AN EPIDERMAL CONFIGURABLE ANTENNA SYSTEM FOR THE MONITORING OF BIOPHYSICAL PARAMETERS

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Abstract

Skin sensors based on Radiofrequency Identification enable non-invasive monitoring of human physiologic parameters. To speed up the experimentations of new sensing modalities and their possible applications, a general-purpose on-skin oriented board is here described. A 3 cm by 3 cm flexible Kapton layer hosts a miniaturized open-loop antenna tuneable in the worldwide UHF RFID band 860-960 MHz, a microchip with internal ADC and pads for interconnecting external sensors and a battery for data-logging mode. When working in Battery Assisted Passive mode it can be read up to 1.5 m and hence the wearer can automatically upload the stored data in mobility. The device is preliminarily experimented in the measurement of the skin temperature and moisture on clothes.

Index Terms – Flexible Electronic, Skin sensor, Radiofrequency Identification.

I. INTRODUCTION

The measurement of biophysical parameters (temperature, sweat index and pH) directly detected onto the human skin can enable fast and non-invasive health monitoring procedures. The recent progress in epidermal electronics [1] and the consolidating Internet of Things technologies for healthcare [2] are currently stimulating the development of a new class of biocompatible skin-worn devices as an effective and low-cost booster for personal diagnostics and wellness. The wireless connectivity of the epidermal sensor with external nodes can be efficiently provided by the Radio-Frequency Identification (RFID) technology that permits to minimize the complexity of the required electronics.

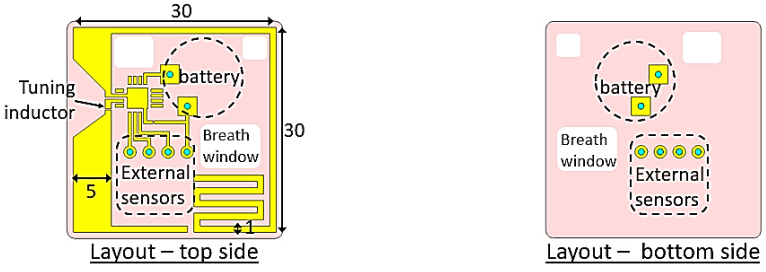
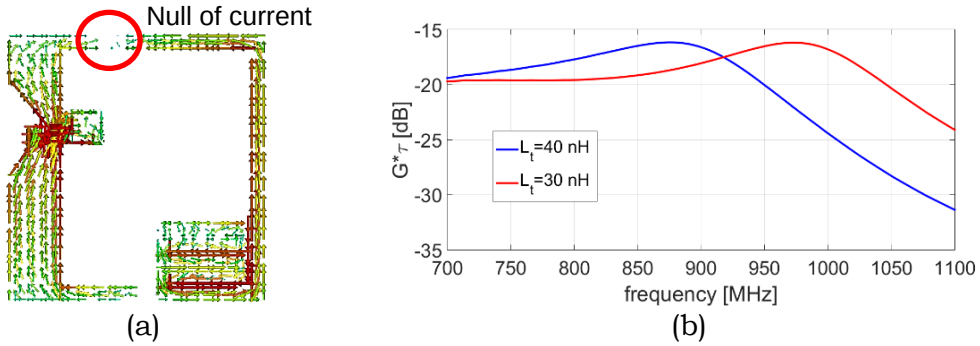


FIG. 1 – Layout of the RFID skin board: (a) main side with the antenna traces and (b) opposite side with replicated pads. Main sizes in [mm].

As the worldwide interest for skin electronics is continuously increasing, a general-purpose epidermal RFID board could ease the experimentation of new epidermal sensors, like a *lab on skin* [3]. In this perspective, we propose here a small-size flexible RFID antenna on a shaped open-loop layout, working in the UHF band (860-960 MHz). The device is suitable for on-skin placement, includes expansion ports for additional sensors and enables data-logging capability. Some examples of continuous monitoring of skin temperature and clothes moisture are reported.

II. SKIN ANTENNA LAYOUT

On-skin RFID data-loggers have to be considered as disposable devices and hence the complexity of the involved electronics has to be minimized. Currently the only available all-in-one RFID microchip with sensor-oriented features and capability to store the measured data into an internal memory is the AMS-SL900A IC [4]. This IC provides a native internal temperature sensor and a 10-bit ADC for sampling external sensors. However, this IC cannot be connected to a closed conducting path and, accordingly, conventional impedance matching techniques like the T-match and the Loop- or Slot-match cannot be used. With reference to Fig. 1, the selected antenna comprises a larger vertical trace, where the IC will be interconnected and whose width and gap position have been optimized to match the input resistance of the chip. The meander line portion is used to move the null of the current so that the two vertical traces will host equal-verse currents. A further degree of freedom is a tuning inductor inserted in series with the chip to change the working frequency of the antenna, e.g. to compensate specific placements over different parts of the body. Finally, the board is provided with some expansion pads for the interconnection of a battery and additional sensors. For improved general use, the terminals are also replicated in the opposite side of the substrate by means of via holes.



(a) (b)

FIG. 2 – (a) Surface current of the epidermal antenna at 868 MHz and (b) numerically evaluated realized gain for two values of the tuning inductors.

Fig. 2a shows the surface currents onto the antenna when it is placed over an homogeneous box model of human body ($\varepsilon_r = 55.1$, $\sigma = 1.02\ S/m$).

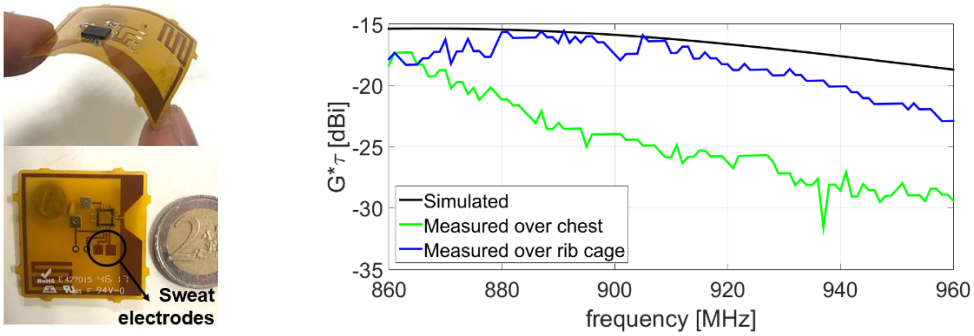
The actual combination of the inductor and the meander line length induces the required current pattern so that the antenna can be considered as a miniaturized folded dipole, in spite of the lower open termination. The realized gain for two values of the tuning inductor $L_t = \{30, 40\}\, nH$ are shown in Fig. 2b for application in the two extreme boundaries of the UHF RFID band.

The expected read distances in BAP mode are 1.4 m (EU) and 1.5 m (US), by assuming an $EIRP = 3.2\, W\ (EU), 4\, W\ (US)$. They are suitable for an automatic data download from the device as the user walks across a door that was equipped with an interrogating module.

III. PROTOTYPES AND PRELIMINARY TEST

A prototype (Fig. 3a) of the skin RFID sensor board was fabricated by etching a copper laminated Kapton substrate ($50\, \mu m$ thickness). A 3 V lithium coin battery was connected in series to the chip throughout a ferrite bead (Murata) to enforce a proper rejection of the RF component versus the chip DC port that will otherwise upset the chip. The resulting device is flexible and can be then embedded into a fabric plaster for healthy and comfortable application onto the skin and easy removal.

The realized gain G_R was measured by the turn-on method when the antenna was placed over two different parts of the body that are the chest and the rib cage of a female volunteer (Fig 3b). Despite some frequency shift and attenuation, probably due to the different electromagnetic behaviour of the considered body positions, the peak values ($-17.5\, dBi < G_R < -15.5\, dBi$) are comparable with the simulation ($-15.5\, dBi$).

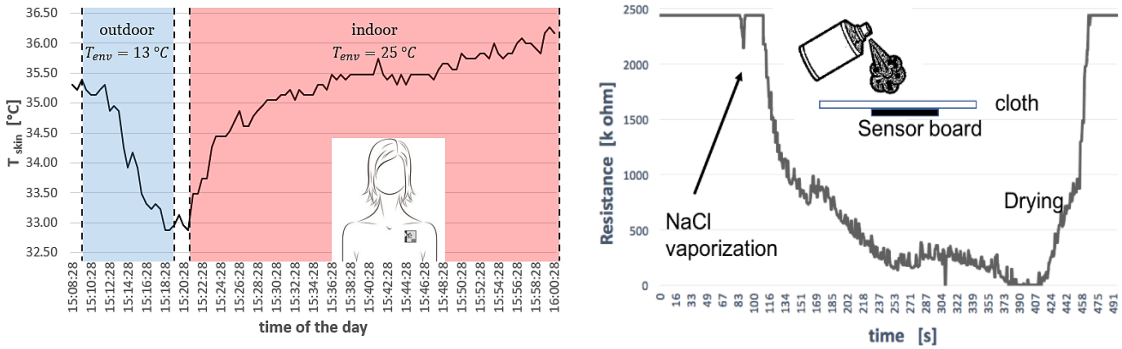


(a) (b)

FIG. 3 – (a) Front and rear sides of the RFID Epidermal Sensor Board prototype with battery mounted onto different faces and (b) measured realized gain when it was placed onto both chest and rib cage of a volunteer.

The RFID skin board was preliminarily demonstrated in the measurement of the skin temperature and the moisture of an underwear cloth. For this purpose, the chip was placed face front the skin and coated with an ultra-thin biocompatible film ($22\, \mu m$ thickness) for sanitary reason, while the battery was soldered in the opposite side. Two

additional copper electrodes were moreover soldered to the expansion ports on the opposite side. The handheld reader to activate the data-logger and download the data was a CAENRFID qIDmini, emitting 150 mW power. An example of measured temperature profile is shown in Fig. 4a and refers to the plaster attached onto the chest of a female volunteer, wearing winter clothes, who moved in the outdoor (13°C for 8 minutes) and then come back inside a university lab (25°C). Finally, Fig. 4b shows the change of surface resistance of a cloth which was artificially humidified with physiologic solution by means of a vaporizer to simulate human sweat production.



(a) (b)

FIG. 4 – (a) Temperature profile moving from outdoor to indoor environment. (b) Surface resistance of a cloth that was humidified by physiologic solution.

IV. CONCLUSION

The proposed epidermal radio-board can be used to test many kinds of sensors suitable to the comfortable monitoring of physiologic parameters in several modalities. The possibility to host a battery could enable a continuous registration of parameters in mobility. The tool is useful for both biomedical applications and diagnostics, as well as to characterize the insulating performance of special clothes, but could be even used in battery-less mode for instantaneous, short-range data download.

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