Performance Analysis of a Low SAR Triangular Patch Textile Antenna for Health Monitoring Systems

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Abstract—In this article, a triangular patch textile antenna has been proposed for health monitoring systems. The patch is fabricated using copper tape and substrate is made up of cotton. Two slots have been introduced near feedline to get larger the bandwidth. The size of the proposed antenna is 90x80 mm². The textile antenna is powered through microstrip feedline structure. The antenna resonates at ISM band of 2.4GHz. The antenna provides a peak gain of 3.15 dBi and radiation efficiency of 81.33% over the resonating frequency. The impacts on human head and hand of electromagnetic radiation are evaluated. The electromagnetic radiation is evaluated using Specific absorption rate at different distances from human head and hand. The antenna parameters like radiation efficiency, radiation pattern, return loss and directivity have been evaluated. The antenna is designed and simulated using ANSYS High frequency structure simulator (HFSS) software and the fabricated prototype antenna is tested using network analyzer.

Keywords—Triangular patch, Textile substrate, Specific Absorption Rate..

I. INTRODUCTION

Health care is one of the basic human rights and, as such, it should be considered as a benefit for all. Normally, the elderly people are often the affected category as Hospitals are not willing to spend their budget on services for elderly people. On the other side, the increase of life expectancy, together with the undeniable right of the elder to live ageing as a positive experience, motivates the need to find technological alternatives at low cost that could make health care provision more economical [1].

In this situation, telemedicine is regarded as one of the methodologies for significantly reducing health-related social expenses, while still offering essential assistance to the elderly people and ensuring a healthy quality of life. Wireless technology is a main factor for remote health monitoring. In fact, the combination of information technology and non-invasive wearable sensors can support the aged people to get the required help, while living in their own homes, unlike admitted in costly hospitals.

The overall block diagram of a health care monitoring system is shown in Fig.1. The following are the four main modules:

(i) RF front end, which consists of a transceiver block for transmitting/receiving data to/from the data monitoring unit and an antenna.

(ii) A Microcontroller unit for processing sensor information and sending it to RF front end module.

(iii) Sensors

(iv) Power supply required for operating all the modules

Fig.1. Overall Block diagram of a Health Monitoring System

Garment-integrated wearable products play an important role in round-the-clock improvement of healthcare provisions. These wearable products not only alert and demand attention but also reduce labor and hospital resources. They also play a prominent role in preventative diseases, health disorders and heart or brain irregularities in people who are likely to be healthy [2].

All the four electronic blocks shown in Fig.1 should be incorporated into clothing or wearable items for efficient use of wearable wireless devices. It is therefore necessary to use non-conventional fabrication methods and materials in conjunction with custom design approaches.

In the recent past, the wearable products have entered into the textile world. In general, Monitoring is a basic activity in endangered environments such as mountain climbing, diving, mining and military. However, medical monitoring is much needed for transmitting messages to hospital patients, home patients or perhaps outpatients. All these significant applications can therefore be accomplished with the help of wearable antennas which helps the wearer with such compact and durable products to stay in comfort zone [3]. Wearable textile materials have been widely utilized for the development of microstrip antenna segment due to the latest miniaturization of wireless systems [4]. Due to small weight, small size, and low fabrication cost, small antennas such as microstrip antenna [5-6], RFID antenna, Fractal antenna, etc. have been used in hand-held devices and other compact communication devices [7].

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As the ground plane in microstrip antenna protects the body tissues and radiates perpendicularly to the planar structure, it is more appropriate to use it in wearable applications [8].

By using a small dielectric substrate, increasing the substrate thickness, and using appropriate feeding methods, the bandwidth of wearable antennas can be improved [9]. The surface wave losses will be lower for small dielectric constant. Measuring the radiation absorbed by the human body as wearable antennas are closer to the human body is vital. Specific absorption rate (SAR) is used to measure the electromagnetic radiation absorbed by human body. SAR is a measure of the rate at which human body absorbs energy when it is subjected to radio frequency [10].

A triangular patch antenna for health monitoring applications is being intended in this paper and its performance is being investigated. Normally, Textile antennas are widely used in wearable applications as they are cost effective, light weight and low profile structures. This wearable antenna can be fully integrated in garments and can be used to transmit or receive information from the sensor.

II. METHODOLOGY

The proposed patch antenna has a physical size of 80x90 mm² and is supplied using microstrip feed line by 50Ω transmission line. The triangular patch and ground plane are made up of copper tape. The substrate is made up of cotton material whose dielectric constant is 1.51, thickness is 3.2 mm and loss tangent is 0.02. Two slots are cut to provide a centre feed for the patch. Geometrical configuration of the proposed microstrip antenna is depicted in Fig.2.

Fig.2. Structure of Proposed antenna

The resonant frequency of equilateral triangular patch is given as,

$$f = \frac{2c}{3a\sqrt{\epsilon}} \quad (2)$$

where,

a is the vertex of triangle

c is the speed of light in free space

ε is the dielectric constant of the substrate

The triangular patch antenna has a ground plane whose length (L) is 90 mm and width (W) is 80 mm. Table 1 shows various dimensions of the proposed antenna. The triangle patch has a vertex (a) of 63 mm. The length (b) of the slot is

9 mm and width (c) is 1.5 mm. These slots are made to provide a centre feed. The feed line has a dimension (e) of 4 mm. The dimensions of the substrate are the same as that of the ground plane. The substrate is chosen with the thickness of 3.2 mm.

Table 1: Antenna Dimensions

Dimensions	Values(mm)
L	90
W	80
a	63
b	9
c	1.5
d	39
e	4

III. RESULTS AND DISCUSSION

3.1. Simulation Results

Using ANSYS HFSS 13.0 software, the triangular patch antenna is designed and simulated. The antenna parameters such as Return loss (S11), VSWR, Radiation Pattern, Gain and Efficiency are analysed. The simulated return loss S11 of the antenna over frequency is depicted in Fig.3. It offers a return loss of approximately -16dB at resonant frequency. Lower the return loss, higher the radiated power

Fig.3. Return loss Vs Frequency

Fig.4 shows the simulated antenna parameters of the proposed antenna at 2.4 GHz. The proposed antenna provides a maximum gain of 3.15 dB, Front to back ratio of 50 dB, and radiation efficiency of 81.33%.

Fig.4 Simulated Antenna Parameters

The simulated 3D and 2D elevation patterns of the Textile antenna at resonant frequency are demonstrated in Fig.5 and Fig.6 respectively.

Here, the elevation pattern is noted, for phi (ϕ) value of 90 degree and for all values of theta. It is noted that the antenna exhibits symmetry uni-directional radiation pattern in elevation plane.

Fig 5. 3D Elevation Radiation Pattern

Fig.6 2D Elevation Radiation Pattern

3.2 Measured Results

The measured results of proposed antenna is discussed in this section. The designed antenna is fabricated and antenna parameters are measured using Microwave Vector Network Analyzer.

In the fabrication process of antenna, the substrate is made up of cotton material. Copper tape is used to make the conducting patches and ground plane. The cotton substrate is placed between triangular patch and ground plane. Fig. 7 gives the front and back view of the fabricated antenna.

Fig.7 Front and back view of Prototype antenna

The measured results of proposed antenna is discussed in this section. The designed antenna is fabricated and antenna parameters are measured using Microwave Vector Network Analyzer.

Fig.8 depicts the measured Return loss of the antenna. The return loss of the antenna is approximately -11 dB at a frequency of 2.4 GHz. Fig. 9 shows the measured VSWR of the antenna. It provides a VSWR of 1.9.

Fig.8 Return loss plot of the Prototype Antenna

Fig.9 VSWR of the Prototype Antenna

3.3 SAR Calculation using HFSS

ANSYS HFSS is used for the measurement of Specific Absorption rate (SAR). SAR is a measure of the rate of energy absorption by the human body when subjected to RF. It is described as the power that is absorbed by tissue mass and has unit of watts per kilogram (W/kg) [11]. It is possible to calculate SAR for electromagnetic energy from the electric field within the tissue as:

$$SAR = \frac{1}{V} \int \frac{\sigma(r)|E(r)|^2}{\rho(r)} dr \quad \text{----- (2)}$$

σ is the sample electrical conductivity, E is the RMS electric field, ρ is the sample density, V is the volume of the sample. The peak SAR values (spatial-peak SAR [IEEE-1529]) are averaged over 1g and 10 g of human tissues by setting excitation equivalent to 0.6 Watts. Usually, SAR is averaged either over the entire body, or over a small sample volume. The permissible or preferred SAR values are 2 W/kg per 10 g and 1.6 W/kg per 1 g of body tissue. [12]. The SAR value also relies on the substrate's dielectric properties. Each substrate deposits distinct amounts of radiation from the antenna to the human body.

A numerical hand and head phantom model of Specific Anthropomorphic Mannequin (SAM) [13] are used in this research work. SAR calculator is provided by the HFSS software. It enables the local and the average SAR to be known in distinct volumes of the antenna design. Thus, a volume with distinct layers can be created that represents some portion of the human body. The most significant thing to do this is to understand the features of distinct body layers that represent the distinct human tissues of that portion of the body.

Fig.10 and Fig.11 show the SAR analysis of a proposed triangular patch antenna for both hand and head respectively. The maximum and minimum SAR values for hand are 0.96W/Kg and 0.08W/Kg over 1g of tissue respectively. The maximum and minimum SAR values for head are 0.51W/Kg and 0.08W/Kg over 1g of tissue respectively. Table 2 summarizes the SAR values.

Table 2. SAR Values for Textile Antenna

	SAR(W/kg)-1g of body tissue	
	1cm from Hand	1.5cm from Head
Min.SAR	0.08	0.08
Max.SAR	0.96	0.51

Fig.10 SAR analysis for hand

Fig.11 SAR analysis for head

IV. CONCLUSION

The proposed article presents a triangular patch textile antenna for health monitoring applications. The patch is fabricated using copper tape and substrate is made up of cotton. The physical size of the proposed antenna is 90x80 mm² and is fed by micro strip line feed structure. The proposed antenna structure resonates at 2.4GHz. The radiation efficiency is 81.33% and peak antenna gain is 3.15 dBi at the resonant frequency. Hence the proposed antenna is appropriate for wireless health monitoring applications. The simulated and measured results are used to validate the fabricated antenna; the measured results are better than the simulation results. The proposed work also analysed the impacts of electromagnetic radiation on the human head and hand in terms of SAR. SAR is measured at distinct distances from antenna to the human head and hand. The maximum and minimum SAR values for hand are 0.96W/Kg and 0.08W/Kg over 1g of tissue respectively. The maximum and minimum SAR values for head are 0.51W/Kg and 0.08W/Kg over 1g of tissue respectively. Because of the low SAR values the proposed antenna can be used for communication and biomedical applications.

REFERENCES

1. Bonato P. Wearable sensors and systems: From enabling technology to clinical applications. IEEE Engineering in Medical and Biology Magazine. 29:25–36, 2010
2. Bariya, M., Nyein, H. & Javey, A. Wearable sweat sensors, Nature Electronics. 1, 160–171, 2018.
3. Mukhopadhyay, S.C. Wearable Sensors for Human Activity Monitoring: A Review. Sensors Journal, IEEE. 15. 1321-1330, 2015.
4. Odame, Kofi & Du, Dingkun. Towards a smart sensor interface for wearable cough monitoring. Proceedings of IEEE Global Conference on Signal and Information Processing, 654-657, 2013.
5. A. Amsaveni, M. Bharathi, J. N. Swaminathan, Design and performance analysis of low SAR hexagonal slot antenna using cotton substrate, Microsystem Technologies 25:2273–2278, 2019
6. A. Amsaveni, Antennas and Wave Propagation. Anuradha Publications, Chennai, 2017.
7. A. Amsaveni, K. Anusha, A circularly polarized triangular slot reconfigurable antenna for wireless applications, International Journal of Pure and Applied Mathematics, 116(11), 81-89, 2017.

8. Varshney, S, Malhotra.M, Sharma S& Aggarwal, P. (2018). Specific absorption rate (SAR) value of mobile phones: An awareness study among mobile users. Indian Journal of Community Health. 30. 156-162,2018.
9. A. RegiSaraI, V. Lavanya, A. Amsaveni, A Triangular Patch Antenna for Wireless Applications” ,Intl.Journal of Advanced Research in Electronics and Communication Engineering, 7(3), ISSN: 2278 – 909X,2018.
10. A K M FazlulHoque, Md. Sazzad Hossain, ASattarMollah, Md. Akramuzzaman. A Study on Specific Absorption Rate (SAR) Due to Non-Ionizing Radiation from Wireless/Telecommunication in Bangladesh. American Journal of Physics and Applications.1(3):104-110,2013.
11. Hengyi Zhou, Arpan Pal, Amit Mehta, Low SAR Capacitively Coupled Compact Multiband Antenna for SmartphonesIEEE Loughborough Antennas & Propagation Conference (LAPC), 978-1-4799-8943-0/15,2015.
12. Mohammad Rashed Iqbal Faruque, MdIkbal Hossain, Mohammad Tariqul, Low Specific Absorption Rate Microstrip Patch Antenna for Cellular Phone Applications, IET Microwave Antennas and Propagation, 9(14),1540-1,2015.
13. IkbalHossainaMd, Iqbal Faruquea M R, TariquIslamb M, Investigation of Hand Impact onPIFA performances and SAR in Human Head, Journal of Applied Research and Technology, 13,447-453,2015.