DESIGN AND ANALYSIS OF WEARABLE ANTENNA FOR WIRELESS BODY AREA NETWORK

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Abstract: The fast development of wearable low-power devices has increased the requirement of solutions for WBAN implementation. In addition to the need, to reduce the device’s dimensions and improve power consumption, it is also important to work on developing flexible antenna’s that may be integrated into a wide variety of applications. This paper is a study of wearable antenna design for wireless body area network applications. A literature review of existing wearable antennas is studied. A wearable antenna is designed with size optimization. The antenna is designed using ANSYS High Frequency Structural Simulator (HFSS) software. The designed antenna works at operating frequency of 2.45 GHz. A rectangular patch made up of copper is used as radiating patch and the ground is also made with copper. The substrate material used is bed sheet cotton with a relative permittivity of 3.27 and the loss tangent is 0.00786. The size of the antenna is 40mm*34mm*1.26mm. The properties such as gain directivity and VSWR are studied for the designed antenna. The properties are studied using the ANSYS HFSS software.

Keywords: - Flexible, Garment, Radiation Pattern, Textile, Wearable, WBAN

1. INTRODUCTION

Portable electronic devices have become a major part of everyday human life. Mobile phones which we carry throughout the day not only allow us to just make telephone calls but also provide internet access, multimedia, personal digital assistant and GPS functionality. This form of continuous connection allows a forward step in the computer paradigm [1]. In the upcoming generations human beings are likely to carry a range of devices and
sensors, including medical sensors which constantly communicate with each other and the outside world and these are very easy to carry. It is of major importance to provide this functionality as the technologies are upgrading every day[3,4]. A key technology to achieve this goal is wearable electronics and antennas. Microstrip patch is a well suited for any wearable application, as it can be made conformal for integration into clothing [2–10]. A wearable antenna is mainly used for biomedical application. Body centric communication systems like paramedics, fire fighters, and military applications are utilized by different specialized occupation segments [11, 12].

The wearable antennas can be applied to all types of aged people and also for athletes for the purpose of monitoring. Wearable antennas should contain the following properties they should be light in weight, very low cost, almost maintenance-free and with no installation [11]. They should be comfortable and conformal to the body shape, but they should be highly reliable and efficient. There are many problems with the applications of Wearable antenna. The major problems are they should be integrated onto a garment and increase the comfort of wearable, the antenna should be of minimum size. Furthermore, it is difficult to keep the antenna flat and operating when the people move, so the antenna under different bending and crumpling conditions has been studied in [6]. Finally, the influence of human body to the antenna should be taken into account as well. Now in this paper we will study about the design of a wearable antenna by optimizing its size. And we will study the analysis of the antenna with different parameters. In this we also study about the interaction between a wearable antenna and human body and the analysis.

2. LITERATURE SURVEY:

A planar inverted-F antenna is designed to operate on WBAN it is preferred because of its low profile and Omnidirectional properties. The patch and the ground layer perform a more important task of isolating and decoupling the wearable antenna from the human body. The patch size of the antenna is increased to reduce the return loss and to improve efficiency even the SAR value is reduced when the patch size increases. Polydimethylsiloxane (PDMS) as the substrate. The design is done using CADFEKO 5.5 and the results are also verified with the same software [4]. A compact planar dipole antenna is built by using fully flexible materials such as nitrile butadiene rubber polymer composition is used as substrate. The patch is made up of copper. The performance of the antenna is analyzed by using three layer human tissue. Design and analysis of the antenna are carried using the full wave electromagnetic simulation software XFDTD which is based on the finite-difference time-domain method a non-uniform mesh technique is used for calculating the SAR [15]. UWB wearable textile antenna for body area networks with Hexagonal patch with a partial ground plane is proposed [20,21]. The ultra-wide bandwidth proposed can be obtained by reducing its size, and by introducing a square notch in the ground and a novel slot in the patch. Dacron fabric with a relative permittivity of 3 is used as a substrate. Commercial electromagnetic simulation package CST Microwave Studio is used for the design and simulation of the antenna [3,7].

3. INTERACTION BETWEEN WEARABLE ANTENNA AND HUMAN BODY

Wearable antennas are very close with the human body. The close proximity of human body with an antenna with a high dielectric constant and loss are known to have some detrimental effect on input impedance and efficiency of the antenna. The body affects some of the major properties of the antenna like the mismatch which is caused by characteristic impedance of transmission lines, electrical length changes, and continuously increasing losses, thus damaging its original operation. The interaction between the body and wearable antenna can be studied under two categories:

3.1 Effects of Antenna on Human Body

The non-ionizing radiations like the sound waves, visible light and microwave may not have enough energy to ionize atoms or molecules but this energy is enough to move atoms or even to make them vibrate. Therefore, the
non-ionizing radiation can move human cells and also increase the cell temperature. This rise in temperature affects the human tissues, the most common of this type is dielectric heating. This occurs when a dielectric material is heated by rotations of polar molecules induced by the electromagnetic field. Specific Absorption Rate (SAR) is the parameter that is used to measure the rate at which energy is absorbed by human tissues. It can also be defined as the rate at which RF electromagnetic energy is imparted to unit mass of biological body. SAR is usually measured average either over the whole body, or over a small patch sample volume typically 1 g or 10 g of tissue [14, 15]. The value thus obtained is the maximum level measured in the body part studied over the stated volume or mass. The formula used to calculate SAR is given as: \( \text{SAR} = \frac{\sigma E}{\rho} \) Where, \( \sigma \) stands for electrical conductivity, \( E \) stands for RMS electric field and \( \rho \) stands for sample density. There are certain rules and regulations to be followed in the world regarding the SAR limit of electromagnetic devices because the high SAR values may have severe consequences on the human body. The SAR limit is set to 1.6 W/kg averaged over 1 g of actual tissue by the Federal Communication Commission (FCC), while the limit is set to 2 W/kg averaged over 10 g of actual tissue by the Council of European Union [14, 15]. The limit of temperature increase in head tissues is 1 K. This increasing in the temperature in the head tissue may affect the behavior, functioning and memory of the people besides causing anatomical injuries [4,13].

3.2 Effect of Human Body on Wearable Antenna

The human body also has some effects on the antenna as it very closely located to the human body. The human body is lossy and disturbs the communication link between antenna and outside world. The human body impact on the antenna is of different types.

3.3 Human Body-Induced Gain

The human body induced gain is the ratio of gains (in dB) between body-worn antenna and that of the antenna in free space. Human body has various tissues with various dielectric properties. Also the electrical properties on different frequencies have different values, the gain of the antenna is affected [13]. So the gain of the wearable antenna differs from that of a normal antenna.

3.4 Human Body-Worn Efficiency

The human body-worn efficiency is the ratio of total radiated power when antenna is worn in the body to the total radiated power in free space isolation. The overall power loss in a human body can be represented by this [6,13].

Human Body Effect on Impedance

The input impedance of the antenna will be low when the user is too close to the antenna. Also the input impedance is dependent on the moisture conditions of the human body. And the position of the placement of the antenna [13].

4. ANALYSIS REQUIRED FOR WEARABLE ANTENNAS

Generally, the measurements required for normal antenna design are return loss, radiation pattern, gain and efficiency. However, these planar antennas always remain flat, so it is not necessary to measure its bending characteristic. But we have to measure the bending characteristics of a wearable antenna and some other factors should be taken into careful consideration to guarantee the performance of the antenna in a body-worn context. They are as follows.

4.1 SAR Modeling

As the wearable antennas are attached very close to the human body the SAR model values must be taken into serious consideration because they may affect the human body. The SAR and its effective values to be maintained are studied in the earlier sections [14, 15].

4.2 Measurement with Different Bending
As we are studying about the wearable antenna we have to study the properties of the antenna under different bending conditions. Because the human body does not remain flat always. We can study the bending affects by attaching the antenna to a cylinder like structure or other different things with different shapes. By studying all the measurements and if the appropriate end efficient only then we have to apply them to the human body otherwise we would get false values. The antenna had to be designed with a wide frequency bandwidth for effective bending effects. The complete bending effects like bending it to 90° and 180° must be studied [16].

4.3 **On Body Measurements**

Beside stand-alone antenna measurements, where the antenna was measured without presence of human body, on-body measurements have to be carried out as well, in order to ascertain the performance of the antenna at different on-body positions. Positions of wearable antennas will differ, depending on the application of the antenna. Wearable antennas might be designed to be placed on the chest, arm, back of the body and etc. In [17] researchers also went as far as including human body for the measurement. From these previous investigations, it was found out that the antenna placed on the back of the body is the most stable location that will reduce the change of body orientation compared other parts such as the arm.

4.4 **Proposed System:**

The main drawback of the existing system is they contain narrow bands and large in size. The proposed antenna overcome all these drawbacks of the existing system. The dimensions of the antenna are 40*34*1.26mm which is compact in size.
Multiple cuts are made on the rectangular patch antenna to make the antenna resonate at 2.4GHz frequency. The size is made compact to make it a wearable antenna. The antenna is designed using bed sheet cotton with a relative permittivity of 3.2 and a loss tangent of 0.0027 as the substrate. The designed antenna is of thickness 1.26mm this makes it even more comfortable for on body applications. A partial ground is used to get good directivity and wider bandwidth.

![Image](image1)

**Fig 3:** gain obtained for the antenna

**ANALYSIS:**

![Image](image2)

**Fig 4:** compared return loss and VSWR for the designed antenna

![Image](image3)

**Fig 5:** a) Radiation pattern of the antenna and b) gain measurement
Fig 7: SAR value for the antenna

Fig 8: directivity of the designed antenna

(A) From fig 3, it can be inferred that the designed antenna has very good return loss. The designed antenna acts as a multiband antenna. The antenna has a good return loss with in the frequency range of 2.1GHz to 2.7GHz and 3.6 GHz to 4.3GHz which is $<-10$dB. The designed antenna has good bandwidth. The designed antenna works in the ISM band which is best suited for wireless body area network.

(B) From fig 4, it can be inferred that the designed antenna has good VSWR which is 1.2391.

(C) From fig 5, it can be inferred that the designed antenna has good radiation pattern. The radiation pattern is good along both the axis.

(D) From fig 6, it can be inferred that the designed antenna has good gain. The gain of this antenna shows that the antenna is well suited for body area network applications. The efficiency of the antenna obtained is also high.

(E) From fig 7, it can be inferred that the designed has a good SAR value compared to the previous works. The SAR value obtained for the designed antenna is 1.25W/kg. This is below the required SAR value range which is 1.6W/kg. So the designed antenna can be well suited for body area network applications.

(F) From fig 8, it can be inferred that the designed antenna has good directivity. The designed antenna has a directivity of 3.840. The efficiency of the antenna can be calculated by using the gain and directivity of the antenna.

The efficiency of an antenna is gain divided with directivity and multiplied with hundred.

$$\text{Efficiency} = \frac{\text{Gain}}{\text{Directivity}} \times 100$$

6. APPLICATIONS ON WBAN

Wearable antennas are mainly designed for the wireless body area networks that is to for body parameters measurement. Like heartbeat and disease detections these are also mainly used by the firefighters and in military operations also. These wearable antennas can be used by the sports persons to measure their heartbeat, blood pressure fatigue measurement and other parameters. Wearable antenna has a future scope also they can be used for IOT applications by using them with the combination of sensors.
7. **CONCLUSION:**

The design of wearable antenna for wireless body area network applications is studied in this paper. The designed antenna is compact in size compared to the previously designed antennas. The designed antenna has given good result in all the properties. As the antenna size is 40*34*1.26mm this can be well suited for wearable applications. Also the designed antenna acts as a multiband antenna and it has wide range of operating frequency. This antenna provides a wider bandwidth with in the frequency range of 2.1GHz to 2.7GHz and 3.6 GHz to 4.3GHz. The antenna has an efficiency of 94%. The SAR value of the designed antenna is 1.25 which is less than the SAR limitation so this antenna will not cause radiation problem when placed on a human body. So based on all the analysis made the designed antenna can be well suited for wearable body area network applications.

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