Textile Antennas for On-Body Communications: Techniques and Properties

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Abstract—Due to the increased demand on multi-frequency and multi-function antenna to be utilised in smart clothing and future consumer-centric communication technologies, fabric and textile antenna designs have received a vast amount of attention in the last few years. The fabrication techniques and materials used in designing textile antennas play a significant role in defining and determining the overall performance. This paper investigates different methods of fabrications applying various material types to analyse the effect those parameters have on a rectangular microstrip patch antenna to be deployed in general wearable applications providing cost-effectiveness, ease of system integration and immunity to performance degradation when placed on the body.

1. INTRODUCTION

The ultimate wireless body area network should allow users to enjoy those applications and more with transmission without interferences, low transmission power and low complexity due to network organisation by base station, extremely small hardware, broadband local area communication and Ad-hoc networking, simple channel and source coding and scalable data rates [1], [2].

Body area networks have distinctive features and requirements that make them different in comparison to other wireless networks. This includes the additional restriction on electromagnetic pollution due to proximity to the human body which requires extremely low transmission power. The devices deployed within BAN have limited sources of energy due to their compact and small size. Fuelled by the idea of user-centric approach to future communication technology, many research projects have been initiated, under the concept of smart clothing/textile, to integrate antennas and RF systems into the clothes with regards to size reduction and cost effectiveness, so the wearer will not notice the existence of these sub-systems [3]–[8]. The effect of the human body on the operation of antennas located in close proximity has been investigated widely and thoroughly in open literature [6]–[8], including the absorption of energy within the body and on specific absorption rate (SAR) for proximate antennas and of the propagation on and off the body for use in mobile phones.

Salonen et al has addressed the design and development of dual-band textile antenna for wearable applications in [3]. Fleece fabric was considered to design antenna for GSM and WLAN bands. The study highlighted the necessity of understanding accurately the sensitivity of dielectric constant of textile materials. The fabricated dual-band textile antenna had good agreement with predictions, however, the effect of conformal placement of the antenna on the body and the influence of non-planar textile surface on the antenna performance has not been analysed in great details.

Although the main application of body-worn sensors and antennas surfacing currently is within the medical engineering community, the military and army have been investigating the potential applications of flexible and hidden wearable antennas for communication purposes for long time especially in the UHF and VHF bands. The key objective of these studies within the military engineering community is to achieve and provide flexible, efficient, multi-functions, multi-bands and hidden antenna systems that can provide reliability and also security to the soldier [9], [10].

The textile antenna integration techniques and hence antenna performance are critical for producing efficient and reliable communication links for body-worn devices. In this paper we investigate various fabrication techniques of textile microstrip antennas and therefore the antenna parameters including return loss and radiation characteristics as function of materials and fabrication methods. More results and detailed parametric comparison between the designed antenna structures are to be presented in the conference.

2. TEXTILE ANTENNA FABRICATION

A. Antenna design

Wire antennas operating in stand alone modes and planar antennas directly printed on substrate will experience changes in wavelength and hence deviation in resonance frequency, depending on the distance from the body. On the other hand, antennas with ground planes or reflectors incorporated in their design (e.g. microstrip patch antennas) will experience less effect when placed on the body from operating frequency and impedance matching respects independent of distances from the body.

In direct relation to antenna patterns and with great interest in wearable antennas is the front-back ratio that defines the difference in power radiated in opposite directions wherever the antenna placed. The ratio varies depending on antenna location on the body and also on the antenna applied [11]. For example, the presence of the ground plane in the microstrip patch antenna causes the current and electric field travelling backwards to be reflected which raises other phenomenon out of this chapters scope, hence the front-back ratio when antenna placed in free space and on the body is not significantly
different, which is not the case for conventional dipole or monopole antennas.

Based on these theoretical considerations the patch antenna was chosen for investigations of different textile antenna structures. Figure 1 presents the dimensions of the microstrip patch antenna applied in the study discussed in the paper.

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**B. Fabrication techniques**

There are various techniques to fabricate textile antennas. In this study four various methods are adopted as follow.

- Copper Foil: The simplest of the methods and it involves the application of commonly available copper tapes that can be directly applied to the substrate of interest (in this case textile fabrics) with no extra fabrication processes.
- Copper Mesh: In this technique, copper thread is woven into the textile substrate which offers more stable and rigid structure comparing to the copper taper method.
- Conductive spray: A spray with a mixture of copper with gases under pressure can be used to obtain a conductive layer in the surfaces of the textile exposed to the spray. This method provides flexibility and reliability for general textile antenna design.
- Copper with rubber: Mixture of conductive nano-particles and rubber to produce flexible and rigid conductor layers to be applied in textile antenna and general textile electronic structures.

**3. EXPERIMENTAL ANALYSIS**

The microstrip patch antenna design presented in Fig. 1 is fabricated using the first three techniques described in the previous section, Fig. 2.

The experimental analysis presented here is related to the textile antenna fabricated applying woven copper thread on leather substrate with relative permittivity of $\epsilon_r=2$ and conductivity of 0.001 S/m. The antenna performance is investigated for both free space and on-body cases. Figures 3 and 4 show the proposed textile patch antenna placed on the human chest and conformal on the human arm, respectively.
4. CONCLUSION

For wireless body area networks to be applicable and accepted by the users and the consumer market, the radio system components, including the antenna, need to be somehow hidden and small in size and weight. This requires the possible integration of these systems within everyone’s daily clothes. The paper presented textile patch antennas designed applying various fabrication techniques to highlight the effect of material type and property on the general antenna performance. Experimental analysis demonstrated the effect of human body presence on the antenna return loss and radiation pattern in comparison to stand-alone cases. Placing the textile antenna conformal to certain parts of the human body proved to degrade performance slightly by introducing frequency detuning and hence pattern deformation at the resonance frequency.

The selection of the substrate is also a good challenge in order to get materials with low conductivity and losses, and with good values of flexibility and permeability. Results of these techniques and differences between them are shown in the conference presentation.

REFERENCES


