Skin-Mounted RFID Sensing Tattoos for Assistive Technologies

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***Abstract* — UHF RFID technology is presented that can facilitate new passive assistive technologies. Tongue control for human computer interfaces is first discussed where a tag is attached to the hard palate of the mouth and the tag turn-on power is observed to vary in response to tongue proximity. Secondly, a stretchable tag is fabricated from Lycra fabric that contains conducting silver fibres. The application of strain to the elastic tag again causes the required power at the reader to activate the tag to vary in proportion. This elastic tag is proposed as a temporary skin mounted strain gauge that could detect muscle twitch in the face or neck of an otherwise physically incapacitated person. Either design might be applied to the steering function of a powered wheelchair, or to facilitate the control of a computer mouse. Better than 3dB isolation is achieved in the tongue switching case and approximately 0.25dBm per percentage stretch is observed for the strain gauge.**

***Index Terms* — RFID, assistive technology, wireless sensors**

I. INTRODUCTION

In recent years Radio Frequency ID (RFID) technology has been proposed and explored for potential in passive wireless sensing and progress has been made in producing strain gauges for use on and off the skin [1, 2], vapor sensing, [3, 4, 5] and proximity or touch sensing [6]. The specific application of passive, skin-mounted wireless sensing as an interface to assistive technologies will be discussed here through two prototype tags, one in the mouth and the other mounted externally on-skin. These tags are developed with so that severely incapacitated people might control their wheelchair or computer based speech synthesizers by their tongues or by twitching a facial muscle. These tags would communicate wireless to a nearby reader system mounted on the chair and sharing the same power supply. The passive nature of the tags, together with their ultra-low profile allows them to be unobtrusive and provide dignity to the user. It is anticipated that new additive manufacturing techniques will provide these passive sensors as integrated units which can be disposed of daily.

II. RFID TAGS FOR ASSISTED LIVING

Tongue control is often a possibility for quadriplegics who can retain fine motor control of their tongues. This is important as even a severely incapacitated person would never rely entirely on an automated, self-navigating wheelchair, and it is essential that the user always retains some element of control. However, it is desirable that any interface facilitating such input should be as discreet as possible. As the enabling technology is passive there is no requirement for a bulky and inconvenient battery, together with supporting electronics to be worn on the skin. However, the low powers associated with passive wireless transmission and the well-known high losses associated with human tissue, mean that designing sufficiently efficient sensors is a challenge [7].

III. PASSIVE WIRELESS TONGUE CONTROL

The tag design in Fig. 1 that is proposed for application to tongue control is a development of an inkjet printed transfer tattoo design [8]. At 800 MHz the hard palate and tongue were modelled with material parameters such that ε_r = 55 and conductivity σ = 0.9 S/m and the teeth with ε_r = 12.5 and conductivity σ = 0.14 S/m. A prototype was etched from copper cladding on a polyester sheet. The tag was assessed using a VoyanticLite system for read performance when mounted in a mouth that was open and closed. Polystyrene blocks ($\varepsilon_r \sim 1$) were used to obtain read ranges for the tongue in a number of controlled proximities to the tag and each result was taken as an average over 5 trials. For each tongue-tag separation, the measured backscattered power was observed to vary in proportion.

The increasing capacitance associated with the approaching tongue progressively detuned the tag and consequently reduced the available backscattered power. 5dB power range was obtained with the mouth open across the maximum and minimum tongue spacing (where minimum spacing is the tongue touching the tag). This allows for the possibility of not just two state switching, but also for an number of up to 5 or 6 states in total [9].

Using the modelled mouth shown in Fig. 1, the back scattered power was obtained in proportion to the antenna terminal match and gain, and this was compared to measurement. The results presented in Fig. 2 are averaged over trials for 3 separate users. An excellent agreement between the modelled and measured values can be seen.

To obtain a more realistic view of user accuracy when required to hit targets that are not systematically increasing, the three users were subsequently tasked to hit target distances

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in a random sequence of 25. Initial errors were no more than 11% in magnitude and all users reduced their average target errors to under 1% towards the end of the 25 target sequence.

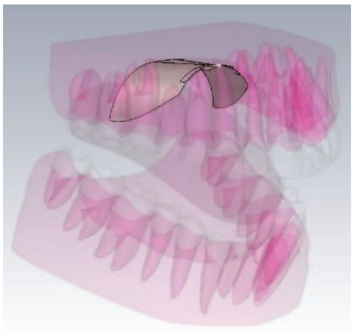


Fig. 1. Simulated mouth and tongue sensing tag. Tag conformed to curvature of hard palette.

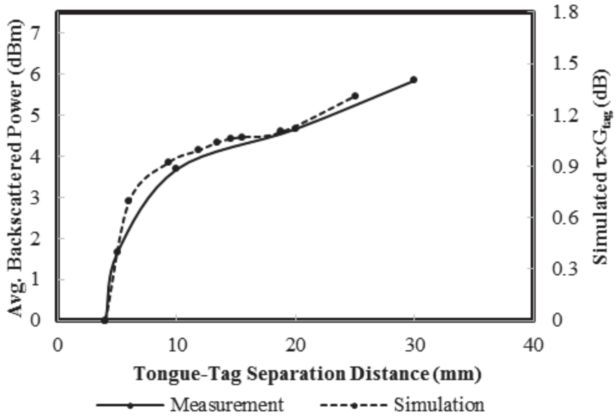


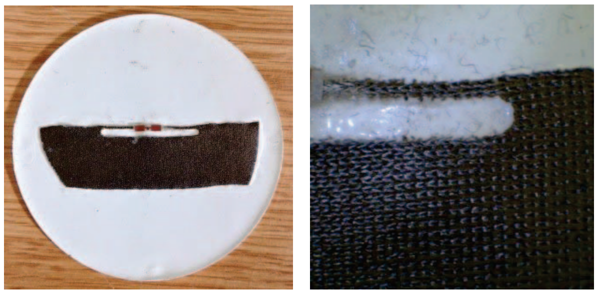
Fig. 2. Average Transmission coefficient simulation

IV. Passive Epidermal Strain Operated Control

An alternative form of passive wireless interface proposed is the epidermal mounted strain gauge shown in Fig.3 [10]. The design is again derived from a transfer tattoo, but in this case is realized using a conductive Lycra fabric mounted on a flexible polymer substrate. A fabric RFID strain gauge is described in [1] using a PVC substrate over strains of 60%. The tag considered here is for mounting directly on-skin to detect muscle twitch. To be compatible with skin elasticity, it is fabricated from silver nano-particle impregnated Lycra [11]. The polymer substrate is PDMS loaded with barium titanate [12] to increase the relative permittivity to 3.4 and reduce tag size. PDMS is widely used for domestic applications and is safe for skin contact. The challenge of finding an adhesive with elastic properties compatible with that of the Lycra and PDMS was avoided by attaching the Lycra antenna to the substrate during the curing process. The liquid polymer then attached to the fibres on the lower side of the Lycra, providing a strong and elastic adhesion. The finished prototype was 1mm in height. Measurement of strain response was taken using a test jig (not mounted on the skin) and backscattered power was measured by the Voyantic system as a function of applied strain. The results were averaged over 5 separate tests are presented in Fig. 5.

Fig. 3. Passive wireless epidermal strain gauge. Length: 57mm, width: 20mm. PDMS substrate thickness: 1mm.

The tag becomes progressively detuned as the antenna is stretched beyond its optimum dimensions in a similar manner to that of [13]. The sensed parameter is therefore related to the backscattered power received at the reader. The trend obtained is largely linear with a sensitivity of 0.25dBm/percent strain and good repeatability was obtained. To assess the amount of stretch the tag would be required to withstand and be sensitive to, a volunteer was observed raising an eyebrow. This indicated that 1cm displacement is typically achievable. This displacement is twice that over which the tag was assessed, meaning that obtaining useful data with typical facial twitches should present useful sensed data.



(a) (b)

Fig. 4(a) PDMS with Lycra®, (b) Expanded view of rounded slot end.

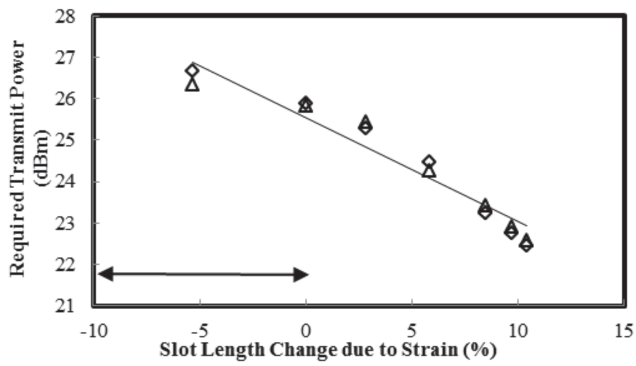


Fig. 5. Transmit power to achieve tag turn-on as a function of slot length with applied strain.

V. Conclusion

Two alternative passive sensing wireless tags for application to assistive technologies have been presented. The in-mouth RFID tongue proximity sensor is on a flexible and low profile design making it potentially convenient to wear without being obtrusive. Tests on volunteers indicate this tag can be used with accuracy to hit targets after a very short period of practice. Further work could explore tags incorporated into dental plates, or directly printed onto them by additive manufacture. The second design considered, the external epidermal strain gauge tags were formed from silver nano-particle impregnated Lycra and adhered to barium titanate loaded elastic PDMS substrates. These designs were found to offer significant and linear sensed responses over strains roughly half of those available in facial muscle tweaks.

The concepts presented here are to be applied to a new EPSRC funded project Adaptive, Assistive and Rehabilitative Technologies Beyond the Clinic. This project addressed the fact that patient use, and compliance with, assistive technologies is very poorly assessed outside of the clinical environment and as a result around half of devices such as wheelchairs are abandoned within 2 years of issue. The passive sensing technologies discussed here for use on, and very close to, the body, will be applied to begin to capture an objective picture of equipment use and suitability beyond the clinic.

It is anticipated that all these passive wireless sensing designs could be fabricated using new additive manufacturing techniques [14,15]. Short run, bespoke manufacturing will be important as any skin-mounted technology must be single use and disposable.

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