Intelligent Wristbands – Fabrication of Wearable RFID Solutions by 3D Printing Pen

Adnan Mehmood, Xiaochen Chen, Han He, Leena Ukkonen, Johanna Virkki
Faculty of Medicine and Health Technology, Tampere University, Tampere, Finland
{adnan.mehmood, xiaochen.chen, han.he, leena.ukkonen, johanna.virkki}@tuni.fi

***Abstract*—We present RFID (radio frequency identification)-based passive UHF (ultra-high frequency) wristbands fabricated with a 3D printing pen. The used 3D printing material is flexible and biodegradable, and thus suitable for fabrication of such inexpensive and widely useful wearable wireless platforms. The tag antenna (that is fabricated from conductive thread) and the RFID IC (integrated circuit) are embedded into the platform by using 3D-printed fasteners. This paper presents the wristband fabrication, ensures their reliability, and carries out practical testing in normal use environments. Based on the achieved results, the studied combination of conductive thread and 3D printing pen is a suitable fabrication solution for intelligent wearable platforms. The fabricated wristbands show high moisture reliability and excellent wireless performance in practical testing situations.**

***Index Terms*— Eco-friendliness, flexible electronics, passive UHF RFID, wearable electronics, 3D printing pen.**

I. Introduction

Wearable RFID (radio frequency identification) technology enables simple, cost-effective and reliable body-centric wireless systems. Thus, these solutions have gathered an extent of research interest in these years [1-8]. 3D printing, on the other hand, has enabled creation of inexpensive and quickly produced prototypes for versatile application fields. 3D printing pen is a fully mobile and extremely simple 3D printing method that enables use of flexible and eco-friendly materials for printing. It has already been successfully used in fabrication of substrates and platforms for passive RFID tags [9,10].

In this paper, a 3D printing pen is used in fabrication of passive RFID-based intelligent wristbands. The tag antenna inside the wristband is fabricated from conductive thread. The antenna and the RFID IC (integrated circuit) are embedded inside the platform by using 3D printed fasteners. Thus, no other materials or chemicals are needed in wristband fabrication. The used material in printing is flexible and biodegradable and thus suitable for fabrication of such simple but widely useful wearable solutions. The paper presents the wristband fabrication, ensures their reliability in water (as in practical use these wristbands need to endure continuous sweating and washing), and performs practical wireless testing in normal use environments.

II. Wristbands

For wristband fabrication, we are using a simple 3Doodler printing pen with fully biodegradable and bisphenol A (BPA)-free printing material (Eco-plastic) [11]. The printed layers of the wristband platforms are horizontally aligned, as visible in Fig. 1. The antenna is fabricated from conductive thread (Shieldex multifilament yarn 110f34 dtex 2-ply HC), with resistance of 500±100 Ω/m and diameter of 0.16 mm. The dimensions of used antenna design (already successfully used e.g. in [9, 10]) are presented in Fig. 1. The total length of one antenna round is 29.2 cm. In order to improve the performance of the wristband, we are using a total of four rounds of conductive thread for the wristband antenna.

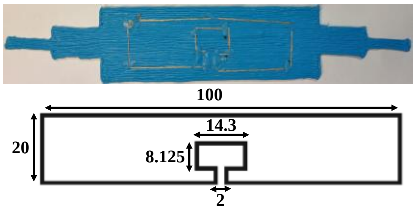

Fig. 1. Platform with integrated antenna (top) and antenna dimensions in millimeter (bottom).

The used RFID IC (integrated circuit) belongs to NXP UCODE G2iL series. It comes with 3×3 mm^2 copper pads fixed on a plastic sheet for antenna attachment. The threshold wakeup power of the chip is –18 dBm (15.8 µW). The tag antenna and the IC component inside the 3D-printed wristband are firstly attached with 3D-printed fasteners. The process is completed with a 3D-printed protective top layer. This manufacturing solution of wireless platforms is successfully tested for the first time in [9].

In this study, the tag platform is bent at a radius of 3.75 cm and the shape of a wristband is made by attaching the end-points of the platform with 3D printed fasteners. A readymade wristband is shown in Fig. 2. Although 3D printing pen fabricated platforms have showed suitable reliability in a previous study [10], the moisture reliability of the ready-to-wear wristbands is ensured by placing them into water for 5 minutes, as shown in Fig. 2.

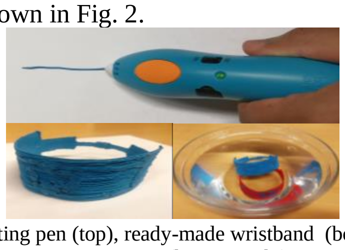

Fig. 2. 3D printing pen (top), ready-made wristband (bottom left), and moisture test (bottom right).

III. Wireless Evaluation

We firstly evaluate the performance of the wristbands inside an anechoic chamber by using Tagformance RFID measurement system. The time-average power detected at the receiver after tag's response to the transmitted power is called backscattered power. The threshold power as a transmitted power from the reader is used for the measurements of the backscattered power.

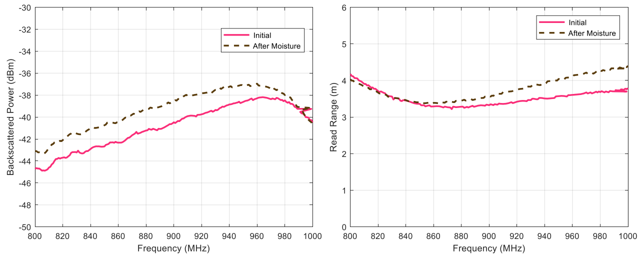

Fig. 3. Backscattered power (left) and read range (right) of wristband tag before and after moisture testing.

Fig. 3 shows the backscattered signal power from the wristband tag. We are showing the initial results as well as the results after the moisture test (measured right after taking the wristbands out from water). Based on these results, moisture does not seem to significantly affect the wristband performance. The most important finding is that after 5 minutes in water, the wristbands are still working effectively throughout the UHF RFID frequency band.

The theoretical read range is the maximal distance between the wristband tag and the reader antenna in free space. The measurement system calculates theoretical read range by using measured threshold power of wristband tag and the measured forward losses. As shown in Fig. 3, the initial read range of the wristband tag (without any disturbances from the environment & human body) is around 3.5 meters. The result is quite similar both in the European and US frequencies. As can be seen, water does not seem to significantly affect the read range of the wristband tags.

IV. PRACTICAL EVALUATION

Next, the fabricated wristbands are tested on-body in normal use environments, using a mobile UHF RFID reader (Nordic ID Medea). The wristbands are tested using the European UHF RFID center frequency band, which is 866 MHz. This mobile hand-held reader can be wirelessly connected to any system through WIFI. Thus, wristbands can be used for example for identification and access control. The practical testing situations are presented in Fig. 4.

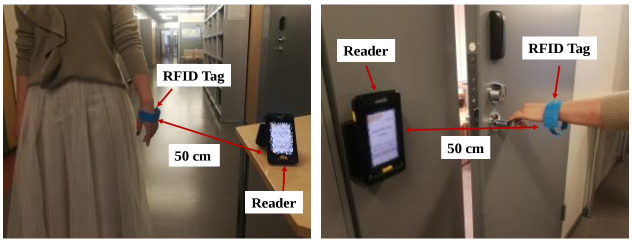

Fig. 4. Practical testing of wristbands for wireless tracking (left) and access control (right).

In the first situation, a female subject is passing through a corridor and the mobile reader is placed on the table. The reader detects the wristband tag at a distance of 50 cm. Next, the mobile reader is attached to a door, while the subject opens the door by grapping the door handle. Also here, the reader detects the wristband from a distance of 50 cm.

Based on these preliminary tests in real-time scenarios, these wristbands show potential for identification and tracking of people. The used read ranges of 50 cm are suitable for many practical use situations. Potential application environments are for example hospitals, nursery homes, and kindergartens.

V. CONCLUSION

We introduced cost-effective and eco-friendly intelligent wristbands fabricated by a 3D printing pen. The antenna (fabricated from conductive thread) and the RFID IC are embedded inside the wristband and attached with 3D-printed fasteners. These intelligent wristbands are accessible with a mobile RFID reader from a distance of 50 cm, while worn by a female test subject. Further, the wristbands remain fully functional in high moisture conditions. Thus, our preliminary results support the use of these wristbands for example for people identification and access control.

ACKNOWLEDGMENT

This work was supported by Jane and Aatos Erkko Foundation and Academy of Finland (294534).

REFERENCES

[1] X. Chen et al., "Fabrication and practical evaluation of glove-integrated passive UHF RFID Tags," 2018 IEEE International Conference on RFID Technology & Application (RFID-TA), Macau, China, 2018.

[2] T. Kaufmann, D. C. Ranasinghe, M. Zhou, C. Fumeaux, "Wearable quarter-wave folded microstrip antenna for passive UHF RFID applications," International Journal of Antennas and Propagation, Article ID 129839, 2013.

[3] C. Occhiuzzi, S. Cippitelli, G. Marrocco, "Modeling, design and experimentation of wearable RFID sensor tag," IEEE Transactions on Antennas and Propagation, vol. 58, no. 8, 2010.

[4] A. Mai, Z. Wei and M. Gao, "An access control and positioning security management system based on RFID," International Conference on Intelligent Human-Machine Systems and Cybernetics, pp. 537-540, Hangzhou, China, 2015.

[5] A. Mehmood et al., "Clothing-integrated RFID-based interface for human-technology interaction," Serious Games and Applications for Health (SeGAH), Kyoto, Japan, 2019.

[6] R. Krigslund et al., "A novel technology for motion capture using passive UHF RFID tags," IEEE Transactions on Biomedical Engineering, vol. 60, no. 5, 2013.

[7] S. Amendola, L. Bianchi, G. Marrocco, "Movement detection of human body segments: passive radio-frequency identification and machine-learning technologies," IEEE Antennas and Wireless Propagation Magazine, vol. 57, no. 3, 2015.

[8] R. Colella and L. Catarinucci, "Application of the pseudo-BAP mode to a 3D-printed wearable UHF RFID tag with sensing capabilities," International Conference on Smart and Sustainable Technologies (SpliTech), Split, Croatia, 2018.

[9] X. Chen, H. He, L. Ukkonen and J. Virkki, "3D-Printed eco-friendly and cost-effective wireless platforms," Electronics System-Integration Technology Conference (ESTC), Dresden, Germany, 2018.

[10] A. Mehmood, X. Chen, H. He, L. Ukkonen, J. Virkki, "Eco-friendly flexible wireless platforms by 3D printing pen," Progress in Electromagnetics Research Symposium (PIERS), Xiamen, China, 2019.

[11] 3Doodler website, https://intl.the3doodler.com (online accessed: Sep. 27, 2019).