Design of UHF RFID tag on PLA substrate for food traceability

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Abstract

This work aimed to study the technical aspects of producing UHF RFID tag on biodegradable Polylactic Acid film (PLA) for food traceability. Dielectric properties of PLA and its variations due to exposure to environmental conditions were investigated. Parametric simulations of the tag's read range, as well as measurement of RFID chip impedance, are described. The realized RFID tag was tested on a commercial dairy product where the maximum measurement range reached around 0,6 meter.

1. Introduction

The food industry is increasingly adopting smart packaging technologies to improve quality, safety, and provide information about the product over the entire supply chain[1]. Compared to the commonly used barcode system, Radio Frequency Identification (RFID) system provides a more reliable traceability solution because of its ability to identify each item, categorize and manage the flow of goods [2]. Moreover, sensor-based RFID tags can monitor the temperature, relative humidity, and light exposure[3] of different products, which can be very useful to extend the products shelf life.

Recently, the food sector is oriented towards green solutions using biodegradable materials for packaging to reduce non-recycled plastic wastes. In this context, RFID could indeed be a part ofgreen IT which is cost effective as well as compatible with regulation and preservation of environmental health[4]. Previous works discussed the realization of RFID tags on different biodegradable substrates such as cellulose acetate (CA)[5], Plywood Substrates[6] and Polylactic Acid (PLA) using 3D printing[7]. Compared to previous works fabricated on rigid substrates, this work presents a UHF RFID tag realized on a very thin and flexible film of PLA which is more suitable for food packaging. The paper is organized as follows. Section 2 introduces the dielectric characterization of PLA and its variation over time. Section 3 presents the impedance measurement of the RFID IC used to realize the prototype. In section 4, results of the read range obtained by HFSS simulation are compared to the tag read range measured by a commercial reader. Finally, section 5 draws some conclusions.

2. PLA Dielectric characterization

The characterization of materials is an indispensable step before the design of tags in RFID systems. From the RF point of view, the dielectric properties of a non-magnetic material are determined by its complex dielectric permittivity$\varepsilon = \varepsilon_r' - j\varepsilon_r''$. The characteristics used to identify a material are the real part of the permittivity $\varepsilon_r'$and the tangent of dielectric loss $tan(\delta) = \frac{\varepsilon_r''}{\varepsilon_r'}$.

As the PLA is a biodegradable material, it was important to study the variation of its dielectric properties versus time and weather conditions. First, the thickness of PLA was measured accurately in a profilometerto obtain an accurate measure of the permittivity. An average of 40µm of thickness is obtained as shown in figure 1.

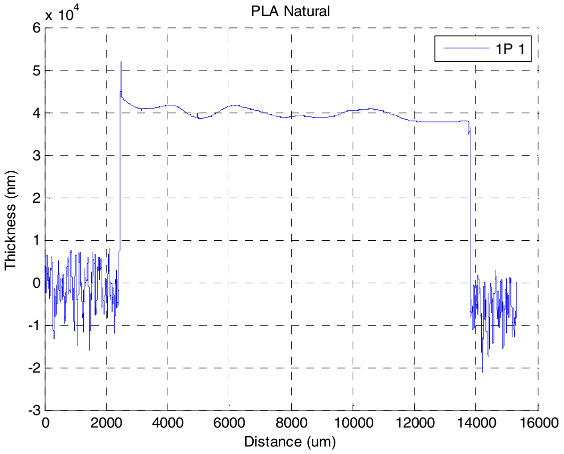


Figure 1. Measurement of PLA thickness obtained by a profilometer.

The permittivity and loss tangent of one factory sample of PLA havebeen measuredusing Damaskos cavity system. Then the dielectric propertiesof the same sample have been measured again after being exposed to weather conditions during two weeks. The results are shown in the following table.

Table 1. PLA Dielectric properties

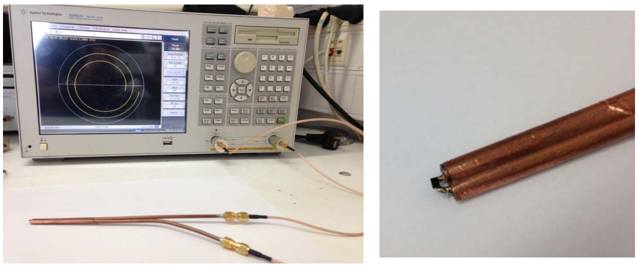
Measure	ε_r'	tan(δ)
Measure of factory PLA	2.72	0.002
Measure after two weeks	2.94	0.004

In order to take into account this variation, the average of these two values was considered during the design and simulation.

3. RFID chip impedance measurement

An RFID tag is comprised of an integrated circuit (called an IC or chip) attached to an antenna that is tuned to receive the waves sent by the reader and enables the chip to transmit the identification information back to the reader. For passive RFID, tag antennas collect energy and channel it to the chip to turn it on. The more an antenna is correctly matched to the chip impedance, the more power it will be able to draw from the field created by the reader and channel toward the tag chip, and therefore the further read range the tag will have.

In order to design an efficient antenna, the chip impedance was measured using a balun and a vector network analyzer as shown in fig.2. The delay introduced by the balun was de-embedded using post-processing.



a *b*

Figure 2. a) Measurement setup b) Balun used for balanced impedance measurement

The impedance of chip Monza-R6 was measured over a frequency band of 200 MHz (from 800 MHz to 1 GHz) at four power levels. The real part of the chip impedance is around 10 Ω at 866 MHz for a low power level (-20 dBm),and the imaginary part is around -135 Ωas shown in figure 3.

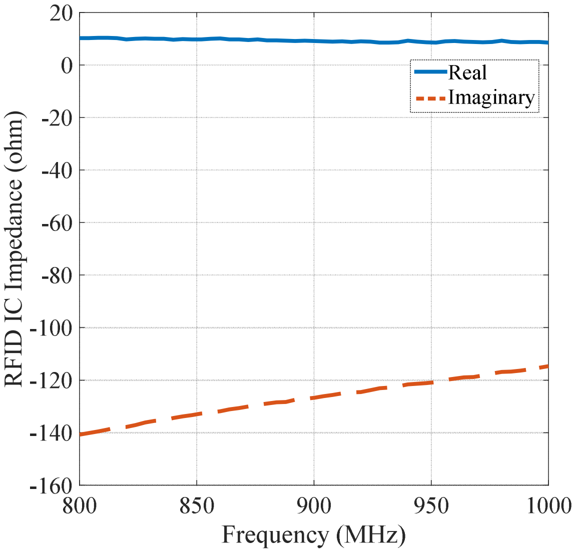


Figure 3. Measurement of Monza-R6 impedance

4. Simulation & Measurements

After measuring the chip impedance, the tag antenna was simulated on a substrate of cheese with $\varepsilon_r{}'= 21$ and $tan(\delta)= 1$. The design is based on a meander line antenna where the final tag dimensions are 11 mm x 78 mm with line's width of 1.5 mm as shown in figure 4:

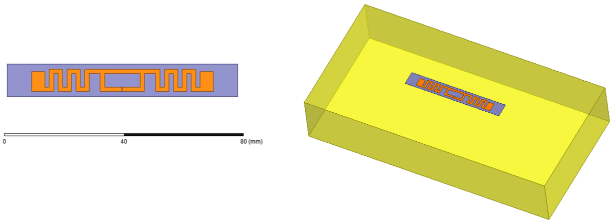


Figure 4.HFSS simulation model of PLA tag on cheese

As the cheese is a very lossy substrate (tan(δ)= 1), the max gain obtained is around -23 dB (figure 5) which affects the tag read range to be in the range of 0.5 meter.

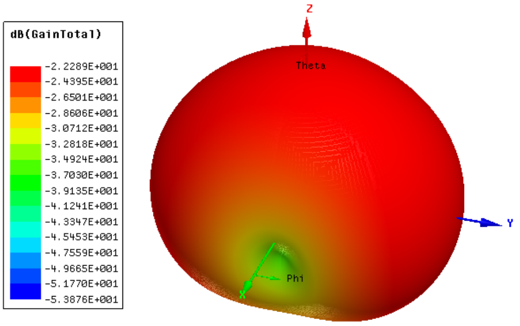


Figure 5.3D Gain (max)= -22,8 dB

A parametric simulation of the read range over frequency was realized for different permittivity and loss tangent values of the cheese substrate. The tag read range was simulated at $\varepsilon_r{}'$ (15,17,19 & 21) and tan (δ) (0.6 & 0.8).

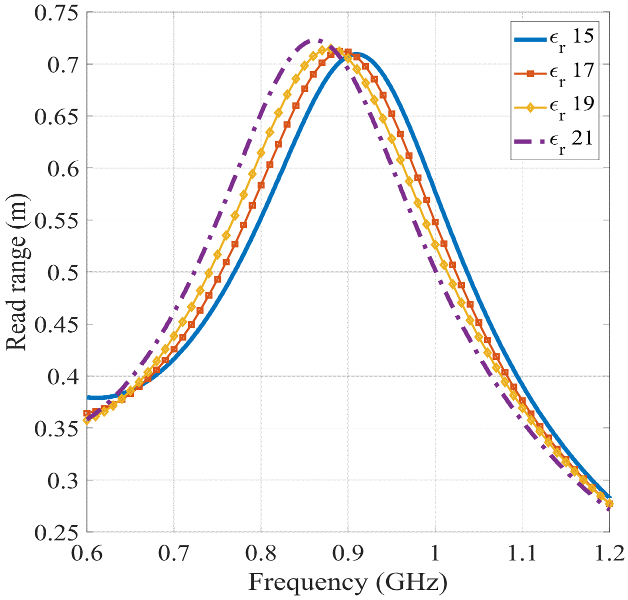


Figure 6. a) read range over frequency for ε_r (15, 17 , 19 & 21) and tan(δ)= 0.6

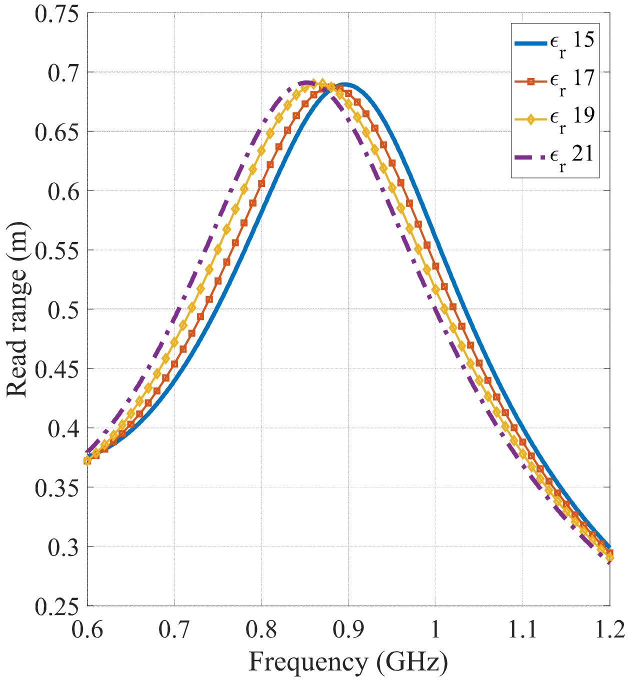


Figure 6. b) read range over frequency for ε_r(15, 17 , 19 & 21) and tan(δ)= 0.8

At 866 MHz,the maximum simulated read range varied between 0.65 m and 0.72 m as shown in figure.6

Read range measurements were realized using a commercial RFID reader in areal environment. The read range obtained at maximum allowed power is around 55 cm as shown in figure 7.

Figure 7. Read range measurement setup

5. Conclusion

The general motivation behind the work was to design UHF RFID tags on a biodegradable substrate for smart labeling of food products. Realized on a thin flexible PLA film and placed in direct contact with a cheese sample, the RFID tag had limited read range due to high dielectric loss of the product. Future work will study the realization of other prototypes on different food products.

6. Acknowledgements

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7. References

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