Compact Size of Textile Wearable Antenna

Eng Gee Lim, Zhao Wang, Mark Leach, Rong Zhou, Ka Lok Man and Nan Zhang

***Abstract*— The utilization of wearable antennas has rapidly developed in recent years for miniaturizing wireless communication devices. The main advantage of wearable antennas is that they are designed as clothing parts for transmitting or receiving wireless signals. The wearable antenna system plays an important role in many field applications, including tracking and navigation. This paper examines the performance of a rectangular microstrip antenna with different substrates/textiles. In addition, to significantly reduce the size of the antenna, the short circuit pins method has been proposed as part of the antenna design. With the proposed method, the antenna size has been reduced from 47.4 mm x 54.06 mm to 20 mm x 41 mm (approximate 68% area reduction).**

***Index Terms*— Wearable, Antenna, Wireless, Miniaturizing, Textile**

I. INTRODUCTION

WEARABLE antenna can be designed as clothing sections, for communication purposes, such as tracking and navigation. They have features such as small size, light weight, low fabrication cost, and unobtrusiveness. Hence, the utilization of wearable antennas has developed rapidly in recent years [1]. The tactical vest antenna system (TVAS) in figure 1 is an application example of a wearable antenna system designed for United States military armed forces. It consists of two antenna inserts, two interconnecting cables, and a cable for radio connection. It is of light weight and is concealable. This type of wearable antenna helps conceal the identity of the radio operator, which provides the crucial link among the ground troops, support units, aircrafts, quick reaction forces, etc. It can also improve troop mobility by reducing the amount of gear attached to the body armour. The weight of the vest is about 255.14 grams and the impedance is 50 Ω. It has a size of 12” x 9’’ [2].

The main distinction of a wearable patch antenna from a regular patch is that the antenna substrate is often made of textile fabrics, because fabric antennas can be easily integrated into clothes. Textiles with a low dielectric constant can reduce the surface wave loss and improve impedance bandwidth [3].

However, wearable antenna is a newly established field, and much work needs to be done. Since the antenna should be suitable for wearing it should have a small size and be flexible. Also, it should withstand bending caused by human body movement. Nevertheless, it should be noted that the textile materials are compressible, so their density and thickness may change with pressure. If the antenna is made by textile fabrics, errors may be caused.

Fig 1: Tactical vest antenna system [2]

The operation frequency of the wearable antenna is set at 2.4 GHz, within the Industrial, Scientific and Medical (ISM) band. ISM radio bands are radio bands reserved for radio frequency (RF) energy use for industrial, scientific and medical purposes other than telecommunications [4].

The wearable antenna in this paper is based on microstrip technology. Microstrip is a kind of electrical transmission line used to transmit microwave-frequency signals. It consists of three layers and can be fabricated on printed circuit board (PCB). The ground plane is at the bottom. The substrate lies in the middle to separate the radiating metallic strip on the top from the ground plane [5].

Microstrip antennas are also referred to as patch antennas. The shape of the patch can be square, rectangular, dipole, circular, elliptical, circular rings or ring sector [6]. In this paper, the patch is rectangular.

Patch antennas have a metalized deposit on a plane dielectric substrate which allows for a very thin printed-conductor topology of any shape. Microstrip is much less expensive than traditional waveguide technology, as well as being far lighter and more compact. Its low profile planar configurations can be made conformal. In addition, it has a low fabrication cost and are amenable to mass production.

To design a textile antenna, knowledge of the electromagnetic properties such as permittivity and the loss tangent of the textile material are required. Conductive textiles such as Zelt, Flectron and pure copper polyester taffeta fabrics are commonly used as radiating elements

Manuscript received November, 2013; revised January, 2014. This work is partially supported by the Natural Science Foundation of Jiangsu province (Grant No. BK20131183) and Suzhou Science and Technology Bureau (Grant No. SYG201211).

E.G. Lim, Z. Wang, M. Leach, R. Zhou are with the Department of Electrical and Electronic Engineer- ing, Xian Jiaotong-Liverpool University, China. Email: {enggee.lim, zhao.wang, mark.leach, rong.zhou}@xjtlu.edu.cn

K. L. Man and N. Zhang are with the Department of Computer Science and Software Engineering, Xian Jiaotong-Liverpool University, China. Email: ka.man, nan.zhang@xjtlu.edu.cn

while non-conductive textiles such as silk, felt and fleece are used as substrates [7].

The human body may also have an effect on the antenna. However in this paper, all simulations are based on the models built in free-space and the effects of the body are left for future research. This paper examines the performance of rectangular microstrip antenna with different substrates/ textiles. In addition, in order to significantly reduce the current size of the antenna, the short circuit pins method on the antenna has been proposed.

II. Design

The design of a wearable antenna in this paper is based on the microstrip. A typical microstrip antenna consists of three layers, ground plane, substrate and the conductor patch. The input impedance should be 50 Ohms, while the resonant frequency should be 2.4 GHz.

This paper aims to examine the performance of a rectangular microstrip antenna with different substrates/ textiles. There are four different substrate/textile materials examined in this paper, namely, wash cotton, curtain cotton, polyester and polycot. The size of the ground plane and the fabric substrate is 120 mm x 120 mm. The thickness of the top metallic layer is 0.1mm, while that of the ground plane is 0.5mm. The material of these two planes is annealed copper. The designed parameters are shown in table 1.

The configuration of the patch antenna is shown as in figure 2.

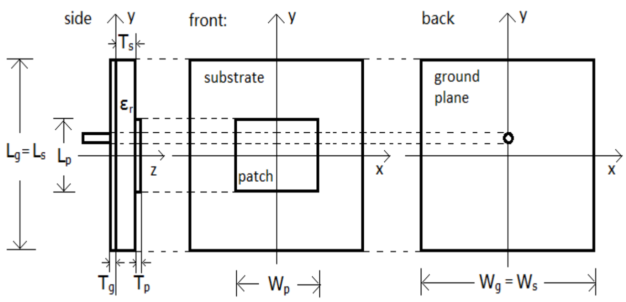

Fig 2: The configuration of the patch antenna.

III. RESULTS

A. Antenna with four textile materials

The wearable antenna is manufactured as shown in Figure 2. After re-optimising the feed position of the source, simulations are carried out over the frequency range of 2 GHz to 3 GHz. The results of four textile materials are shown below.

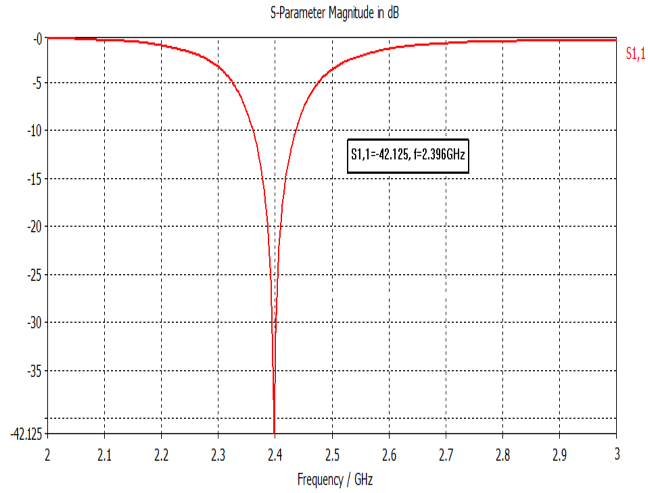

Figure 3: The simulated return loss of patch antenna with wash cotton as a substrate.

In figure 3 the resonant frequency of the patch antenna with wash cotton as a substrate is 2.396 GHz and the return loss is -42.125 dB.

TABLE I.
The antenna design specifications

Design parameters	Antenna 1	Antenna 2	Antenna 3	Antenna 4
Insulating fabric material employed	Wash cotton	Curtain cotton	Polyester	Polycot
Resonant frequency (GHz)	2.4	2.4	2.4	2.4
Substrate dielectric constant (ε_r)	1.51	1.47	1.44	1.48
Loss tangent of the substrate	0.02	0.02	0.01	0.02
Substrate thickness (Hs: mm)	3.0	3.0	2.85	3.0
Patch length (L) in mm	46.9	47.4	47.9	47.5
Patch width(W) in mm	54.65	55.06	55.43	55.20
Ground plane and substrate dimension(W x L: mm x mm)	120x120	120x120	120x120	120x120

ISBN: 978-988-19253-3-6
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

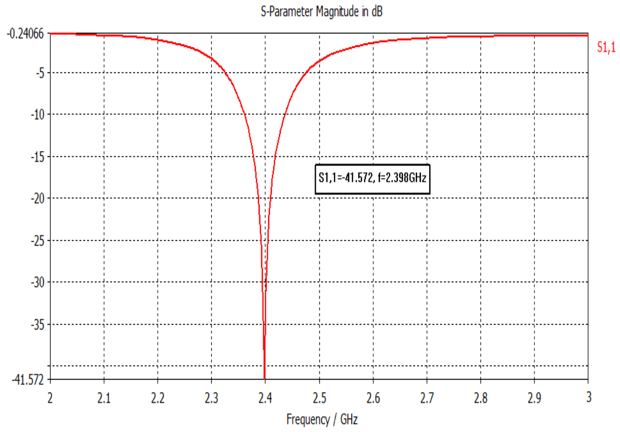

Fig 4: The simulated return loss of patch antenna with curtain cotton as a substrate.

In figure 4 the resonant frequency of the patch antenna with curtain cotton as a substrate is 2.398 GHz and the return loss is -41.572 dB.

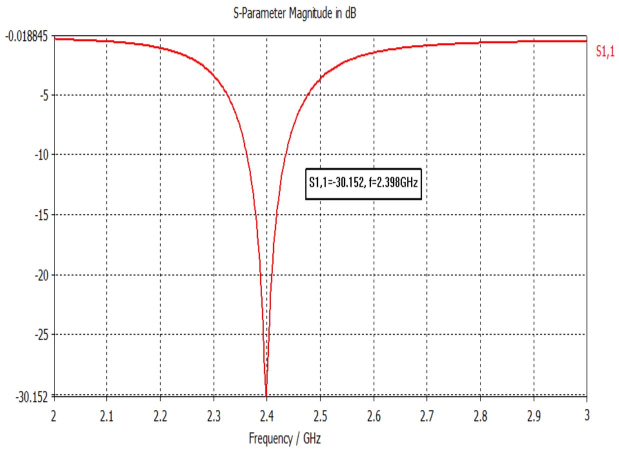

Fig 5: The simulated return loss of patch antenna with polyester as a substrate.

In figure 5 the resonant frequency of the patch antenna with polyester as a substrate is 2.398 GHz and the return loss is -30.152 dB.

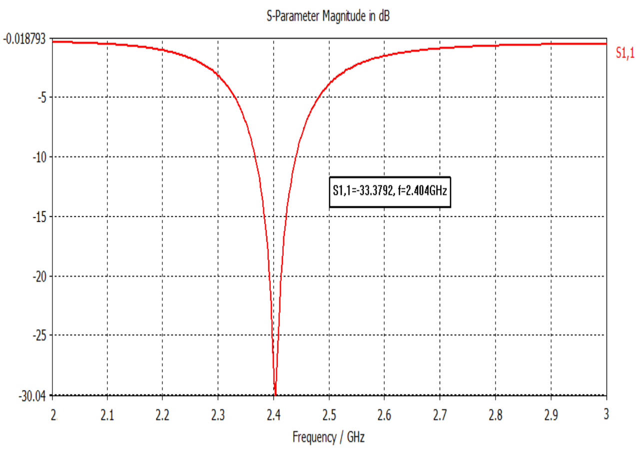

Fig 6: The simulated return loss of patch antenna with polycot as a substrate.

In figure 6 the resonant frequency of the patch antenna with curtain cotton as a substrate is 2.404 GHz and the return loss is -33.3792 dB.

From the results above, it can be seen that at the resonant frequencies, around 2.4GHz, the return losses of these antennas with polycot and polyester as the substrates are about -30dB, while those with wash cotton and curtain cotton are about -40dB. Hence, curtain cotton and wash cotton displays better performance for the same antenna configurations.

B. Compact size of wearable antenna

From a return loss point of view, the antenna designs with four textile materials are very similar. Therefore only the antenna with curtain cotton as a substrate will be used to design the proposed compact size antenna.

In order to change the resonant frequency, some metallic pins are inserted between top patch and ground plane as shown in figure 7.

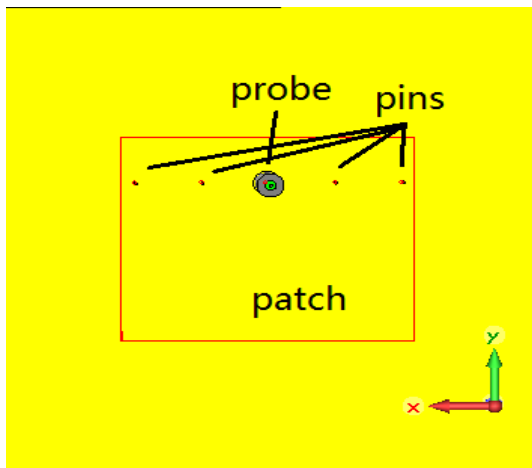

Fig 7: Patch antenna with four inserted pins.

By examining different insert positions and varying the number of the pins, it can be found that when the pin (pins) is inserted to the left side or right side or both sides of the probe, the resonant frequency and return loss will change significantly. However, if the pin is inserted right above or below the probe, there is only slight change on the resonant frequency and return loss.

Based on the design configuration shown in figure 7, the patch size is reduced. The patch width Wp is reduced from 55.06mm to 41mm, while the length Lp is reduced from 47.4mm to 20mm (in x-y coordinate, Lp max=10.9mm, Lp min=-9.1mm). The patch size is reduced to about (32%) of the original size. After the size reduction, the antenna is simulated again. The resonant frequency is re-optimised to 2.4GHz as shown in figure 8.

ISBN: 978-988-19253-3-6
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

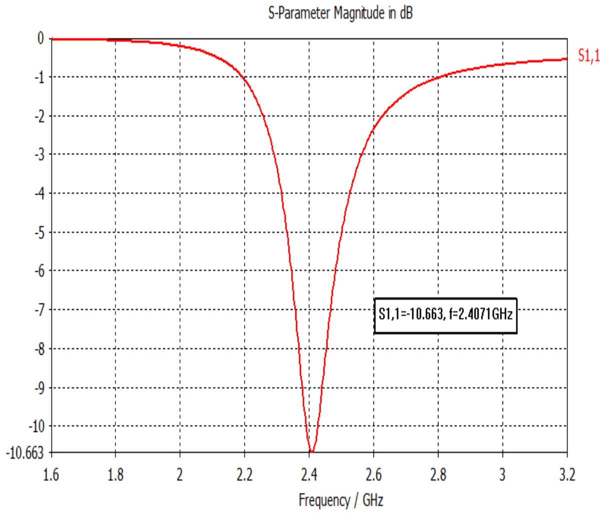

Fig 8: Retun loss of patch antenna with four inserted pins.

IV. Conclusions

In this paper the characteristics of patch antennas with different textile substrates are investigated. At the resonant frequency of around 2.4GHz, the return losses of both wash cotton and curtain cotton less than -40dB, while those of polyester and polycot are around -30dB. The ideal return loss should be minus infinity, hence, the antennas with substrates of wash cotton and curtain cotton seem better than those with polyester and polycot.

By introducing metal pins connecting the top patch and ground plane, the resonant frequency of the antenna has been changed. When the pins are inserted through the plane to the left or right side or both of the antenna feeding point, the resonant frequency and return loss were changed significantly. However, when the pins are inserted right above or below the antenna feeding point, the changes were negligible. The patch size is the main influence on the resonant frequency of the antenna. The resonant frequency is increased by reducing the width and length of the antenna. Hence, by combining pins insertion and patch size reduction, the size can be minimized while the resonant frequency is maintained. With the proposed method, the antenna size has been reduced from 47.4mm x 54.06mm to 20mm x 41mm (approximate 40% reduction)

In this paper, only four textile materials have been examined and the antennas are only modeled in free-space. In the future, more materials will be examined and the case when these antennas are worn on the body should also be taken into consideration to see how human body may influence the antenna.

Rreferences

[1] C. Balanis, “Antenna Theory: Analysis and Design”, John Wiley, 2005.

[2] Wearable Antenna Technologies Inc. (2013), Tactical Vest Antenna System, [Online]. Available: http://wearableantenna.com/tactical_vest_antenna_system

[3] B. Gupta, S. Sankaralingam, , S. Dhar, Development of wearable and implantable antennas in the last decade: a review, In 2010 Mediterranean, Guzelyurt, pp. 251–267. Aug. 2010

[4] E. G. Lim, M. Mathian, E. Korolkewicz, P. Gale,: “Design of a Circularly Polarized 2□2 Patch Array 2.45 GHz ISM Band”, Microwave Journal, May 2002.

[5] E.G. Lim, Z. Wang, G. Juans, N. Zhang and K. Man, “Design and Optimization of a Planar UWB Antenna”, *in IEEE Proceedings of the 11th East-West Design and Test International Symposium (EWDTS'13)*, Rostov-on-Don, Russia, September 2013.

[6] E. G. Lim, Z. Wang, C. Lei, Y. Wang, K. Man, “UWB Antennas – Past and Present”, *IAENG International Journal of Computer Science*, Vol. 37, Issue 3, pp 304-314, August 2010.

[7] N.H.M.Rais, P.J.Soh, F.Malek, S.Ahmad, N.B.M.Hashim, P.S Hall, “A Review of Wearable Antenna”, *2009 Loughborough Antennas & Propagation Conference*, Loughborough, UK. November 2009.