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Passive UHF RFID Sensor Tag for Pressure and Temperature Conditions Monitoring

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Abstract

In this study, we proposed the UHF RFID technology with its passive character and low power consumption as an effective solution for monitoring the operating parameters that improve the plant growth in closed conditions. The designed RFID sensor operates autonomously in a full passive mode and provides measurements of absolute pressure and temperature.

1. Introduction

When it comes to the control and optimization of growth plant or improving its quality in closed growth environment, a suitable monitoring of climate factors is necessary. In the literature, some studies have shown that optimal growing plant parameters, such as absolute pressure and temperature, may improve photosynthesis and respiration of plant, thereby enhancing its quality, growth rate and saving its health. In literature, varying these parameters has shown a great impact on the plant's production. In [1], changing the growth environment temperature and amount of water have shown a significant change in the amounts of vitamins and amino acids in plants, where high temperature showed a direct effect on photosynthesis and respiration. In [2], the effect of temperature extremes on plant growth and development has been studied during the pollination phase.

Beside temperature, information about air pressure is necessary to better understand the impact of gases. The effect of the partial pressure of CO2 on the rate of photosynthesis has been investigated by some research groups. In [3], authors show that the rate of photosynthesis of C3 plants is increased with increasing atmospheric CO2 level.

Because it can directly affect the rates of photosynthesis and respiration, total pressure is important for plant growth. According to [4], the rates of photosynthesis and transpiration increase under reduced total pressure. Additionally, total pressure can be controlled at a low cost compared with the control of the partial pressure of CO2 that need producing a large amount of high-CO2 gas.

In this work, we propose an autonomous RFID sensor that can measure simultaneously temperature and absolute pressure. The proposed architecture is a fully Passive UHF RFID tag equipped with multi-sensing element.

This paper is organized as follows. Firstly, the block diagram of our developed RFID sensor is presented. In the second part, simulation and some measurements results are detailed. Finally, we conclude.

2. Approach

The studied architecture in this work is given on Fig.1. It consists of several circuit blocks: a passive UHF SL900a RFID tag that can provide through its V_{Rectf} output pin, a regulated voltage signal to the isolated part of super tantalum storage element capacitor and an additional block that contains a microcontroller unit and connected sensors. The value chosen for the storage capacitor is the optimal value that meets the needs of our application in terms of rapid start working and low energy consumption. This regulated voltage supply for microcontroller (MCU) and the sensors. A low power consumption MCU PIC16LF1707 can perform two tasks: sampling the received sensor signals using I²C communication protocol and organizing the pressure and temperature data into the user memory of the SL900A chip using the SPI communication protocol. A diode is set here to prevent the discharge of the capacitor in the internal circuit of the chip.

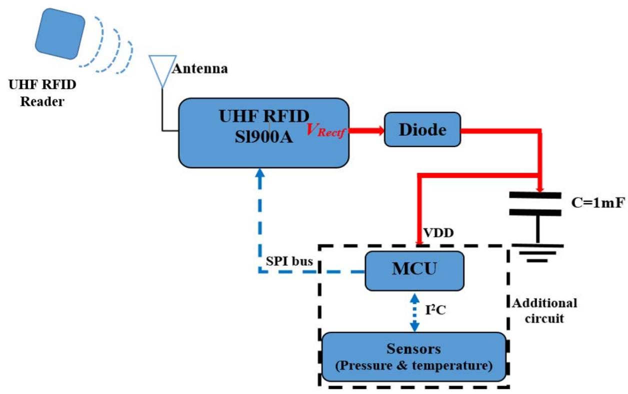


Figure 1. The block diagram of the proposed tag architecture

3. Prototype Simulation and Design

The proposed antenna structure is a folded dipole exhibiting an impedance that is conjugate to the SL900a input impedance for full passive mode operation. The tag was simulated and fabricated on a FR4 substrate having a relative permittivity $\varepsilon_r = 4.2$ and loss tangent $tan(\delta) = 0.02$ as shown Fig. 2.

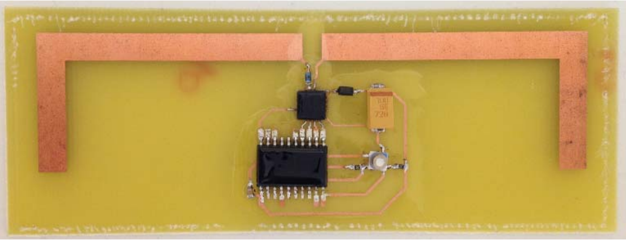
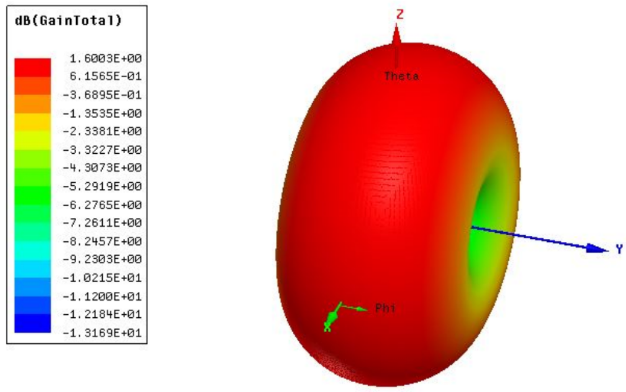
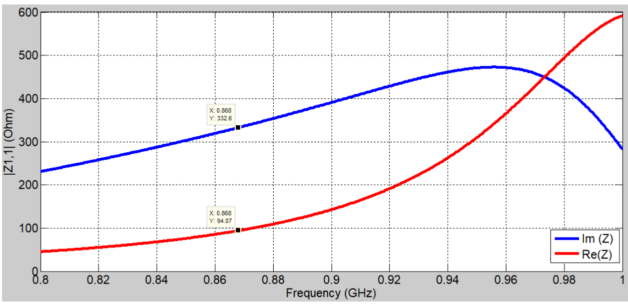


Figure 2. Fabricated prototype.

The simulation of the complete antenna structure was carried out in HFSS. It was adapted in order to conjugate the chip impedance to operate at the frequency 868 MHz when the RFID chip exhibits the following impedance [5]: (135 – j 315) Ω for passive mode.
The obtained results show good performance in terms of gain around -2,6 dBi, good matching and a return loss < -10 dB, as shown in respectively Fig. 3*a*, Fig 3*b*, and Fig 3*c*.



a



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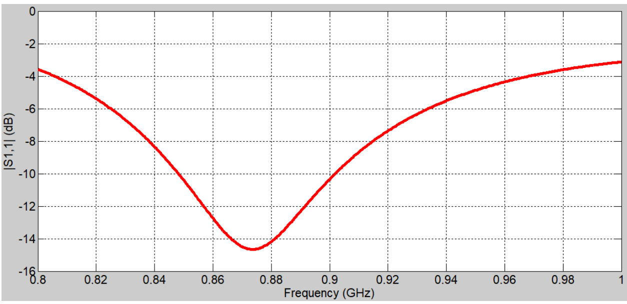

c

Figure 3. Antenna simulation results
(a) Radiation pattern at 868 MHz (phi = 90 deg), (b) input impedance, (c) return loss

4. Pressure and temperature measurement setup and test results

To optimize the energy consumption of the architecture, we have implemented only the necessary routines in the microcontroller that allow us to deduce and calculate the actual values of pressure and temperature. Six 16-bit factory calibration data coefficients (C1-C6) and two others 24-bit digital value D1 and D2 must be read by the MCU from PROM sensor [6].
All these obtained values are written in the user memory of the RFID chip. By using any standard UHF RFID Reader it is possible to read all these stored coefficients and extract the current values of the temperature and the pressure with a first order or second order of temperature compensation.
Several experiments have been made with the fabricated prototypes. The test bench used is shown in Fig. 4. It uses a closed plastic enclosure in which the tag is placed, a vacuum machine that can suck up all the air inside the bag gradually reducing the internal pressure. The pressure inside the plastic bag was changed progressively by the vacuum machine and the measurement results showed coherent values with the ambient temperature and pressure. Also the sensors showed a very high measurement sensitivity. The reading range of the tag in sensing mode is lower than that of the RFID ID mode and was around 1.6m. This difference is due to the effect of decrease in the amplitude of the signal at the SL900a chip rectifier output when a distance between reader and RFID sensor increases.

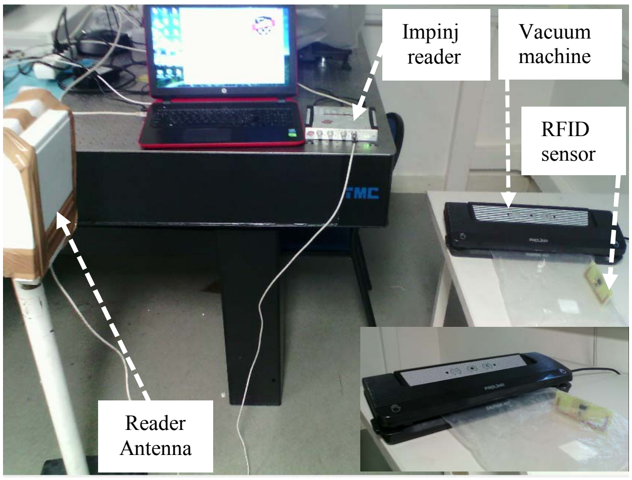

Figure 4. The View of the bench used during measuring absolute pressure and temperature.

4. Conclusion

In this paper, we have shown a methodology to design and develop with the SL900A chip, which has a rectified voltage output pin (V_{Rectf}), a passive UHF RFID tag sensor that is capable of measuring with accuracy ambient pressure and temperature.
The adopted energy harvesting strategy based on sharing the rectified power between RFID chip and additional circuitry block. This architecture demonstrated good power stability and showed that the circuit can operate

continuously performing measurements for a distance around 1.6 meters

Based on UHF RFID technology, these battery-free pressure sensor tags use EPC C1G2 standard commands to communicate their unique identification number and the associated pressure and temperature data to the RFID reader. Finally, for the simplicity of the devices used in the design, it can be considered as a cost effective alternative solution for optimization of growth crops and plants.

5. References

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