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Performance Analysis of T Slot UWB Patch Antenna for WBAN Applications

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Abstract — Ultra-wideband (UWB) technology, systematized by IEEE 802.15.6 TG-6 for ultra low power consumption, is one of the speedy technologies for short range communications. In this paper, performance of a T-slot UWB patch antenna for body-worn application is investigated. The presented antenna is of dimension 30 mm× 30 mm× 1.6 mm. This paper explores the effect of antenna-body gap in terms of reflection coefficient and voltage standing wave ratio (VSWR) in free space and modeled layered human body tissue phantom. The antenna designed in such a way that it can show good execution over free space as well as over modeled tissue phantom. All the simulations were carried out by CST microwave studio. Details of the suggested antenna and the results are presented and discussed.

Keyword — Ultra wideband (UWB), Body-worn antenna, Wireless body area network, patch antenna, Phantom, human tissue.

1. Introduction

The body-worn antenna and body-centric communication systems have received considerable recognition over the past few years in healthcare monitoring applications [1]. Advances in wireless communication and micro-electronics have authorized a way to make compact and lightweight monitoring devices. Such smart monitoring devices can be used together to form wireless body area network (WBAN). Scheming antenna for WBAN has many essential issues, one such issue is presence of human body in the near-field that can considerable affect on antenna's performance [2,3]. Also, WBAN antenna must be smaller in size and draws ultra-low transmission power in order to limit electromagnetic absorption. The lessening of the size of antenna creates several other problems due to critical performance of antenna characteristics, such as bandwidth, efficiency and impedance. Hence it is absolutely challenging to construct a compact UWB on-body antenna with considerable performance in the vicinity of human body.

The FCC (Federal Communications Commission) furnished a ruling in 2002 that allowed intentional UWB emissions in the frequency range between 3.1GHz and 10.6GHz [4]. FCC has approved a huge bandwidth of 7.5 GHz and defined the spectral shape and maximum spectral power density of - 41.3 dBm/MHz for the UWB radiation in order to restrict unwanted interference with other communicating device. Such distinct characteristics make UWB technology to be a novel solution to all promising applications used for healthcare monitoring, especially WBAN. Ultra-wideband (UWB) technology has been considered as one of the most favorable wireless technology that has a potential of revolutionizing high data rate transmission.

Various type of monopole antenna has been developed for ultra-wideband application, such as rectangular patch, circular disc etc.

In this paper a small-scale T slots UWB antenna is presented. In this paper, we examine the antenna performance in free space and in direct contact to human body phantom. The main goal is to study the nature of dispersive human tissue and their electrical properties, and how the antenna parameters changed by introducing the antenna-body gap. Since, interaction in the vicinity of human body can affect the EM wave propagation environment [5], [6], which is basically comprised of free space and dispersive human tissue phantom. Thus the evaluation of antenna performance in the close proximity of human body is quite difficult. The various layer of human body have its own significance with different dielectric constant and conductivity. These different human tissues degrade the performance of antenna.

The rest of the paper is as follows- The T-slot antenna design and related parametric studies are given in section 2. The result discussions with WBAN are provided in section 3. Finally in section 4, we present conclusions of results.

2. Antenna Design and Parametric Study

In this section, we present a novel wideband body-worn T-slot antenna operating over a frequency range of 3.1-10.6 GHz.

In order to attain broad impedance bandwidth and omni-directional radiation pattern, in compact size antenna, we have employed the concept of partial ground plane with slot in the radiating patch, with the cut or notches at the bottom. These techniques are applied to reduce the antenna size without influencing antenna performance. The impedance bandwidth of antenna is mainly affected by the size of feed width, notches, and slot. Thus, to attain a broader bandwidth, proper examinations on those parameters are required. The consequence of notch and slot is explained here in details to develop a design methodology to control the matching bandwidth of antenna.

The suggested geometry of T-slot UWB antenna are shown in Fig. 1. The dimension of the antenna is of 30 mm × 30 mm × 1.6 mm. The radiating patch and ground plane are placed on opposite sides of dielectric substrate (FR-4) having relative dielectric constant of 4.7 and loss tangent of 0.025.The radiating patch of size 14 mm × 14 mm is fed by a micro stripline of width 3 mm. The two notches size of 1.5 mm × 1.5 mm and 1 mm × 1 mm are at the two bottom corners of the radiating patch. The feed gap between patch and the ground plane is 1 mm. The length of ground plane is 11 mm. The proposed T- slot is printed on top of radiating patch. Simulations of this antenna have been done by using CST Microwave studio suite. The concept of making T slot in the radiating patch is to reduce the conductance between rectangular patch and ground plane so that a small resistance can be capable of distributing the surface current along the symmetrical slot.

2.1 Effect of the notches at the bottom of patch

In order to obtain broad bandwidth without enhancing the antenna size, notches are made at the bottom of radiating patch and slotting techniques are employed to the suggested UWB antenna. Fig.1 shows three variations of the same patch with Fig.1 (a) having one notch of dimensions 1.5 mm × 1.5 mm, Fig. 1(b) having second notch added to it with changed dimensions 1 mm × 1 mm. Finally Fig.1(c) shows the T-slot created at the center of above patch in Fig. (b). These type of notch techniques have been utilized for better capacitance tuning between ground plane and lower part of antenna. Such techniques are used to achieve wider impedance bandwidth.

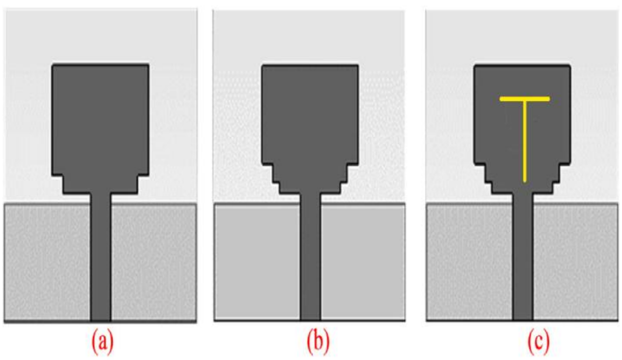

Fig 1 Different step notches at the bottom of patch and T-slot at center of patch (a) 1 step notch, (b) 2 step notch and (c) 2 step notch with T-slot at the center of patch.

Fig. 2 shows the return loss of antenna with 2 steps notch cutting at the bottom of radiating patch with T slot. The return loss curve here is best, covering the frequency range from 3.24 GHz to 13.52 GHz. Two notches at the bottom of the patch provide a good impedance bandwidth which matches with the standard IEEE 802.15.6. One-step notch provides less bandwidth covering frequency range from 3.74 GHz to 12.45 GHz.

Table 1 shows the effect of two notches at the bottom and the T- slot at the center of patch respectively to the antenna bandwidth. The basic rectangular patch of dimensions 14 mm × 14 mm (WP × LP) with one notch cutting of dimension 1.5 mm × 1.5 mm provides the fractional bandwidth of 107.59%. This fractional bandwidth increases to 119.42% by cutting second notch of dimension 1 mm × 1 mm at the bottom. Moreover, a fractional band-width of 122.67% is achieved by cutting T- slot at the center of patch along with two notches at the bottom of patch.

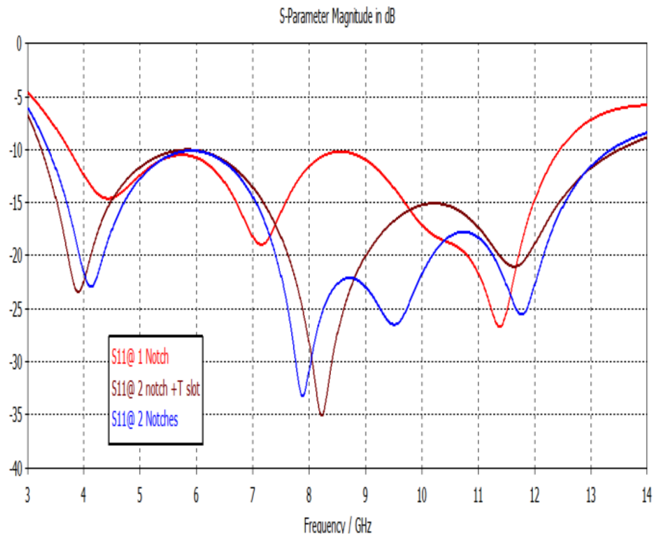

Fig.2 Simulated return loss of various steps notches with T slot

Table1 The effect of notches and T-slot on bandwidth (simulated -10 dB) of proposed antenna

Notches	F_L(GHz)	F_U (GHz)	Fractional Bandwidth (%)
1	3.74	12.45	107.59
2	3.37	13.36	119.42
2 and T- slot	3.24	13.52	122.67

We also investigated the effect of cutting three notches at the bottom of patch, which leads to degradation in fractional bandwidth. Hence, the optimal selection of the antenna is with two notches at the bottom and T-slot at center of radiating patch.

2.2 Effect of feed gap

The feed gap between the lower edge of the radiating patch and the ground plane is required to achieve impedance bandwidth. The printed partial ground plane on the backside of the substrate served as an impedance matching element. We have taken four different values of feed gap (0.5 mm, 1 mm, 1.5 mm, and 2 mm) in order to determine the optimal size of feed gap.

Fig. 3 shows the simulated return loss (S11) curves for different feed gaps to the ground planes of T- slot UWB antenna with increasing frequency. Fig. 3 shows the change of absolute fractional bandwidth with variation of feed gap. The optimal feed gap from simulated result is found to be 1 mm with the fractional bandwidth of 116.08%.

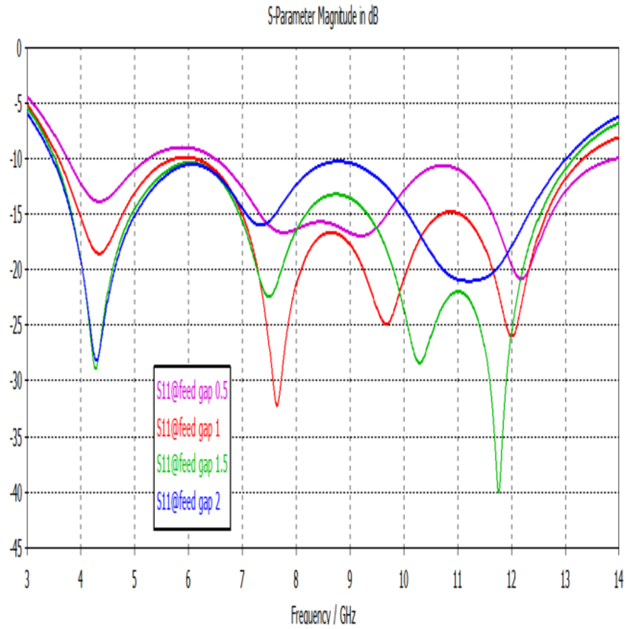

Fig.3 Simulated S_{11} curves of proposed antenna for different feed gaps

These simulated results show the dependency of antenna impedance bandwidth on feed gaps of the ground plane. Here, the ground plane acts as the impedance matching element.

2.3 Effect of feed width

The feed width plays an important role toward achieving desired impedance matching bandwidth. It is found that good impedance matching can be obtained by appropriate feed design [7]. Moreover, impedance matching can be obtained by enhancing the coupling between the lower edge of radiating patch and the ground plane. When the coupling increases to a certain limit, an optimum impedance matching can be obtained. However, a further increment in the coupling level above this limit may deteriorate the impedance matching performance of the antenna. We have taken five different values of feed width (1.5 mm, 2 mm, 2.5 mm, 3 mm, and 3.5 mm) in order to determine the optimal size of feed width. It is shown in Fig. 4 that the antenna with −10 dB bandwidth varies with the variation of the feed widths. We observed from simulated result for feed width values of 1.5, 2, and 3.5 mm the S_{11} curve is above -10dB level. Out of the feed width of 2.5 mm and 3, we have selected 3 mm as feed width.

Table2 The effect of feed width on bandwidth (simulated -10dB) of proposed antenna

Feed Width (Wf in mm)	F_L(GHz)	F_U (GHz)	Fractional Bandwidth (%)
2.5	3.38	13.36	119.16
3	3.29	13.49	121.57

It can be clearly visualized that the lower edge of frequency bandwidth is quite dependent of the feed widths variations, while upper edge of frequency bandwidth is independent on different feed width variations.

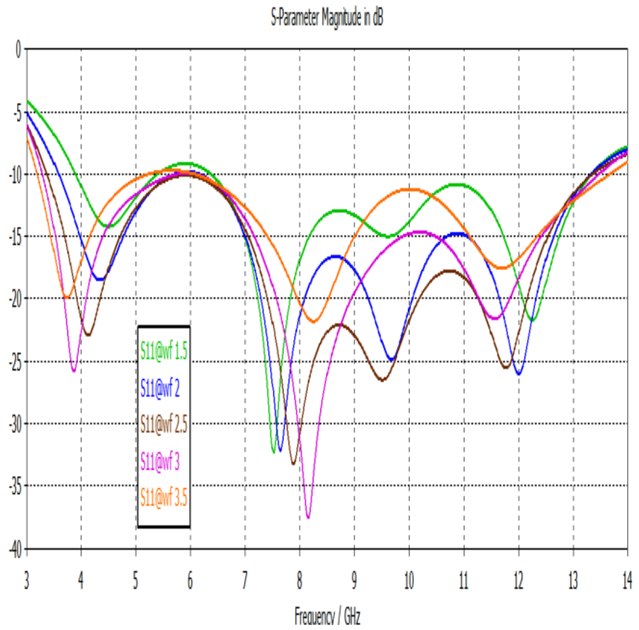

Fig.4 Simulated S_{11} curves of proposed antenna for different feed width

2.4 Voltage Standing Wave Ratio (VSWR)

The simulated VSWR curve of proposed wideband antenna is shown in figure 5. The variation of VSWR s plotted over different antenna design (1 Notch, 2 notches and 2 notches with T-slot). For the T-slot antenna a small increment in VSWR at starting frequency range of 5.5-6.5 GHz is observed and for rest of the frequencies VSWR is always less than 1.5.

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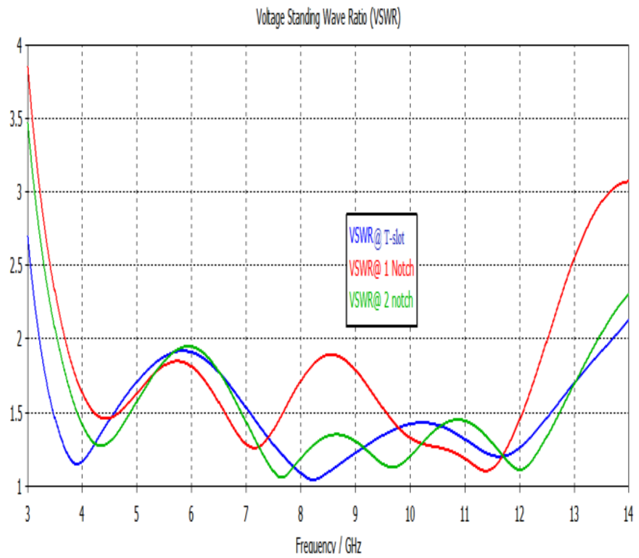

Fig. 5 Simulated VSWR of proposed antenna

3. Wireless Body Area Network

Due to rapid modification in wearable technology as fast computing, microelectronics and their miniaturization have made practicable development of wireless body area network (WBAN) in past few years [8,9]. The main concern of these devices is to improve the quality of life or the comfortness of human being. These types of the systems are deployable in real time health monitoring system, entertainment, defense and sports [10]. Above said intelligent devices can be integrated together to form WBAN [11]. Presently many researchers are doing work in this field to integrate the devices in proximity of body to improve the working ability of sports persons, patients and soldiers in battle field [12, 13].

Microstrip patch antenna is designed and simulated in computer simulation software, i.e. CST Microwave Suite. Various researchers used single layer skin model as in [14], but in this work four layered phantom model (skin, fat, muscle, bone) is utilized for making the study more viable. This electrical equivalent four layered canonical model (Phantom) of human tissue is more realistic than single layer model for simulations as shown in Fig. 6.

Fig 6. Four layered canonical model of human tissue (Phantom)

Four layered canonical model is constructed for making an electrical equivalent of human body and observe the consequences of the model on the characteristics of WBAN antenna. WBAN antennas are utilized in proximity of human body and the human body also affects the characteristics of antenna, hence the properties of different parts of human tissue (skin, fat, muscle and bone) are a very important concern for observation.

3.1 Reflection Coefficient Vs Frequency

Reflection Coefficient is obtained in various cases at the same port, the cases are; free space, 4mm, 6 mm and 8 mm depicted by S11@ free space, S11@ 4 mm, S11@ 6 mm, S11@ 8mm respectively in Fig.4. The purpose of inserting the air gap is to analyse more realistic results in proximity of human body.

Table 3 Comparison of reflection coefficient in proximity of phantom

Proximity cases	F_L(GHz)	F_U (GHz)	Fractional Bandwidth (%)
Free Space	3.24	13.52	122.67
Air gap 4mm	6.98	13.97	66.73
Air gap 6mm	6.82	13.7	67.05
Air gap 8mm	6.61	13.65	69.50

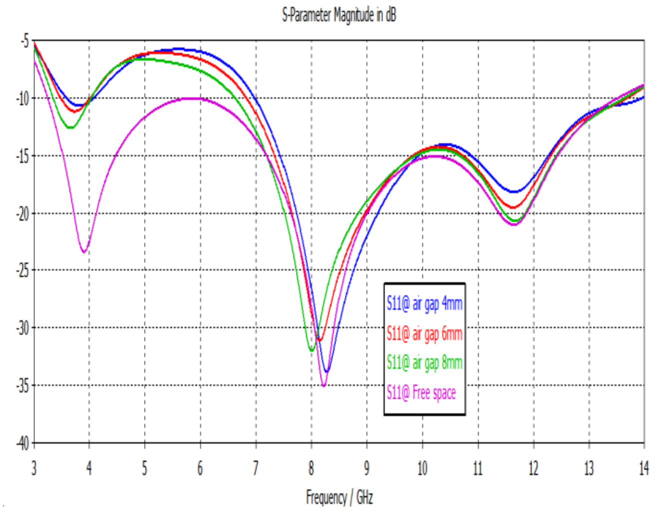

Fig 7 Comparison of reflection coefficient Vs frequency plots

4. Conclusion

In this paper, a rectangular patch antenna having T-slots has been presented. The bandwidth properties of the antenna were analyzed in detail. The T-slot UWB patch antenna structure occupies 30 mm × 30 mm × 1.6 mm, which is acceptable small antenna for on body application. The T-slot antenna exhibits the wider frequency range of 3.24-13.52 GHz, providing a bandwidth of 10.28 GHz. But when the antenna is placed over body the operating band shifts down in frequency due to interaction with human tissue and operates in the desired band and achieves a good performance. The simulation results show that a UWB can be obtained by optimizing these parameters.

REFERENCES

[1] Hall PS, Hao Y. “Antenna and propagation for body-centric wireless communication systems” Artech House: Norwood, MA, USA; 2006.
[2] See TSP, Chen ZN. Experimental characterization of UWB antennas for on-body communications. IEEE Trans Antennas Propagation 2009; 57(April): 866–74.
[3] Klemm M, Troster G. EM energy absorption in the human body tissues due to UWB antennas Progress Electromagnetic Research 2006; 62:261–80.
[4] FCC, First Report and Order 02-48, February 2002.
[5] J. Gamio, J. Parron and J. Soler, “Human Body Effect on Implantable Antennas for ISM Band Applications: Models Comparison and Propagation Losses Study”, Progress in Electromagnetics Research, vol.110, pp.437-452, 2010.
[6] T. Tuovinen, K. Y. Yazdandoost and J. Iinatti, “Monopole Ultra Wideband Antenna for On-Body Communication in Wireless Body Area Network,” Loughborough Antennas and Propagation Conference (LAPC), Loughborough, United Kingdom, pp. 1-4, November 2011.
[7] Zasowski T, Althaus F, Stager M, Wittneben A, Troster G. UWB for non-invasive wireless body area networks: channel measurements and results. In: Proceedings of the IEEE Conference on Ultra Wideband Systems and Technologies. 2003. p. 285–9.
[8] Baber, C., et al. (1999). Ergonomics of wearable computers. Mobile Networks and Applications, 4, 15–21.
[9] Guha, D., & Antar, Y. M. M. (2011). Microstrip and printed antennas: New trends, techniques and applications. London: Wiley. ISBN-10 0470681926. Design Aspects of Body-Worn UWB Antenna for Body-Centric… 123 Author's personal copy.
[10] Latre, B., Bream, B., Moerman, I., Blondia, C., & Demeester, P. (2011). A survey on wireless body area networks. Wireless Networks, 17(1), 1–18.
[11] Patel, M., & Wang, J. (2010). Applications, challenges, and prospective in emerging body area networking technologies. IEEE Wireless Communications, 17(1), 80–88.
[12] Lymperis, A., & Dittmar, A. (2007). Advanced wearable health systems and applications, research and development efforts in the European Union. IEEE Engineering in Medicine and Biology Magazine, 26(3), 29–33.
[13] Hao, Y., & Foster, R. (2008). Wireless body sensor networks for health monitoring applications. Physiological Measurement, 29, R27–R56.
[14] Yong-Xin Guo and Shaoqiu Xiao Changrong Liu, "A Review of Implantable Antennas for Wireless Biomedical Devices," Forum for Electromagnetic Research Methods and Application Technologies.