Conformal RFID Sensing for Assisted Living

J.C. Batchelor[1], O.O. Rakibet[1], M.A. Ziai[1], C.V. Rumens[2] and S.J. Holder [2].

[1]School of Engineering, Jennison Building, The University of Kent, Canterbury, Kent, CT2 7NT, UK.
j.c.batchelor@kent.ac.uk.

[2] School of Physical Sciences, Ingram Building, The University of Kent, Canterbury, Kent, CT2 7NH, UK.
s.j.holder@kent.ac.uk

Abstract

Two passive sensing designs based on UHF RFID technology are presented for assisted living application. The first tag is mounted on the hard palette of the mouth and detects tongue position, while the second is a skin-mounted strain gauge. Both designs are proposed for wheelchair or computer mouse control applications. Measurements show the sensors can communicate over short ranges comparable with the distance expected between a patent's mouth or face and a reader antenna. The mouth sensor is demonstrated to act as a tongue controlled switch, while the epidermal sensor is intended for eyebrow twitch control, tests indicate both designs have a useful and repeatable sensing function, with more than 3dB isolation in the switching case and approximately 0.25dBm per percentage stretch in the strain gauge.

1. Introduction

There has been significant progress in developing RFID technology for passive sensing in recent years. For instance strain gauges for use on and off the body [1, 2], vapor sensing, [3, 4, 5] and touch sensing [6] have all been reported. We consider two prototype designs for applications such as assisted living using passive wireless RFID sensing, both in the mouth and mounted externally on skin. The intention is that severely incapacitated wheelchair users could use tongue control or eyebrow twitching to communicate wirelessly to a relatively low power reader mounted a short distance away on the wheelchair. The expectation for both sensor designs is that they should be passive, low profile and conformal to the body surface on which they are mounted. Additionally, the tags should be capable of being fabricated by cost effective means using future additive manufacture processes.

2. RFID application in Assisted Living

To obtain wheelchair control we outline a new wireless switching and joystick technology where an individual retains fine motor control of the tongue. It is acknowledged that a wheelchair user should always where possible retain some element of control and any such interface should be as discreet as possible. The underpinning technology for the designs presented is passive UHF RFID which operates at 868MHz and has unobstructed read ranges of several metres for tags well isolated from their mounting platforms. However, there is a design challenge in creating low profile tags for use on human tissue and the read range is significantly reduced when tags are mounted on skin [7], or on dental plates within the mouth.

2.1 Passive Wireless Tongue Operated Control

A single layer UHF RFID bag based on a conducting inkjet ink transfer [8] has been created, Fig. 1. A prototype on thin Mylar was trialed in a volunteer's mouth using a VoyanticLite system and reading occurred when the mouth was both open and closed. Bringing the tongue within a range of distances from the tag caused the measured backscattered power to vary as presented in Table 1 where each measurement is averaged over 5 trials.

As the tongue approached the tag, increasing capacitive loading occurred and the tag became progressively more detuned with an associated reduction in measured backscattered power. For the open mouth, there was a 5dB range in reader power between the maximum and minimum tongue-to-tag distances giving reasonable switching isolation between distant and touching tongue positions, and also scope for proximity sensing at intermediate distances [9].

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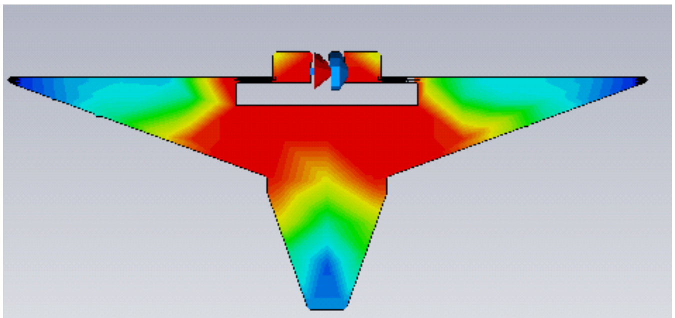

Figure 1. In-mouth single layer tag design with simulated current distribution. Total length = 58 mm, width = 20 mm.

Table 1. Normalized measured average backscattered power for in-mouth tag of Fig.1.

Tongue to Tag Separation (mm)	Normalized Backscattered Power (dBm)
6	0
10	2
15	2.4
20	2.9
30	4.6

2.2 Passive Wireless Epidermal Strain Operated Control

As an alternative to the tongue touch sensor described in Section 3, an epidermal mounted strain gauge has also been developed with the structure shown in Fig. 2, [10]. A wearable fabric based RFID strain sensor has been reported in [1] where a PVC substrate for application to fabric was compared to a tag printed directly onto a commercial fabric layer and assessed over strains of up to 60%. For the skin-mounted design considered here, and to allow for significant stretch, the tag conductor is fabricated from silver nanoparticle loaded Lycra [11] and mounted on a flexible PDMS substrate containing barium titanate [12] to raise the substrate relative permittivity to 3.4. To avoid the need for an adhesive, the Lycra was attached to the PDMS as part of the substrate curing process and the resulting material sample was 1mm thick. The tag was placed in a calibrated strain jig and measurement of backscattered power as a function of strain was assessed using a VoyanticLite system. The results averaged over 5 tests are given in Table 2.

Figure 2. Epidermal strain gauge tag. Total length = 57 mm, width = 20 mm, substrate height, 1mm.

Table 2. Measured transmit and backscattered powers for epidermal tag of Fig.2.

Strain referred to original slot length	Measured Transmit Power at tag turn on (dBm)	Measured Backscattered Power (dBm)
0	25.8	0.51
2.9%	25.4	0.53
5.8%	24.3	0.63
8.5%	23.4	0.70
9.7%	22.9	0.73
10.4%	22.6	0.75

Similar to the process described in [13] the tag is detuned by the sensed parameter and the magnitude is proportional to the backscattered power received by the reader. The linear trend of the data in Table 2 gives a sensitivity of 0.25dBm/percent strain with good repeatability. Measurement on a volunteer indicates that 1 cm displacement occurs in raising an eyebrow, and this corresponds to twice the strains over which this tag has been assessed. Therefore, obtaining significant read values should not be problematic.

3. Conclusions

An in-mouth RFID tongue proximity and touch sensor, and an external epidermal strain gauge have been demonstrated. The in-mouth designs are currently mounted on thin flexible mylar stubstrates, while future tags will be incorporated into dental plates. The epidermal strain gauge tags are fabricated on elastic PDMS substrates which have been loaded with barium titanate. Ultimately, digital and additive manufacturing processes will be applied to produce sensing tags on bespoke functional materials [14,15].

3.4 References

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