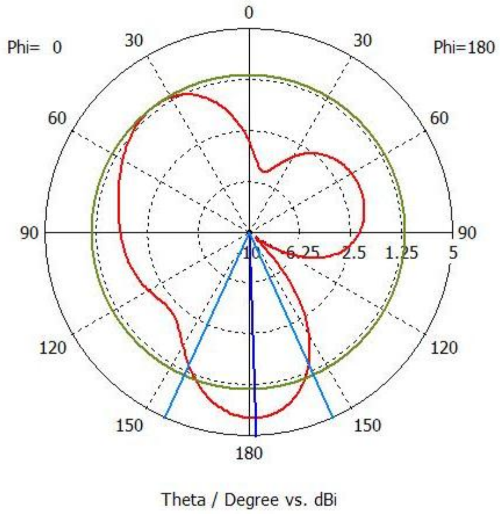


Fig. 2 Return loss Vs Frequency graph



(a)



(b)

Fig. 3 Radiation Patterns: (a) on 2.63 GHz (b) on 5.2 GHz

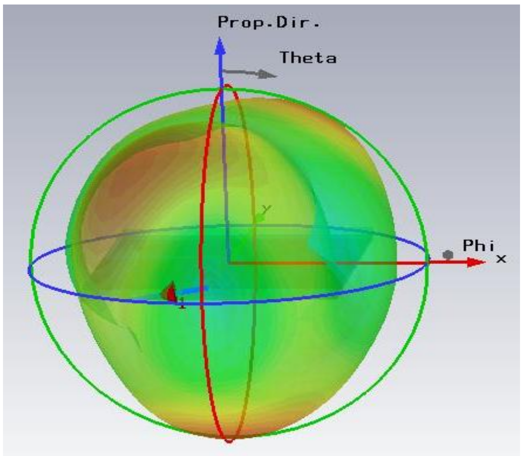
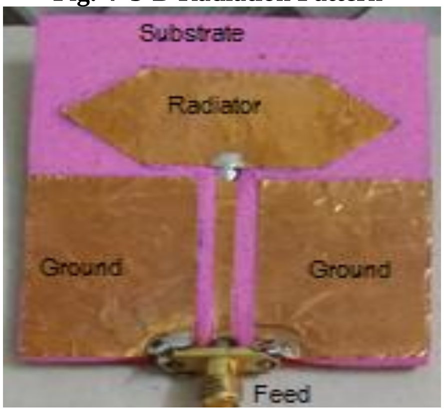
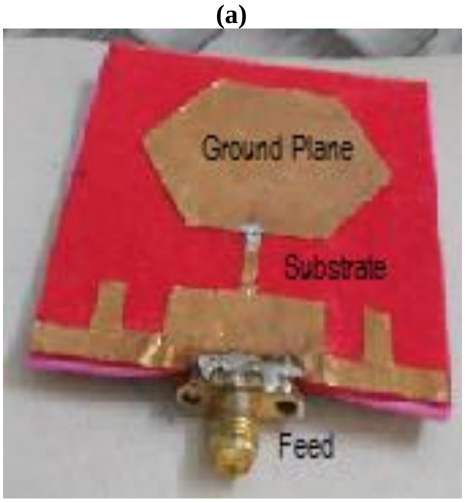


Fig. 4 3-D Radiation Pattern



(a)



(b)

Fig. 5 Fabricated Antenna: (a) Top View (b) Bottom View

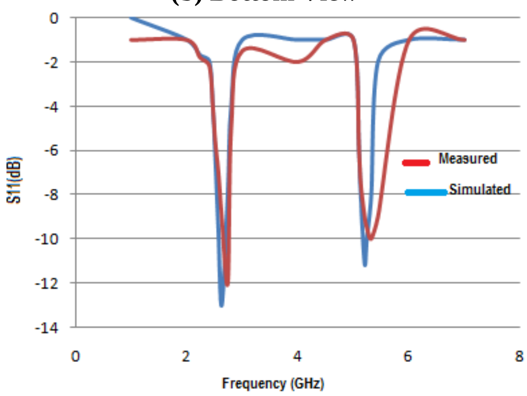
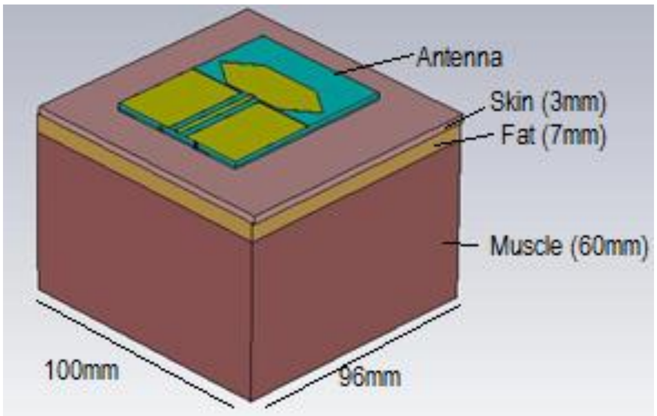
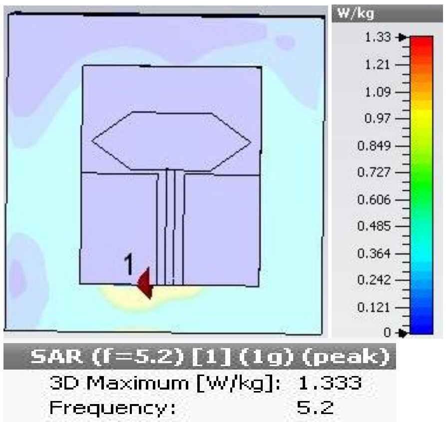


Fig. 6 Comparison of Simulated and Measured Return loss



(a)



(b)

Fig. 7 SAR Measurement: (a) Cubic human body model (b) Simulated SAR

V. CONCLUSION

A low profile, simple design and low cost antenna has been proposed in this work. The measured results of S11 are in good agreement with simulated results. The antenna has demonstrated sufficient impedance bandwidth, radiation characteristics and gains for short range body area wireless operations. The stack layers of felt and ethylene-vinyl acetate (EVA) make the structure flexible, waterproof and mechanically robust. The properties of substrate materials, good bandwidth and low value of SAR make it suitable for body area networks.

ACKNOWLEDGMENT

The authors gratefully acknowledge the department of electronics and communication Engineering, RTU Kota and Rohde & Schwarz laboratory New Delhi for providing assistance to complete this work.

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