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Compact On-body Antennas for Wearable Communication Systems

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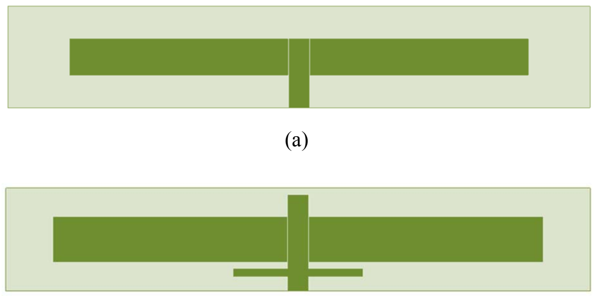
Abstract

This paper presents performance analysis of compact on-body antennas over a female body phantom. These antennas are designed to operate in 2.4GHz industrial, scientific and medical (ISM) band. In the design process, full ground plane is used to minimize radiation towards the body as they are intended to operate in near-body scenarios for Wireless Body Area Networks (WBANs). They offer significant advantages of compactness, light weight, wide radiation pattern over the body surface to provide maximum coverage, and less sensitivity to the variation of the gap between the antenna and the human body. These advantages make them of high interest for on-body communications and wearable applications. Results show that these antennas have good performance and successfully communicate under various near-body scenarios.

1. Introduction

With the rapid growth of technology and significant advancements in wireless communications, particularly in wearable technology, there is a constant need to develop novel antennas and components to support modern communication systems. Wearable technology focusing on practical aspects of Body Centric Wireless Communication (BCWC) is a fast growing research area in modern communications, with its applications in healthcare, sports, defense, public security and personal communications [1-3]. The antenna is a key front end component in any wireless system. Although many antennas have been designed over past decades, still there are several challenges when designing such antennas for modern systems. These challenges include space constraints, compactness, weight, cost effectiveness and desired radiation characteristics. Moreover, multi-band operation in addition to advanced features such as, reconfigurability, interference mitigation, and stable performance under varying conditions make designing more difficult for antennas designers.

In past, we have reported several narrow-band antennas with full ground planes for wireless body area networks [4-10]. These antennas provide single- and dual-band operation for the 2.45GHz ISM band and for 4.9GHz public safety WLAN/5GHz IEEE 802.11 WLAN. These antennas have significant advantages of compactness (only 14mm wide), a wide radiation pattern over the body surface to provide maximum coverage, full ground plane that reduces radiation towards the body, and less sensitivity to the variation of the gap between the antenna and the human body. These advantages make them suitable for on-body communications and wearable applications. In this paper we investigate their performance over the human body equivalent phantom.



(a)

(b)

Figure 1. Antennas considered for measurement over human body equivalent phantom (a) Antenna-I (b) Antenna-II.

2. Human Body Phantom

To analyze the performance of designed antennas, three layer human tissue body model is considered for simulations. For measurements, gels equivalent to human body tissues are used. The gels were manually prepared at Electro Science Lab at Ohio State University, USA, and measurements were also performed there. Table I presents the theoretical and measured properties of skin, fat and muscle tissues. These gels consist of gelatin A, polyethylene glycol mono phenyl ether (Triton X-100), sodium chloride, de-ionizing water, vegetable oil, soap and food coloring. Different cases were considered and the communication between the antennas has been observed over the female phantom filled with muscle equivalent gel, and having layers of skin and fat equivalent gels.

3. Results

Only two of the considered communication cases due to space constraint are presented here. Results show that the antennas has acceptable performance over the female body phantom

CASE-1:
First case, when Antenna-I and Antenna-II are placed over the abdomen as shown in Fig. 2 The corresponding reflection and transmission behaviors are shown in Fig. 3. In this case both antennas are having partially filled nulls facing each other (i.e. partially filled nulls are present in direction opposite to feed).

Figure 2. Placement of antennas over the phantom for Case-I.

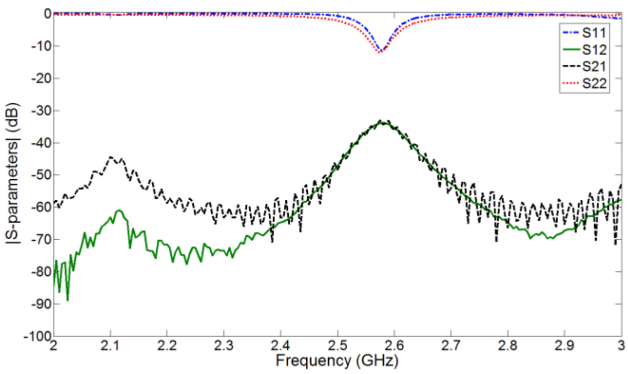


Figure 3. Measured S-parameters corresponding to Case-I.

CASE-1I:
When Antenna-I and Antenna-II are placed over the chest and the abdomen, respectively, as shown in Fig. 4. The corresponding reflection and transmission behaviors are shown in Fig. 5. In this case both antennas are having lobes facing each other (i.e. lobes are present along the antenna's length).

Table I. Measured properties of gel equivalent tissue model at 2.45GHz.

Tissue	Theoretical ε_r	Measured ε_r
Skin (2mm)	$38.01+i*10.74$	$38.09+i*2.65$
Fat (10mm)	$5.28+i*0.77$	$7.95-i*1.88$
Muscle (Phantom)	$52.73+i*12.76$	$69.88+i*15.80$

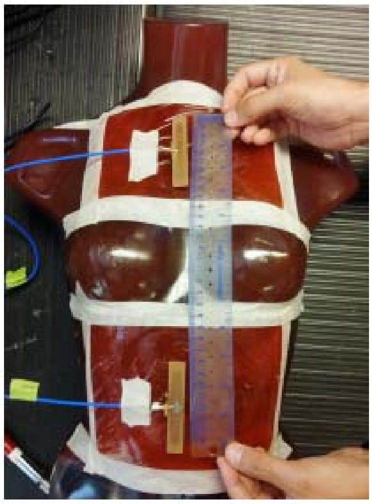


Figure 4. Placement of antennas over the phantom for Case-II.

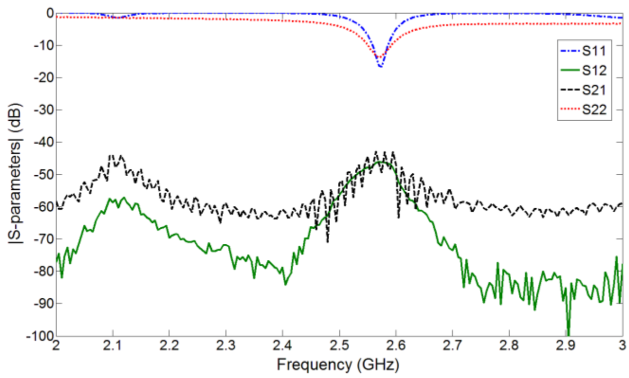


Figure 5. Measured S-parameters corresponding to Case-I.

4. Conclusion

Compact antenna designs are presented for on-body communications and their performance has been investigated for near-body scenarios. Results shown that these antennas can successfully communicate when placed in close proximity to the human body. They offer significant advantages of light weight, low profile, wide radiation pattern for maximum coverage over the body surface, minimum radiation towards the body due to full ground plane and stable performance under varying distance between human body and antenna, thus making them suitable for wearable applications

7. References

1. P. S. Hall and Y. Hao, *Antennas and propagation for body-centric wireless communications*: Artech House, 2006.

2. H. Khaleel, *Innovation in Wearable and Flexible Antennas*: WIT Press, 2014.

3. M. R. Yuce and J. Khan, *Wireless Body Area Networks: Technology, Implementation, and Applications*: Pan Stanford, 2011.

4. Syed Muzahir Abbas, Yogesh Ranga, and Karu P. Esselle, "A Printed Antenna with a Ground Plane and Electromagnetically Coupled Feed for 2.45GHz Body Area Networks," presented at the IEEE AP-S/USNC-URSI Symposium, Orlando, Florida, USA, July 7- 13, 2013.

5. Syed Muzahir Abbas, Yogesh Ranga, and K. P. Esselle, "Stub-Loaded Printed Antenna with a Ground Plane and Electromagnetically Coupled Feed for 2.45GHz Body Area Networks," in *IEEE MTT-S International Microwave Workshop Series on RF and Wireless Technologies for Biomedical and Healthcare Applications (IMWS-Bio 2013)*, Singapore, December 9-11, 2013.

6. Syed Muzahir Abbas, Karu P. Esselle, and Yogesh Ranga, "A Printed Dual Band Antenna with a Ground Plane and Electromagnetically-Coupled Feed for Wireless Body Area Networks," presented at the The International Workshop on Antenna Technology (iWAT), Sydney, Australia, March 4-6, 2014.

7. S. M. Abbas, K. P. Esselle, and Y. Ranga, "An armband-wearable printed antenna with a full ground plane for body area networks," in *Antennas and Propagation Society International Symposium (APSURSI), 2014 IEEE*, 2014, pp. 318-319.

8. Syed Muzahir Abbas, Yogesh Ranga, and Karu P. Esselle, "A Switchable Printed Antenna with a Ground Plane for 2.45/5 GHz Wireless Body Area Networks," presented at the The International Workshop on Antenna Technology (iWAT), Seoul, Korea, March 4-6, 2015.

9. Syed Muzahir Abbas, Yogesh Ranga, and Karu P. Esselle, "Reconfigurable Antenna Options for 2.45/5 GHz Wireless Body Area Networks in Healthcare Applications," in *37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, Milano, Italy, 2015.

10. Syed Muzahir Abbas, Yogesh Ranga, and Karu P. Esselle, "Sensitivity of a Wearable Printed Antenna with a Full Ground Plane in Close Proximity to Human Arm " in *9th European Conference on Antennas and Propagation*, Lisbon, Portugal, 2015.