Passive Sensors for Food Quality Monitoring and Counterfeiting

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***Abstract*— This paper presents the design and proposal for a passive sensor for food quality, monitoring and counterfeiting, based on alternative materials.**

***Keywords*— RFID, Passive Sensors, Cork**

I. Introduction (*Heading 1*)

Radio frequency identification (RFID) is currently a major enabling technology. It is being extensively used in many different kinds of applications and is one of the most promising bets for the development of the Internet of Things concept [1]. Some of the applications span from identification and localization to various types of monitoring and sensing [2]. Another area that begins to take the first steps is its use for food quality monitoring and counterfeiting.

The diversity of scenarios of application of the RFID technology bring many challenges for the tag design when different applications are seek. To tackle those challenges the use of different substrate materials, especially materials that can be commonly found on consumable products, should be used. Materials such as paper, plastic (PET) [2], plywood [3], fabric and cork, to name a few, as well as the use of different fabrication techniques targeting large volume production such as inkjet printing [3], and consideration of low cost conductive materials such as paperclips [4].

In this particular case we propose a possible design of a very small conformal RFID tag antenna that can be embedded into a cork bottle stopper for identification purposes and to avoid adulteration or counterfeiting of the bottle contents.

It is necessary to analyze an antenna application environment, because the different materials in the vicinity of the antenna will affect its radiation properties.

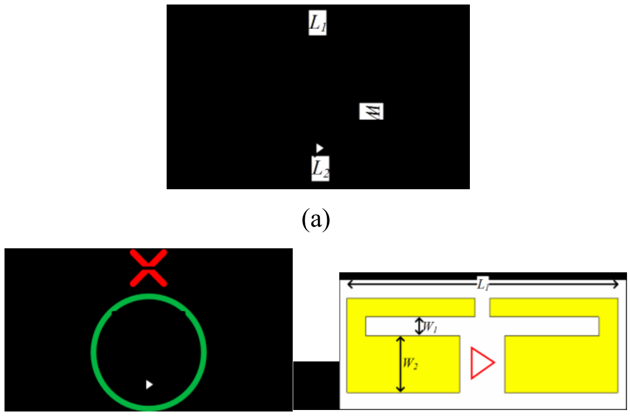
In order to simulate this scenarios and simulate antenna designs with relatively good accuracy, the properties of the materials that are used in the surroundings of the antenna need to be known. So we determined the permittivity of the dielectrics [5, 6] involved in the considered application, namely the cork and the bottle glasses and designed the antenna considering the application scenario, hence, the presence of the glass, plastic and liquids.

Besides, it is also necessary to consider the dissipation factor of the materials (tan δ) since this will affect the antenna efficiency and therefore the reading range of the RFID tag.

II. Passive RFID tag deisng

The proposed RFID antenna is based on a dipole ring folded around the RFIC [7]. The RFIC is a UCODE SL3ICS1002 by NXP which has an input impedance of 16-j158 Ω at 866 MHz.

The typical antenna approach for RFID is the inductive loop with dipole or monopole arms attached, as shown in Fig. 1 (a). To miniaturize the antenna size, we discarded the inductive arms and focused on the loop as shown in Fig 1 (b).



(a)

(b)

Fig. 1: Typical RFID antenna design approaches.

Given the inductive characteristic of the folded ring dipole matching the input capacitance of the RFIC was doable with a rather small antenna. However, the resistive part of the input impedance of the antenna was very hard to achieve with this configuration and there was a large impedance mismatch between the antenna and the chip. To solve this, we looked into the current distribution of the antenna as depicted in Fig. 2.

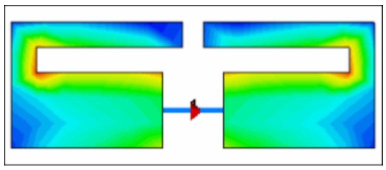


Fig. 2: Current distribution in the folded ring surface.

The highest impedance point of the antenna, this is, the area in which the current level were smaller, was in the slimmer arm upwards of the feed point. Therefore, if we could increase a little more the resistance at this point we would be able to match the input resistance without changing the overall behavior of the antenna. Closing the gap on the top arm however makes the resistance on that point small, and therefore the input resistance increases considerably. Hence, we placed a SMD resistance, and by controlling its value we could achieve the desired input impedance.

The proposed antenna is optimized to perform when bended around the cork stopper as shown in Fig. 3. The physical dimensions are for the final prototype matched to be inserted in a glass wine bottle, which was simulated as a whole, as shown in Fig. 5.

Fig. 3: Implementing an antenna in cork.

The input impedance of the simulated antenna is shown in Fig. 4. The several traces are respectful to the antenna when standing alone in empty space, just with the bottle neck around and inserted inside a bottle with liquid. The last case showcasing an input impedance very close the RFIC input impedance being 15+j154 Ω. This is obtained with a SMD resistance for matching purposes of 6.2 Ω.

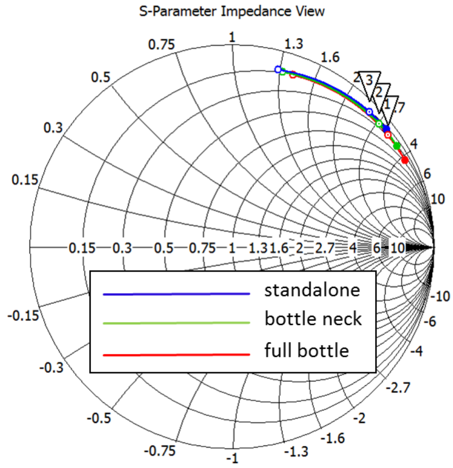


Fig. 4: Antenna impedance with and without bottle.

The radiation pattern is slightly directive which is rather convenient for the application envisioned, so the bottle can be read when laying down on shelves. However, with the presence of liquid the direction changes towards the liquid, as can be seen in Fig. 3.

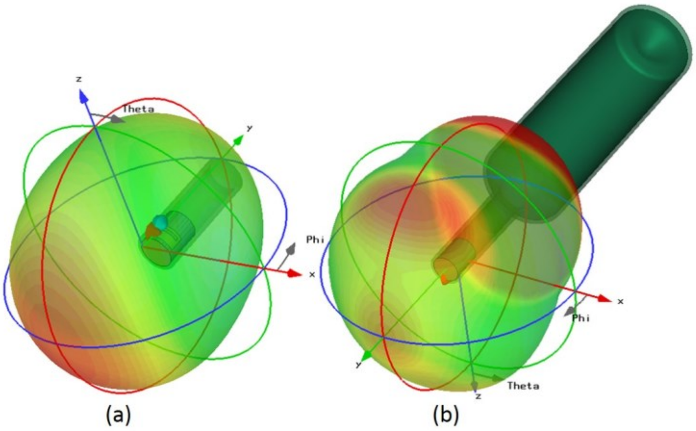


Fig. 5: Radiation diagram with and without the bottle.

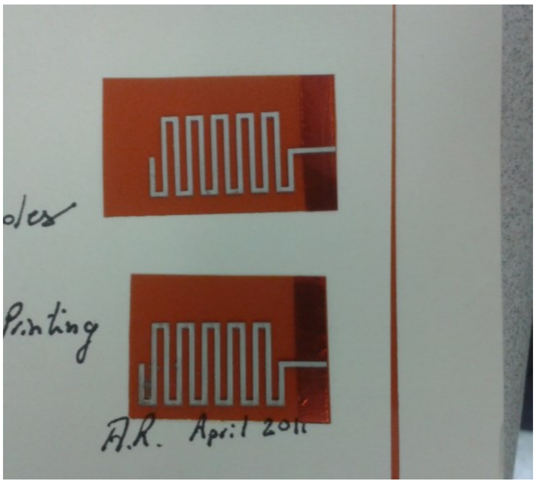
In order to determine the maximum read range of the designed RFID tag, we tested the tag with an Alien ALR8800 commercial RFID reader and verified that the maximum reading range was 0.45 m.

III. CORK VARIATION WITH HUMIDITY

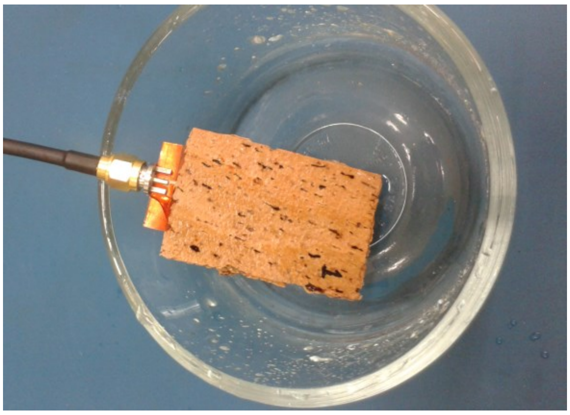
In the previously shown scenario cork was used for support for a RFID tag antenna to be inserted into wine bottles, for logging and monitoring purposes. However, cork can also be used has a passive sensor by taking advantage of its properties.

In this section we make a brief analysis of the variation of the cork properties with variation of humidity which can be used for sensing purposes.

In order to assess the cork variability with the humidity changes, we picked a printed monopole antenna on a known substrate, in this case DuPont's Kapton HN, and used pieces of cork covering the antenna, working as substrate and superstrate. The proposed antenna is shown in Fig. 6 (a) and the prototype with the cork laminates on the top and bottom is shown in Fig. 6 (b).



(a)



(b)

Fig. 6: Printed monopole antenna (a) standalone, (b) inside cork laminates.

By soaking the cork in water and measuring the reflection coefficient we can see a clear difference in the resonant frequency of the antenna due to the permittivity changes in the cork. This is depicted in Fig. 7.

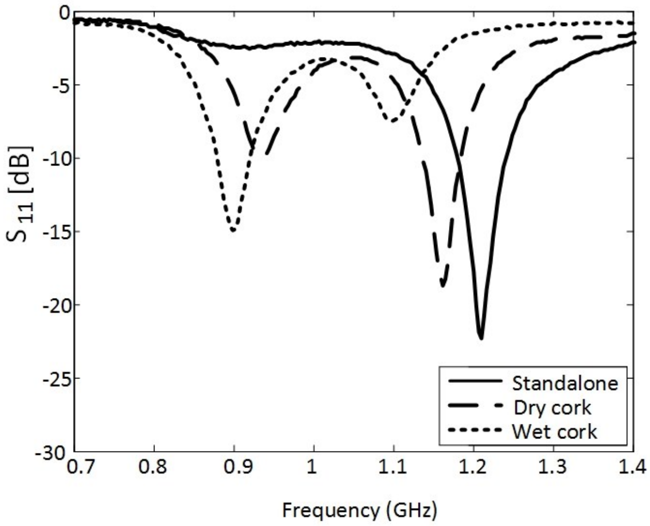


Fig. 7: Resonant frequency shift of the antenna due to the changes in the cork humidity conditions.

By testing the antenna with the cork at room temperature and humidity values of around 30% and comparing to a situation where the cork is completely soaked in water and therefore near 100% humidity condition, there is a shift of approximately 38 MHz in the resonant shift. This is a very reasonable difference, imposing a frequency drift comparable to the state-of-the-art sensors as reported in [8].

IV. CONCLUSION AND FUTURE WORK

Given the properties of the cork reported in this paper, we can say that this material can be a great candidate to be used for sensor applications. Besides, its natural properties and resistance to abrasion turn the cork into a very desirable product for food industry applications. Allied to the miniaturization techniques opens the door for small form factor passive sensors with very reasonable sensitivity to the ambient changes.

Currently we're working on the design of RFID tag antennas printed on cork surfaces in order to ally the cork sensitivity to humidity to the passive communication device, in order to create a passive sensor totally embedded in cork that can be used for food and beverages appliances.

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