An Accurate Technique to Model the Substrate of Wearable Textile Antennas

Ghufran M. Hatem, Ali J. Salim, and Jawad K. Ali
Microwave Research Group, Department of Electrical Engineering, University of Technology, Iraq

Abstract— The utilization of wearable textiles in the antennas has shown a dramatic increase due to the recent challenges imposed on wireless devices to be miniaturized. For RFID purposes, a wearable antenna is meant to be a part of the clothing used. This includes tracking and navigation, mobile computing and public safety applications. Investigating the wearable textile antennas reported in the literature, it has been noted that when modeling the antenna using the commercially available EM simulators, the substrate (textile) has been dealt with as a solid homogenous material. This is fact is not the case, since the textile as a substrate is composed of woven threads (fibers). As a result, this adds some inaccuracy when comparing the simulated results with measured ones. In this paper, the textile antenna material, as a substrate, has been modeled in a way closer to the real practice. It has been modeled as horizontal and vertical fibers with different thread levels. A case study, representing a wearable textile antenna structure, has been investigated and the relevant textile material is being modeled using the proposed modeling technique. Simulation results of the antenna return loss responses using the proposed modeling technique; have shown to be more accurate than those obtained using the conventional modelling technique in that they are more close to measured results relevant to the antennas involved in the case study.

1. INTRODUCTION

Wearable and textile-based antennas have attracted more attention for the use in body-centric communications because of the ease to be integrated into clothes. The electromagnetic properties of the textiles play important roles in antenna design and performance [1]. This will include the adopted woven threads and the concentration of threads. The dielectric behaviour of textile materials are highly dependent on the properties of their contained fibers and polymers, and on fiber packing density in the fibrous materials. However, textiles fabrics are rough, porous and heterogeneous having air in between the fibers, making their characterization difficult [2].

Investigating the wearable textile antennas reported in the literature, it has been noted that when modeling the antenna using the commercially available EM simulators, the substrate (textile) has been dealt with as a solid homogenous material. This fact is not the case in the real practice, since the textile as a substrate is composed of woven threads (fibers). As the results, this adds some inaccuracy when comparing the simulated results with measured ones.

In this work simulated the textile material has been modeled and built as horizontal and vertical threads woven as textile with a suitable radius for each thread which will results in the electromagnetic features for the material. In order to make insure the efficiency of the proposed method for modeling the wearable antenna printed on a textile substrate, and because of the disability to make the measurement on the proposed antenna, use of the proposed antenna simulation technique has been applied to modeling one of the wearable textile antennas reported in literature.

2. THE PROPOSED TEXTILE MODELING

The proposed method for modeling the textile material of a wearable antenna is demonstrated in Figure 1, where a dual-band E-shaped textile antenna for wearable applications is depicted [3]. The substrate has been considered to be felt fabric for the antenna to offer dual-band resonant response. Figure 1(b) shows a magnified portion of the substrate in the form of textile. The magnified portion of the substrate reveals how the textile material has to be modeled using the commercially available Finite Integration Technique (FIT) based EM simulator, CST Microwave Studio (CST MWS) [4]. In addition to the woven vertical and horizontal threads that compose the textile material, there will be some air gaps thoroughly distributed amongst the threads.

The proposed modeling technique of the textile materials, as being prescribed, will add some reality to the modeling process in that the textile is composed of threads and air. Consequently, simulation results are expected to be more close to the measured ones as compared with those based on the conventional modeling of textile as a homogenous solid material.

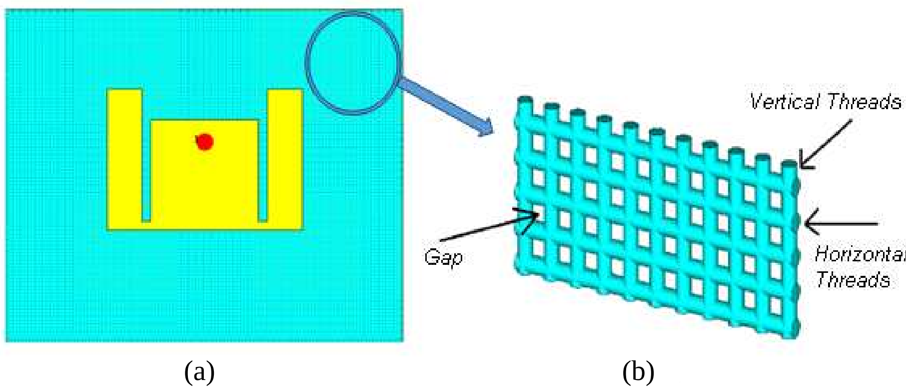

Figure 1: (a) The layout of the modeled antenna, and (b) a magnified portion of the modeled textile substrate material.

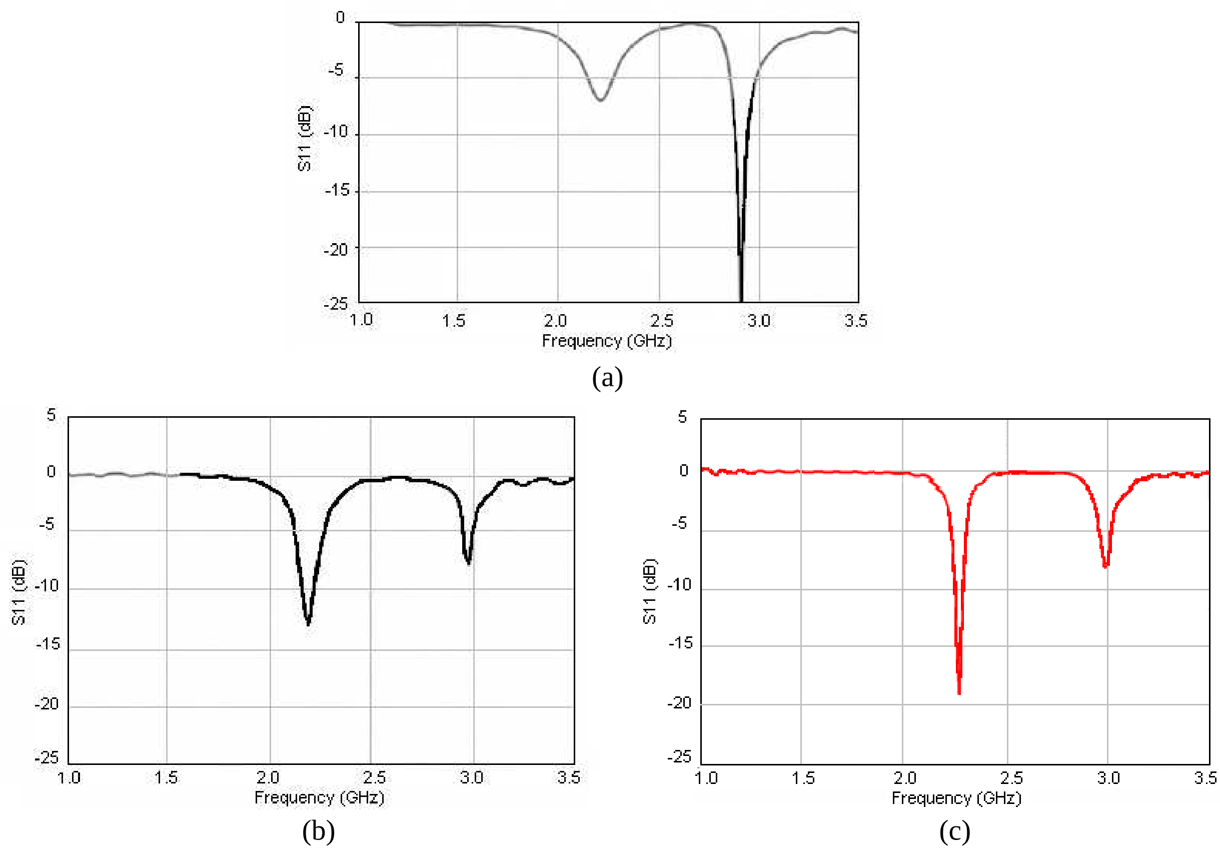

Figure 2: The modeled antenna performance: (a) simulated results using the conventional modeling technique, (b) measured results, and (c) simulated results using the proposed modeling technique.

This antenna has been simulated by a conventional method where the substrate is considered solid and homogenous material, as shown in Figure 2(a). Measured results of the antenna return loss are depicted in Figure 2(b). Simulation results of the antenna return loss, using the proposed textile modeling technique are shown in Figure 2(c).

3. VALIDATION OF THE PROPOSED METHOD

Figure 2 summarizes the adopted dual-band wearable antenna performance in terms of its input reflection coefficient. Simulated results using the conventional method are shown in Figure 2(a), while Figure 2(b) demonstrates the measured results of the fabricated prototype. Results depicted in Figure 2(c) represent the antenna performance as simulated using the proposed modeling technique. In an attempt of comparison, Table 1 presents the main features of the antenna performance in terms positions of the dual-band resonant frequencies and the relevant reflection coefficient levels. It is quite clear that simulated results using the proposed modeling technique are in better agreement with the measured one the those simulated using the conventional modeling technique in both the positions of the resonant bands and the corresponding reflection coefficient levels.

Table 1: Summary of the antenna performance evaluation.

Parameters	f_1 (GHz)	S_{11} (dB)	f_2 (GHz)	S_{11} (dB)
Measured [3]	2.23	−12.5	2.9	−7.5
Simulated [3]	2.20	−7.0	2.8	−25
Simulated (proposed)	2.24	−19.0	2.9	−8.5

4. CONCLUSIONS

In this paper, the substrate material of a wearable antenna has been modeled as horizontal and vertical threads woven as textile with suitable radii, in an attempt to obtain more accurate results as compared with the case where the textile material is considered as a solid homogenous material. The proposed technique has been applied to assess the performance of a fabricated antenna reported in the literature. Simulation results, using the proposed modeling technique, are found better than those obtained using the conventional method. The results using the presented technique are more close to the measured ones in both the positions of the resonant frequencies and the levels of the antenna input reflection coefficient. To gain more insight about the validity of the proposed modeling technique, it has to be justified in terms of the other antenna parameters such the antenna gain and radiation characteristic in addition to the input reflection coefficient.

REFERENCES

1. Lui, N., Y. Lu, S. Qui, and P. Li, "Electromagnetic properties of electro-textiles for wearable antennas applications," *Frontiers of Electrical and Electronics Engineering in China*, Vol. 6, 563–566, 2011.
2. Salvado, R., C. Loss, R. Gonçalves, and P. Pinho, "Textile materials for the design of wearable antennas: A survey," *Sensors*, Vol. 12, No. 11, 15841–15857, 2012.
3. Salonen, P., J. Kim, and Y. Rahmat-Samii, "Dual-band E-shaped patch wearable textile antenna," *IEEE Antennas and Propagation Society International Symposium*, Vol. 1A, 466–469, 2005.
4. CST, Available Online: www.cst.com.