Performance Analysis of Wearable UWB Logo Antenna for Healthcare Monitoring

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ABSTRACT
In this paper, a logo textile based antenna has been designed and its performance has also be analyzed under close vicinity of the human body. The proposed antenna is designed as "UMD" logo and can be used for health monitoring purpose. The substrate of this antenna is purely jeans material which is widely available. The permittivity of the substrate is 1.7 with overall dimension of the antenna 60mmX75mmX2.6mm. The proposed antenna is assessed and optimized in the operational range from 1.2985 GHz to 21.326 GHz. Since the antenna is designed with flexible material, the antenna has also been tested under different bending conditions to ensure a stable characteristic. Specific Absorption Rate (SAR) on human body has also been measured at a distance of 20mm.

Categories and Subject Descriptors
C.2.1 [**Sensor Networks**]

General Terms
Performance, Design, Verification.

Keywords
Super Wide Band, UWB, Logo Antenna, Textile, SAR, medical monitoring.

1. INTRODUCTION

The popularity of UWB (Ultra-wideband) antennas has significantly increased recently, due to the advantages of UWB communication links such as low susceptibility to multipath fading, secure communications, and potentially high data rates over short ranges. Common UWB applications include medical imaging, sports monitoring, ambient intelligence or military communication [1]. Textile materials are one of the most widely used and easily available, to design wearable antennas for in- and on-Body communications [1-2]. In addition, logo antenna is another fast growing innovative area in the application oriented fields [2-3]. Wearable logo antennas is becoming one of the most fascinating and cutting edge research areas. There has been some research related to logo antenna. For example, in [4], two patch antenna were analyzed and in [5] a logo antenna were designed on FR4 substrate. In this paper we have designed a logo textile antenna with three letters encircled by radiating patch. These three letters are the abbreviation of "UMD".

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Enhancement in communication and electronic technology has enabled the development of compact and intelligent antenna devices which can be positioned on the human body or implanted inside it [6-8]. Hence, all these broad applications of monitoring with data transmission functions can be achieved by using wearable logo antenna that do not force the wearer to abandon the comfort zone with such compact and durable materials. Moreover, the logo antenna is almost non-noticeable. Medical monitoring using such antennas is found to be necessary in order to transfer and transmit data for inpatients in hospital environment, in home for homebound patients or even outpatients. The usability of the textile logo antenna for on body communications has been emerging and can be applied for real time physiological measurements systems, pulse rate monitoring in sports, and navigation support in the car and so on. They can also be used to keep continuous record of wearer's health by monitoring their vital signs. Multiple sensor devices mounted on a human body for On-body communication, has gained much attention since the IEEE802.15.6 study group announced the standard for WBAN, and the channel and link performances have since been studied by many researchers.

The effect of the body on a UWB antenna can be generally characterized by the impedance matching, the specific absorption rate (SAR), the radiation pattern, the reduction of the efficiency and the gain of the overall antenna near proximity of the human body. Choosing textile material as a substrate has some advantages. For example, low profile and high efficiency are the main criteria for textile antennas. Moreover, it's easily available, reusable, washable and most important it does not hamper the natural activity of the wearer. The dielectric constant for textile material is very low which increase the bandwidth and performance of the overall antenna [9]. However, when textile materials are used, the factors such as wetness, humidity, crumpling and bending effects must be considered. Compared to other UWB textile antennas [10], this proposed design of UWB antenna is more robust, smaller in size and consume less power. In addition, this textile UWB antenna has to work properly in the close proximity of human body with the fact that the SAR has to be 1.6W/kg for 1g and 2W/kg for 10g. Because UWB antenna has property of Omni-directionality and effects of human body over high electromagnetic wave has been discussed later in this paper. For designing a textile based communication system, we considered several aspects like absorption of water of the textile material as water has high dielectric constant. This logo antenna wearable antenna has been bended in different angels in which the overall performance of the system is analyzed.

The designed logo antenna is printed on 60x75mm2 substrate material with a relative permittivity of 1.7 and thickness of 1.6mm and woven copper thread is used as the conductive part of the antenna patch. The proposed logo antenna successfully operates throughout the operational range of our interest; finally, our simulations results show good performance of the antenna for SWB application.

2. ANTENNA DESIGN AND IMPLEMENTATION

2.1 Antenna Design:

The presented antenna has three letters and it is encircled by a radiating patch. To design the radiating patch, we used the following equation to calculate the radius.

$$a = \frac{87.94}{fr * \sqrt{(\varepsilon r)}} \qquad (1)$$

Where a is the radius, f_r is the resonance frequency and ε_r is the relative permittivity of the conducting material. The size of the ground plane has great effects on the impedance matching of the antenna. Hence, the width of the ground cannot be adjusted randomly. As we cannot use any other strips or slots except the original logo, these three letters have to be adjusted symmetrically with the 50ohm feed line to get the maximum power on load. From the ground plane, 4mmx4mm of a rectangular notch was implanted to improve the impedance matching of the system. Selected textile material has high tensile strength, durability and good electric property. The substrate selected for the designed UWB logo type textile antenna is jeans material.

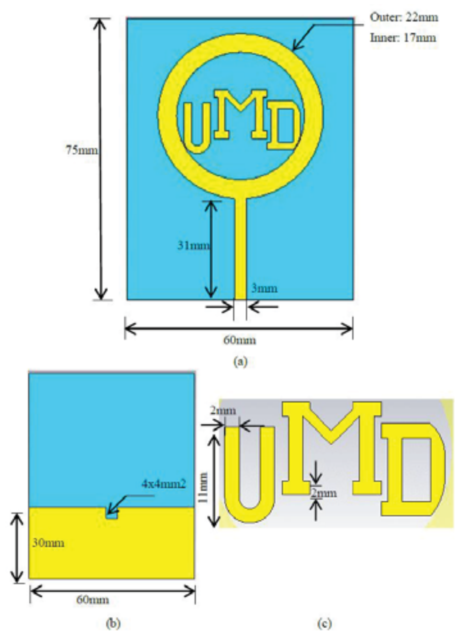

Figure 1: Geometry of the overall antenna (a) Front view (b) Back view (c) Three Letters of the logo

2.2 Fabrication Process:

The proposed antenna has been designed by combining three letters of "UMD". By controlling the shape of the radiating patch and these three letters the input impedance of the antenna could be matched. The "U", "M" and "D" was aligned horizontally to get the impedance matched with the feed line.

In Figure 1. The designed UWB logo antenna has been demonstrated with its entire dimension. Figure 1(a) and (b) are the front and back side of the proposed antenna respectively. Figure 1(c) shows the dimension for the three letters. The presented logo antenna design was simulated. The logo antenna was designed on a jeans textile which is 100% cotton material with relative permittivity 1.7, thickness 1 mm. The conductive plane and partial ground plane are made of copper tape with the thickness of 0.03mm. However, the substrate dimension is 40x60 mm^2 and the partial ground dimension is 40x30 mm^2. In addition, the partial ground has a square notch and the dimension of the slot is 4x4 mm^2. So, it can be inferred that the total dimension of the antenna is reasonably small, light in weight and very low profile compared to other proposed textile antenna. Hence, it enables this antenna to be fully integrated into the textile materials. The designed antenna operates almost from the frequency of 1.2985 GHz to 21.326 GHz. The patch of the antenna is fed by a 50 ohm microstrip feed line with a width of 3mm.

Table 1: Simulation Parameters

Parameters	**Size (mm)**
Circular Disc (Outer Radius)	22
Circular Disc (Thickness)	0.5
Circular Disc (Inner Radius)	17
Substrate	Width = 60, Length = 75
Substrate (Thickness)	1.6
Partial Ground	Width = 30, Length = 60
Partial Ground (Thickness)	0.5

3. EFFECTS ON HUMAN BODY WITH AND WITHOUT BENT CONDITION

3.1 Human Model:

To simulate the effects on human body due to the logo antenna, we have taken a portion of a muscle from voxel model. This muscle is a combination of skin, bones, flesh and blood with effective & relative permittivity and permeability [11]. The Specific Absorption Rate (SAR) for harmonically varying EM fields is defined as-

$$SAR = \frac{\sigma|E^2|}{\rho} \qquad (2)$$

Here σ and ρ are the conductivity and mass density of human tissue respectively and E is the peak value for electric field component. The logo antenna is kept at distance of 20mm from the human muscle. Then it has been observed the effects of logo antenna on human body.

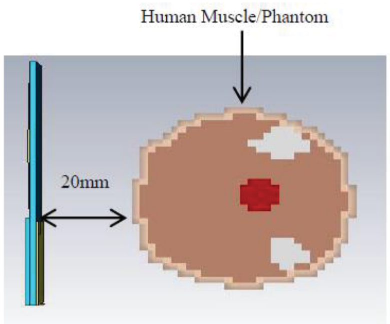

Figure 2: The phantom at distance of 20mm.

3.2 Bending Experiment:

The performance of the logo textile antenna in terms of radiation pattern and S-parameters the antenna has been experimented under different bending angles. The equation to calculate the radius of the cylinder is given below-

$$S = r\theta \qquad (3)$$

Where,

S = Length of the Arc

r = Radius of Circular Patch

θ = Measure of the central angle in radius

The presented antenna was simulated in four different angles and the performance was compared with near proximity of the human body. The antenna has been bended in 20, 40, 60 and 80 degree respectively and the width of the antenna patch as the arc length has been used. From the above formula we have calculated the value of the radius of the cylinder for our intended angle. Now, if we place the antenna new phantom high value of permittivity and the conductivity of human tissue may influence the radiation pattern and propagation loss. Hence, the antenna has to be placed where the return loss and performance degradation are optimum.

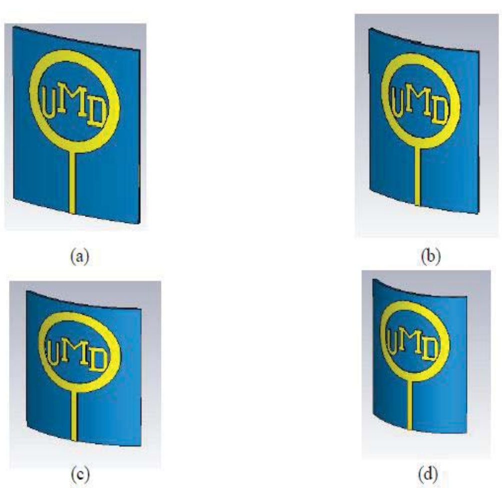

Figure 3: Logo antenna with different bending angle: (a) 20 Degree (b) 40 Degree (c) 60 Degree (d) 80 Degree

4. RESULTS AND DISCUSSION

4.1 S-Parameter Analysis:

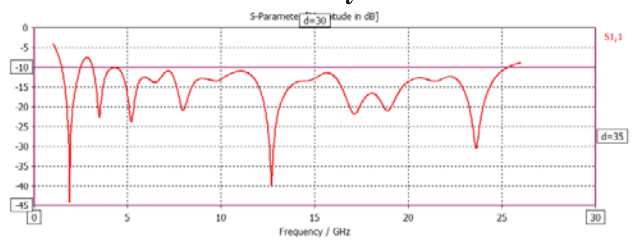

Figure 4: S-parameter for SWB logo antenna

The s-parameter plot of the SWB textile antenna is shown in Figure 2 shows that this occupies a bandwidth of almost 24 GHz starting from almost 1.5 GHz to 25.4 GHz with 3 significant resonances. The first resonance occurs at 1.8GHz with a reflection coefficient of -20.39 dB and the second occurs at 3.722 GHz with the return loss of -44.178dB. Though from 2.66 GHz to 3.12 GHz the frequency is above -10dB but this is still able to cover our desired range of frequencies. These results further indicated that the measured value of the relative permittivity was valid to provide design information.

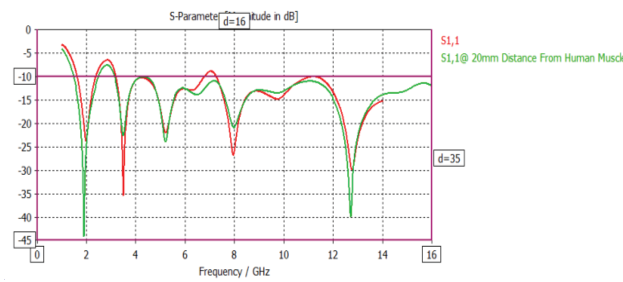

Figure 5: Comparison of S-parameter with close to phantom

Figure 5 represents the comparison of the return loss when the antenna was placed in 20mm distance from the human body. It can be noticed that the performance of the overall antenna has not been degraded significantly. The human tissue supposed to affect the performance due to high permittivity and conductivity we have used placed the antenna on another jeans material covering the human muscle.

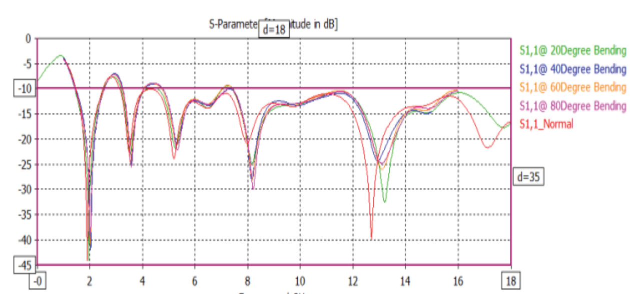

Figure 6: Comparison of S-parameter under different bending angles

Figure 6 above shows the return losses at different bending angles. The performance of the antenna is increasing as the bending angles are increasing; the last resonance frequency at 12.812GHz has return loss -40db.

4.2 Analysis of Radiation Pattern for Different Frequencies:

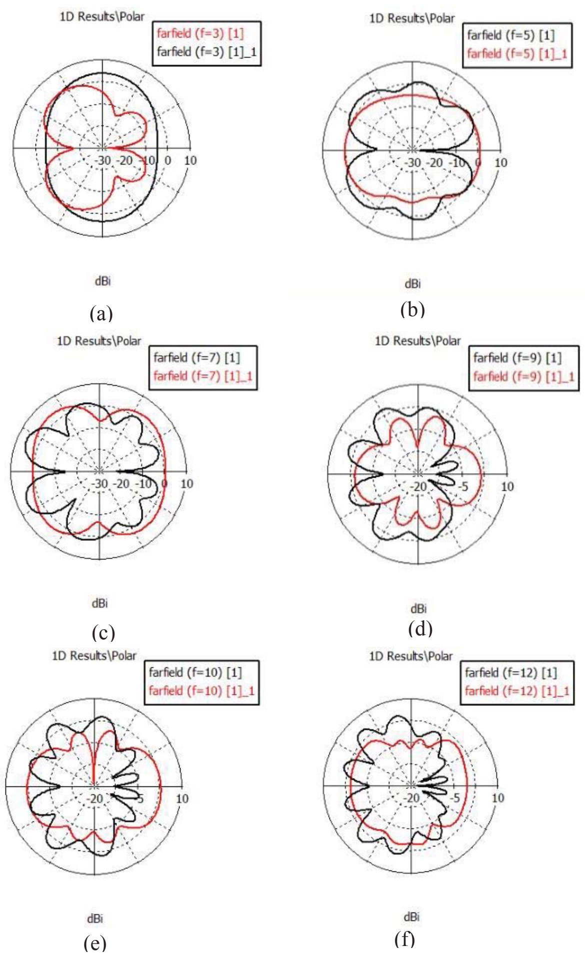

Figure 7: Azimuth and elevation [1] radiation pattern for different frequencies: (a) 3GHz (b) 5GHz (c) 7GHz (d) 9GHz (e) 10GHz (f) 12GHz

Radiation pattern measurement is also completed for the presented antenna. Figure 7 displays the azimuth and elevation radiation for 3, 5, 7, 9, 10 and 12 GHz respectively. The azimuth radiation was measured when the value foe theta is set to 90 degree for all values of pi and for elevation pattern Pi was set to 0 for all values of theta. It can be observed that at the lower frequency of 3 GHz, the radiation pattern in the H-plane is omni-directional with low cross polarization values. Also as the frequency is increasing, the lobe of the radiation pattern is getting more directional. In addition, with increased frequency the radiation pattern gets more distorted, which can be the explained with the help of current distribution of the antenna system.

4.3 Experiment of SAR at 2GHz:

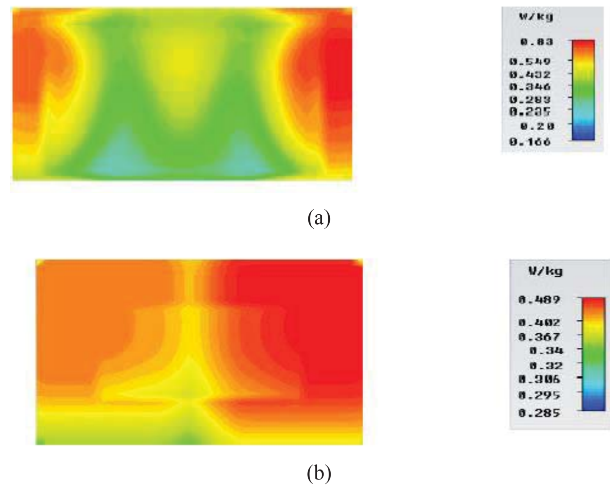

Figure 8. SAR analysis at 2GHz: (a). 1g (b). 10g

In Figure 8, SAR values for 1g and 10 at 2GHz has been shown. The FCC (Federal Communications Commission) of the United States requires less than 1.6 watts per kilogram (W/Kg) over a volume of 1 gram of tissue, and European Union, following IEC (International Electro technical Commission) standards, requires less than 2 watts per kilogram (W/Kg) over a volume of 10 grams of tissue. The peak SAR values of the proposed antenna are 0.83 W/Kg (1g tissue) and 0.489 W/Kg (10g tissue). Therefore, the SAR value of 10g and 1g tissue is below the level of the international standard (IEC) and international standard (FCC).

5. CONCLUSION

In the paper, the S-parameter of has been compared with different bending angles and it can be inferred that with increasing angle it gives more improvement on the impedance matching as the number of resonance frequency has been increased. However, with the increasing frequency there has been a significant distortion in radiation pattern due to human tissue absorption. The overall efficiency of the logo antenna varies from 76% to 85% depending on the frequency. We conclude that bending of the antenna does not affect significantly, rather it improves impedance matching. More research works can be done with crumpling and twisting effects of textile antenna. Surprisingly, at 2GHz we got low SAR which could guide the design for wireless sensors for human health. In future, a ferrite sheet can be used to make the distance between antenna and phantom lower with even lower SAR.

6. ACKNOWLEDGEMENT

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