Ultra-Wideband Microstrip Antenna for Body Centric Communications

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***Abstract* ─** A novel low profile reconfigurable wide band microstrip antenna for impulse radio ultra-wideband (IR-UWB) WBANs and targeted for on-body sensor node has been introduced. The printed monopole antenna consists of a heart shaped radiating patch and an elliptical ground plane. This antenna has a frequency bandwidth of 130% with a VSWR of 1.5 and average gain is about 3.6 dBi. There is a slot on the patch which is loaded by two varactor diodes to form a tunable notch band. The antenna operates from 2.4 GHz to 12 GHz. The proposed antenna is a good candidate for medical purpose since it has a sufficient amount of gain and bandwidth. We used active circuit to increase the flexibility of setting rejection band to prevent having interference from other sources such as Wi-Fi. The antenna is fabricated and there is a good agreement between the simulation and measurement results.

***Index Terms* ─** Body-centric wireless communication, miniaturized microstrip antenna, wireless body networks.

I. INTRODUCTION

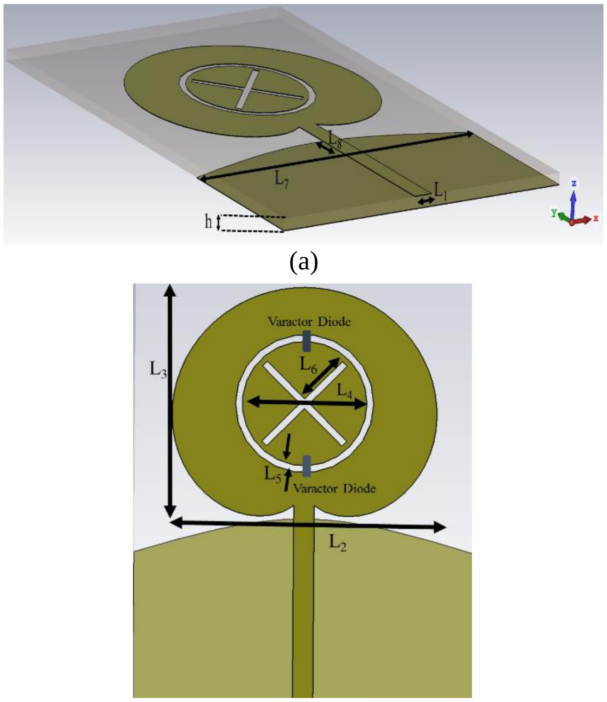
Antenna designing for WBAN system is challenging due to the human body effect. Especially, providing the sufficient gain and efficiency of an antenna is the main issue of on-body to on-body communication. To overcome this problem, an on-body antenna should have vertical polarization relative to the human body surface. In addition, to satisfy the propagation along the body surface for on-body to on-body communication, the antenna is required to have omnidirectional radiation characteristic [1]. Also, a number of techniques aimed at minimizing the cost of such antenna without significantly sacrificing performance have been considered. One of the most important techniques is using slots on the patch surface. Slots perturb antenna current on the antenna surface and increase antenna bandwidth [2]. Another advantage of using slots is changing antenna polarization or using as a Frequency Selective Surface (FSS) to filter unwanted frequencies [3]. In some paper, small slots are imbedded on ground plane or feeding point to have better matching response. These techniques are well-known as Defected Ground Structure (DGS) and Defected Microstrip Structure (DMS) [4]. PIN diodes have been also used to change the antenna dimensions electrically and increase the frequency bandwidth [5]. In this paper, we use varactor diodes to increase the frequency bandwidth. The varactor diode is a variable capacitor which can be modelled as a series capacitor and a resistor to model the ohmic losses [6, 7]. To improve frequency and pattern bandwidth, heart-shaped printed monopole antenna is proposed in [8]. In this paper, a low profile ultra-wideband on-body antenna is presented. The proposed antenna has a low profile, omnidirectional radiation patterns in the whole UWB band, and maximum radiation along the near body surface. We also use antenna with slot and taper heart-shaped to increase frequency bandwidth. In some purposes we need filter to cut the frequency bandwidth, two varactor diodes are used to change the notch in frequency bandwidth. When we change the DC bias of the diodes, their capacitance values change. So this antenna is combination of filter and antenna. The proposed low profile UWB antenna is suitable for on-body communications since the field is vertically polarized and propagated along the body surface for IEEE 802.11b/g and IEEE 802.11a. The antenna is considered to operate as a relay between sensors located on the body and non-local station so it is an advantage for the antenna to be able to have tangential radiation over the body surface in the on-body mode and a bore sight pattern in the off-body mode at the frequency bands of 802.11a and 802.11b/g, respectively [9, 10]. This antenna has a frequency bandwidth of 130% with a VSWR of 1.5, average gain is about 3.6 dBi.

II. DESIGN OF A SLOTTED MICROSTRIP ANTENNA

As it is shown in Fig. 1, the proposed slot antenna

Submitted On: September 14, 2016
Accepted On: December 26, 2016

with line feed has been designed on Rogers RO4003 with permittivity of ε_r=3.2 and substrate thickness of h=0.813 mm and substrate size of 42×30 mm. The dimensions of slots and antenna are mentioned in Table 1.



(a)

(b)

Fig. 1. Proposed slotted microstrip antenna: (a) side view, and (b) top view.

Table 1: Physical dimension of loaded-monopole

Parameter	L_1	L_2	L_3	L_4	L_5
Dimension (mm)	1.8	22	20	10	0.5
Parameter	L_6	L_7	L_8	h	
Dimension (mm)	4.7	30	2.3	0.813	

Two varactor diodes are used to change the capacitance value of the circular slots and these slots create notch in the frequency band. The notch band avoid interference with other frequency bands. Circular slots create notch in the frequency band. Line feed should be adjusted for 50Ω transmission line [11].

To increase the frequency bandwidth, two crossed slots are designed on the surface of the microstrip patch. These slots decrease antenna patch area and based on the following formula, quality factor of the microstrip antenna decreases. S is the area of the patch and f_r is the resonant frequency of the microstrip antenna. Frequency shift for patch is given as [12]:

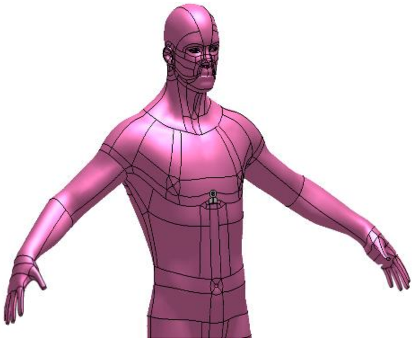
$$\left|\frac{\Delta S}{S}\right| = \frac{1}{Q_0}\,, \tag{1}$$

$$\Delta f_1 = f_{0r}/2Q_0\,. \tag{2}$$

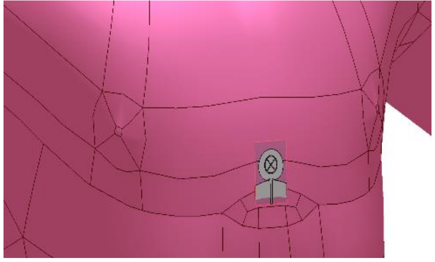
III. RESULTS AND DISCUSSION

With the dimensions given in Table 1, the proposed antenna was simulated in close proximity of the human body. To obtain the human effect on the antenna behavior, VOXEL model of body with CST software is simulated. The human body model was developed in the CST microwave studio. It is an adult male of mass 100 kg, height 180 cm and chest circumference of 115 cm, including muscle, skeleton and brain with human tissue. The electrical properties were defined at the frequency band of 2.5-12 GHz with resolution of 100 MHz. Figure 2 shows the placement of the antennas on the model. The antenna is placed 2 mm apart from the chest of the model. The on body simulated and measured S_{11} of the proposed antenna are illustrated in Fig. 3 and Fig. 5. As shown in Fig. 3, the bandwidth of the antenna can be changed from 2.5 GHz to 12 GHz in transmitting purposes and 2 GHz to 12 GHz in receiving purposes. As it is shown in Fig. 6, the human body behaves like a reflector and improves gain of the antenna because the permittivity of the body is about 42. The backlobe part of the antenna pattern is removed. In these types of antennas each part of the antenna has different resonant frequency, therefore the impedance bandwidth is wider than typical microstrip antenna. To obtain better results all dimensions are optimized. We have used Particle Swarm Algorithm with CST software. It is observed that the variation in the diameter of the metallic arcs has major effect on the lower frequency bandwidth. In case of impedance bandwidth, it improves return loss at higher frequency region and does not affect the lower cut-off frequency. The simulated antenna VSWR referenced to 50Ω is shown in Fig. 4. The improvement in the input impedance bandwidth using slots and curved ground plane is clear. It is interesting to mention that at low frequencies, the input impedance of the antenna is depended on the patch dimensions not the substrate dimensions.

At high frequencies the input impedance is intensively affected by the substrate thickness. We can improve matching parameter using elliptical ground plane. It is obvious that the radiation patterns changes slightly at higher frequency because of variation antenna dimensions at different frequencies. It means that radiation pattern bandwidth is smaller than impedance bandwidth. In portable system, this is negligible since we do not have constant and stable direction for transmitter. This antenna is so small and can be used in medical purposes. For example, in some frequencies such as Wi-Fi, interference is inevitable and we need an antenna that can filter unwanted frequencies. These diodes are used for creating notch to reject these frequencies. In this paper we used tapered elliptical form for the structure to get better impedance matching. The radiation patterns of the antenna when the antenna is attached to the body are changed. The body behaves like a reflector because the body permittivity ε_r=42 is so high. To verify the simulation result, the antenna has been fabricated and tested (see Fig. 7).



(a) Remote view



(b) Close view

Fig. 2. The proposed antenna placed on the chest human body model.

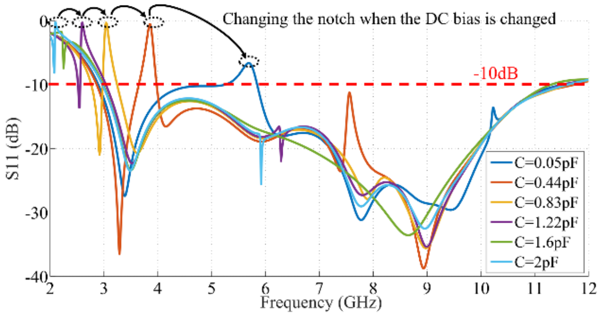


Fig. 3. Simulated S_{11} with CST software for different capacitance values on body.

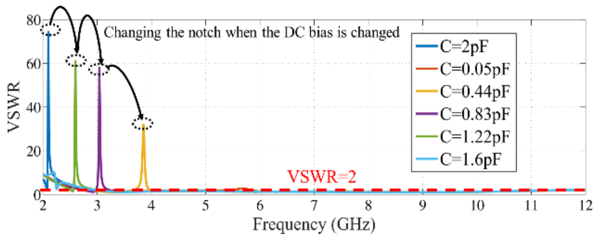


Fig. 4. VSWR of the slotted microstrip antenna.

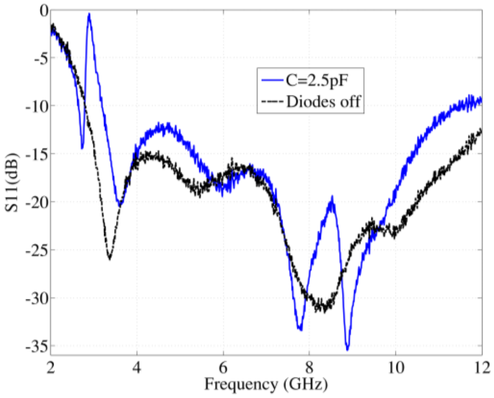
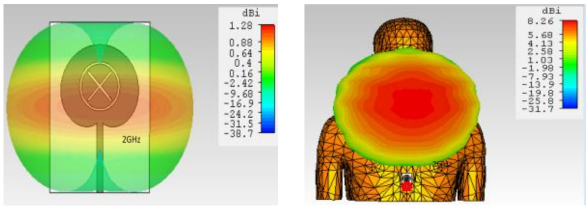
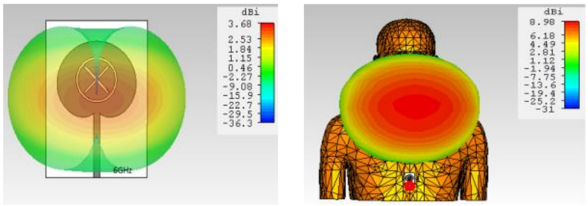


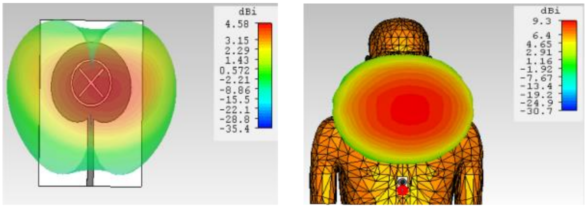
Fig. 5. Measured S_{11} in two states: 1-Diodes ON, 2-Diodes OFF.



f=2 GHz, Gain=1.28 dB f=2 GHz, Gain=8.26 dB



f=6 GHz, Gain=3.68 dB f=6 GHz, Gain=8.98 dB



f=12 GHz,Gain=4.58 dB f=12 GHz, Gain=9.3 dB

Fig. 6. Comparision of the antenna radiation patterns at different frequencies with human body and without human body.

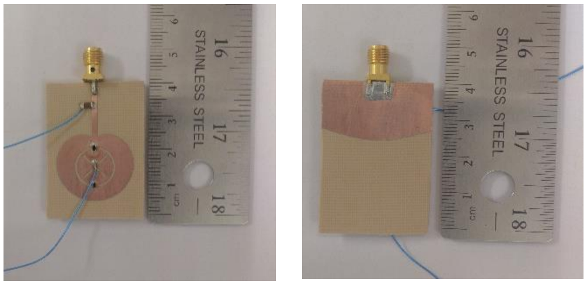


Fig. 7. Photo of fabrication.

VI. CONCLUSION

An efficient wide band and dual pattern heart-patch antenna with two varactor diodes and strip line feed is proposed for on-body and off-body communication modes is proposed and analysed with respect to the bandwidth, average gain, radiation pattern. The impedance bandwidth of proposed antenna achieved 130% from frequency range 2.8 to 12 GHz. The average gain of the antenna is about 3.5 dBi. The radiation pattern of E- plane & also studied. It has Bi-directional E-plane & Omni-directional H-plane. This antenna is simple in structure and easy to fabricate with MIC/MMIC systems. This antenna can be used for wireless communication systems, especially for medical purposes. We can adjust notch frequency band of the antenna easily by changing DC bias of the varactor diodes. The proposed antenna presents much improved gain with one tapered shape radiating element than the previous works of the compact dual band and dual mode antennas. The results show that this antenna does not experience significant frequency detuning from the free space resonance at whole frequency bands when simulated on the human body.

REFERENCES

[1] G. A. Conway and W. G. Scanlon, “Antennas for over body-surface communication at 2.45 GHz,” in *Antennas and Propagation, IEEE Transactions on*, vol. 57, no. 4, pp. 844-855, Apr. 2009.

[2] K. M. Chang, R. J. Lin, I. C. Deng, J. B. Chen, K. Q. Xiang, and C. J. Rong, “A novel design of a CPW-fed square slot antenna with broadband circular polarization,” *Microwave. Opt. Technol. Lett*., vol. 48, no. 12, pp. 2456-2459, Dec. 2006.

[3] O. Manoochehri, S. Abbasiniazare, A. Torabi, and K. Forooraghi, “A second-order BPF using a miniaturized-element frequency selective surface,” *Progress In Electromagnetics Research C*, vol. 31, pp. 229-240, 2012.

[4] M. A. Salari, O. Manoochehri, and S. Abbasiniazare, “Miniaturized microstrip ring hybrid with defected microstrip structure,” *Microwave and Optical Technology Letters*, vol. 55, pp. 2245-2248, 2013.

[5] S. Abbasiniazare, O. Manoochehri, and K. Forooraghi, “A reconfigurable printed dipole antenna using RF PIN diodes,” *Microwave and Optical Technology Letters*, vol. 56, pp. 1151-1155, 2014.

[6] M. Norooziarab, Z. Atlasbaf, M. Rafaei-Booket, and F. Farzami, “A tunable transmission line based on an SIW loaded by a new single-cell meta-material,” *Telecommunications (IST), 2012 Sixth International Symposium on*, Tehran, pp. 75-79, 2012.

[7] F. Farzami and M. Norooziarab, “Experimental realization of tunable transmission lines based on single-layer SIWs loaded by embedded SRRs,” in *IEEE Transactions on Microwave Theory and Techniques*, vol. 61, no. 8, pp. 2848-2857, Aug. 2013.

[8] C. Hua, Y. Lu, and T. Liu, “Printed UWB heart-shaped monopole antenna with band-notch reconfigurability,” in *2016 IEEE International Workshop on Electromagnetics: Applications and Student Innovation Competition (iWEM)*, pp. 1-3, 2016.

[9] G. A. Conway, W. G. Scanlon, and D. Linton, “Low profile microstrip patch antenna for over-body surface communication at 2.45 GHz,” in *Vehicular Technology Conference, 2007, VTC2007-Spring, IEEE 65th*, pp. 392-396, Apr. 22-25, 2007.

[10] S. Khaledian and Z. Atlasbaf, “Dual band and dual mode microstrip antenna for body centric wireless communication,” *Applied Computational Electro-magnetics Society Journal*, vol. 31, 2016.

[11] I. J. Bahl and R. Garg, “A designer’s guide to stripline circuits,” *Microwaves*, pp. 90-96, Jan. 1978.

[12] J. R. James, et al., *Microstrip Antenna Theory and Design*. Steven-age, UK: Peter Peregrinus, 1981.