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RFID Tags as Passive Enabling Technology

Osman Ozgur Rakibet, John C. Batchelor, Steve. W. Kelly

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RFID Tags as Passive Enabling Technology

Osman Ozgur Rakibet, John C. Batchelor, Steve. W. Kelly
Electronics and Digital Arts
University of Kent
Canterbury, UK
oor3@kent.ac.uk, j.c.batchelor@kent.ac.uk, s.w.kelly@kent.ac.uk

Abstract—**This paper illustrates the concept of passive tongue touch and tongue proximity wireless sensors. The sensors use the principle of changing the capacitive loading of the tag feed network by moving the tongue closer to the sensor. The application of these devices could be as control actuators for people with severe physical disability.**

Keywords; RFID; wireless sensing; sensors; assisted living

I. Introduction

RFID is becoming a pervasive technology. It is used in a wide range of applications, such as logistics, inventory management as well as for prospective uses in systems for disabled people, homeland and personal security, distributed sensor networks and mobile healthcare [1].

In real world applications, human assistive devices need to be effective in real-time such as for powered wheelchair users requiring appropriate and reliable support, especially in collision avoidance. It is important that the intelligence of assistive technology systems must be engineered to be sufficiently able to recognize and accommodate for patient provided inputs of varying reliability. Robotic assistance employed in the healthcare arena must therefore emphasize positive support rather than adopting an intrusive role [2] especially in rehabilitation scenarios where patients should be encouraged to offer increased independence as they learn to manage their condition. This is the objective of SYSIASS, a European Commission funded project to develop new systems providing increased independence to disabled people where an autonomous powered wheelchair is supported by collision avoidance sensors.

In addition to providing inconspicuous support, it is also desirable for the human-chair interface to be as low profile as possible, especially in situations when input sensors are mounted on the face or in the mouth. Therefore, a mouth mounted RFID tag, which acts as a tongue touch controlled switch, can offer joystick functionality on a powered wheelchair steered by the tongue.

In this paper a mouth mounted tongue touch RFID switch is presented and investigated for operation when mounted within the mouth.

II. Body Mounted Tag

A passive UHF RFID tag design has been presented in the form of a transfer patch similar to a temporary tattoo that is mountable directly onto the skin surface [3]. This was proposed to monitor people over time in critical healthcare and secure environments using an inkjet printed tag mounted on the skin by a tattoo transfer process [4].

In a passive systems, the power collected by the tag antenna activates the transponder IC and modulated backscattered power is returned to the reader. The achievable read distance, R, is given by the following equation [x]:

$$R \leq \frac{\lambda}{4\pi}\sqrt{\frac{EIRP_{reader} \times G_{tag} \times \eta \times \tau \times \rho}{P_{th}}} \qquad (1)$$

where, $EIRP_{reader}$ is the reader effective isotropic radiated power, G_{tag} is the tag antenna gain, η is the transponder rectifier efficiency, τ is the impedance matching coefficient between the tag antenna and the transponder chip, ρ is the polarization coefficient between the reader and the tag antenna and P_{th} is the chip activation threshold power.

Very low profile skin mounted tags have low radiation efficiency and it is therefore important to obtain a good value of impedance matching coefficient if read ranges more than a few cm are to be achieved. The power transmission coefficient is given as [ali]:

$$\tau = 1 - |\Gamma|^2 = \frac{4R_a R_{IC}}{(R_a + R_{IC})^2 + (X_a + X_{IC})^2} \qquad (2)$$

where:

$$0 \leq \tau \leq 1 \quad \text{and} \quad \Gamma = \frac{Z_{IC} - Z_a^*}{Z_{IC} + Z_a}, \quad 0 < |\Gamma| < 1. \qquad (3)$$

A low profile tag developed with surface dimensions small enough to fit comfortably onto the hard palate is shown in Fig.1 with the dimensions listed in Table I. To aid the fit, two corners are rounded. A prototype tag was created on thin Mylar sheet and in order to verify the tag operation on human tissue, it was first mounted on a volunteer's arm. Fig.2 shows measured tag performance in terms of read range as a function of frequency while Fig.3 gives the simulated S_{11} obtained using CST Microwave Studio. The peak measured read range occurs at about 870MHz which corresponds well the simulated S_{11} null.

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Voyantic Tagformance Lite equipment was used for the measurements.

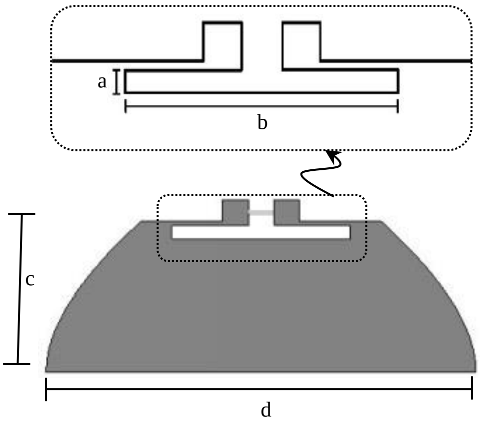

Fig. 1 Geometry of the tongue touch RFID sensor

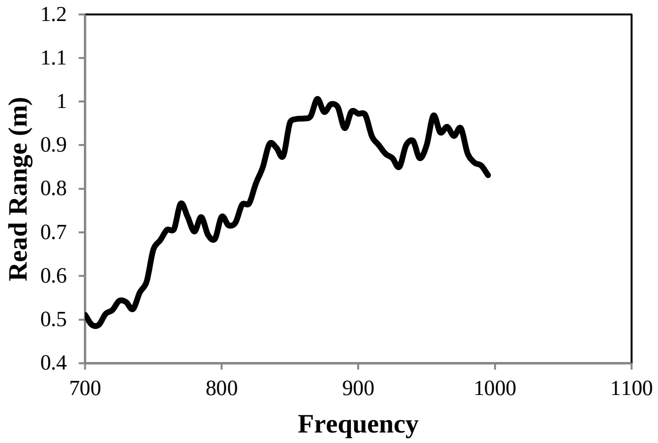

Fig.2 Measured read range on arm

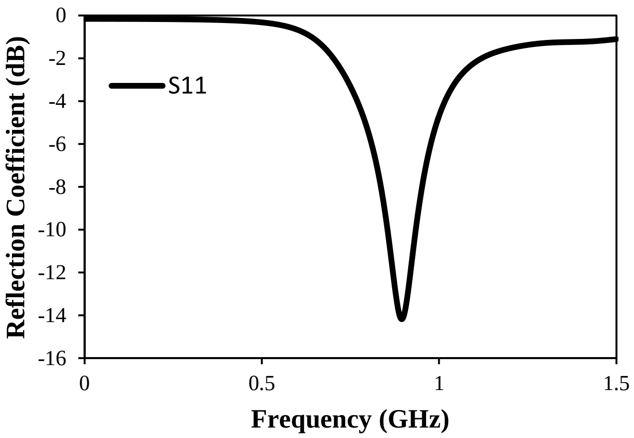

Fig. 3 RFID on arm simulated reflection coefficient

TABLE I DIMENSIONS OF TONGUE TOUCH RFID SENSOR

Slot Width	a	1.5 mm
Slot Length	b	20 mm
Tag Width	c	20 mm
Tag Length	d	50 mm

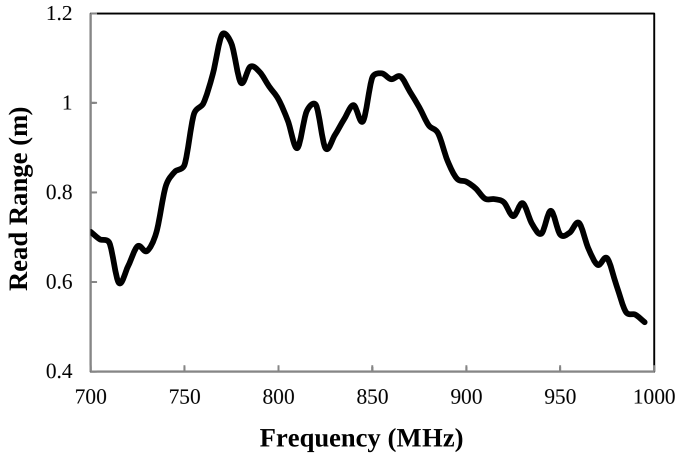

Fig.4 Measured read range in mouth

III. RFID OPERATION IN MOUTH

Read ranges of about 1m will be required in this application and Fig.4 shows an acceptable read range was measured when the tag was mounted in the mouth of a volunteer. The peak read range was detuned to about 770MHz after mounting on the hard palate, though this could be compensated for. A commercial dental adhesive was used to affix the Mylar tag substrate to the hard palate, Fig.5.

To assess tag operation as a tongue switch, expanded polystyrene foam spacers (relative permittivity approximately that of air) with known thicknesses were used to characterize the distance between the tag and the tongue. Each measurement data set was repeated five times and the average is presented to remove the variations introduced by human movement and narrow band fading.

The VoyanticLite system ramps transmit power and records the value when tag communication is established. Transmitted and corresponding backscattered power values were measured for each tongue-tag separation distance and the results are listed in TABLE II. A critical point for the tongue separation is found to be at 4 mm as smaller distances mean the tag is not read, corresponding to an “off” state. Further, for separations greater than 4mm, increasing tongue-tag separations lead to increasing backscattered powers and this could offer a proximity sensor with an analogue scale for finer control.

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Fig. 5 Denture adhesive applied to stick the tag to the upper palate

TABLE II IN-MOUTH MEASUREMENT RESULTS

Polystrene Thickness (mm)	Transmitted Power (dBm)	Backscattered Power (dBm)
30	22	-52.8
20	23.5	-54.5
15	24	-55
10	26.5	-55.4
6	27	-57.4
4	Tag not detected	Tag not detected
2	Tag not detected	Tag not detected
0	Tag not detected	Tag not detected

In order to represent the signal propagation in the mouth, a very simple homogeneous flesh model has been modelled in CST Microwave Studio as shown in Fig. 6. The hard palate and tongue are comprised of a material with $\varepsilon_r = 55$ and conductivity $\sigma = 0.94$ S/m.

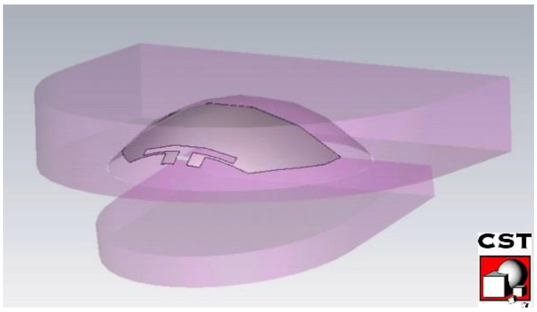

Fig. 6 CST mouth model for UHF RFID tag simulations

Simulations were taken for the same tongue-tag separations as measurement. The impedance matching coefficient τ was derived from the simulated reflection coefficient, Fig.7. The trend with tongue separation predicts the required change in tag match with a degradation as the tongue approaches the tag. The tag gain was also obtained for each simulated tongue position.

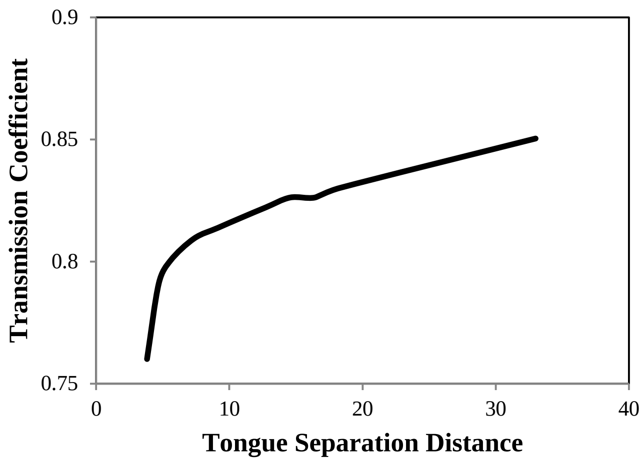

Fig. 7 Transmission coefficient vs Separation distance graph

As the impedance coefficient and the tag gain are the two parameters most affected by tongue proximity, the product of the two is given in Fig.8 together with measured back scattered power for each tongue-tag separation. There is evidence of an agreement in trend between the measurement and simulation, especially in the middle range, and to some extent, for smaller tongue separations. When the tongue is at larger distances from the tag (more than 20mm), the agreement is lost. The reason for this is primarily expected to arise from the simplified model of the mouth used in CST. There are no cheeks, lips, teeth or bone included and all tissue is modeled as a single homogenous material. Therefore, at larger tongue separations, the wider mouth environment can be expected to be most significant in tag performance. As the tongue moves closer its significance increases and the simple homogenous tissue model is sufficient until the tag becomes very close (less than 5mm) and a better validated tissue representation is required and small experimental error in tongue position becomes important.

The simulated model assumed that tongue movement did not affect tag polarization as the hard palate should not change position. However, in measurements, moving the tongue large distances from the hard palate did cause some volunteers to move slightly, and this may have an effect on backscattered power that was not accounted for in the model. To reduce uncertainty, measurements have been taken as two sets of 5 and the average taken.

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CONCLUSION

An innovative wireless passive tongue switching assistive technology using RFID tags has been presented with an application for wheel chair control for patients with severe movement impairment. The preliminary simulation and measurement results indicate that multi-chip RFID tags for mouth mounting could form a 4 point joystick controlled by the tongue. When mounted on the hard palate, the tag offered read ranges of more than 1m, which is appropriate for a system where the read antenna would be mounted on the wheel chair in front of the operator. In this instance power would be supplied from the chair and the significant processing capability of the chair autonomous navigation system would be available to calibrate and train the system for the patient.

Future development resulting in much smaller sensors could have application in tongue position monitoring in speech therapy where current technologies require a loom of many wires to pass out of the patient's mouth during monitoring. The removal of these wires would create a much more natural condition for speech.

ACKNOWLEDGMENT

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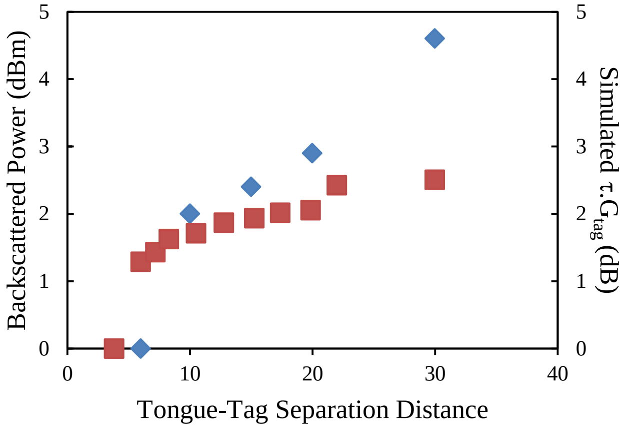

Fig. 8 Normalized measured backscattered power (blue diamond) and simulated product of impedance match coefficient and tag gain (red square) as a function of tongue-tag separation.

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NOT UPDATED!!!!!!

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