A Proximity Wireless Sensor Based on Backscatter Communication

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***Abstract*—A proximity sensor is designed as an antenna-based sensor, operating at 2.4 GHz. The operating principle relies on the fact that when an object approaches an antenna, it affects its radiation properties and its input impedance. A diode power detector is used to sense the antenna input impedance variation as a reflected wave at the input terminals of the antenna. The detector output analog dc voltage is read using an analog-to-digital (ADC) of a low power microcontroller and subsequently it is conveyed back to a reader using UHF backscatter communication based on the WISP architecture.**

Keywords—RFID, power decteor, antenna based sensor, proximity sensor, IoT

I. Introduction

The design of ultra-low power wireless sensor circuits is receiving significant interested as part of implementing the Internet-of-Things (IoT) [1]. RFID technology is considered one of the enabling technologies of IoT due to the simplicity of the tag circuit as well as the ability to operate with very low power based on backscatter communication.

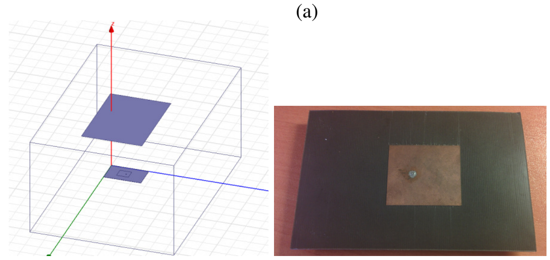
Antenna based sensing has been introduced in RFID systems, to enhance their functionality by integrating sensing features in addition to identification in a simple manner [2]. Specifically, the circuit external to the tag IC is designed in such a way that a desired sensing parameter like the presence of a gas, temperature or humidity variation, object proximity results in a modification of the tag antenna radiation and impedance properties, or the impedance matching between the antenna and the tag IC, thus modifying the backscattered signal from the tag which can be detected by an RFID reader as a measure of the sensing parameter.

In this paper, the feasibility of a proximity sensor based on a 2.4 GHz patch antenna is investigated. First, the effect on the patch input impedance of a metallic rectangular sheet placed at a certain distance above the patch is investigated in simulation and measurements. Second, a diode detector circuit is designed and used to convert variations in the reflected signal at the patch input due to the presence of the metallic object in dc voltage. The patch antenna is excited using a continuous wave signal from a commercial signal generator. Third, a wireless sensor board is designed based on a MSP430 microcontroller, operating as a passive RFID backscatter node based on the WISP prototype [3] and one of its analog-to-digital (ADC) input pins is used to read the detector voltage and return this information in addition to its identification number when interrogated by a commercial RFID Impinj reader. Preliminary experiments utilizing a wired connection between the reader and the RFID enabled sensor tag are shown. Future work consists of implementing a low power high efficiency oscillator (similar to [4]) and integrating the oscillator and patch antenna with the RFID circuit in order to demonstrate wireless operation.

II. Antenna-Based Proximity Sensor

The input s-parameters of a probe fed patch antenna designed on a 0.5 mm Duroid 5880 substrate, are measured while a metallic plate is placed on different distance values above the patch. The measurement and simulation setup is shown in Fig. 1.

(a)



(b)

Fig. 1. Patch antenna with metallic object in placed in proximity, a) measurement setup, b) simulation setup.

A power detector using the SMS7630 Schottky diode connected in parallel to the antenna feed line was implemented (Fig. 2) in order to convert the antenna impedance variation due to the presence of the metallic object in dc voltage. Fig. 3 and Fig. 4 show the output voltage of the detector for different RF frequencies and object distance values respectively.

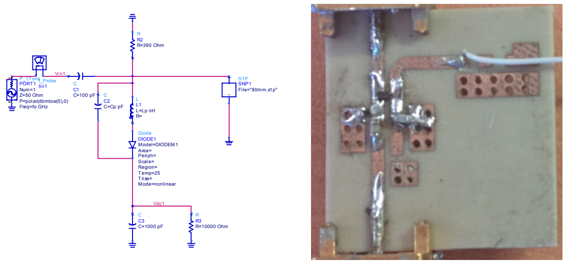


Fig. 2. Power detector circuit schematic (left) and prototype (right).

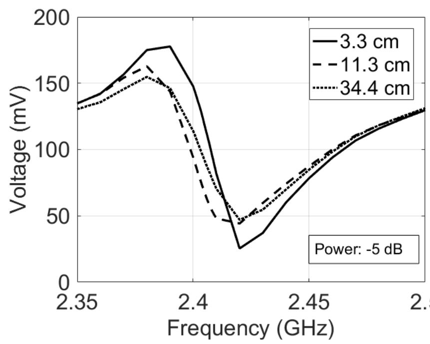


Fig. 3. Power detector output dc voltage versus the RF signal frequency for different distances of the metallic object from the patch. The transmit power is fixed at -5 dBm.

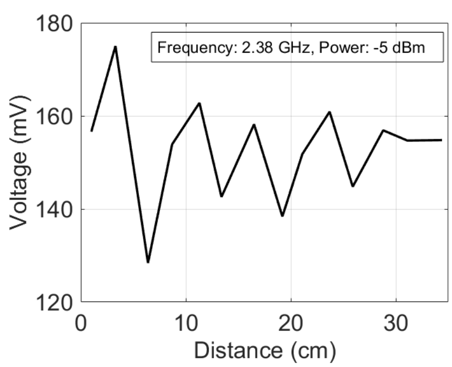
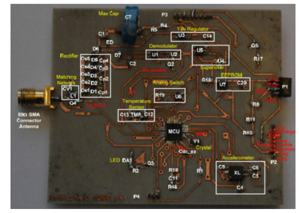


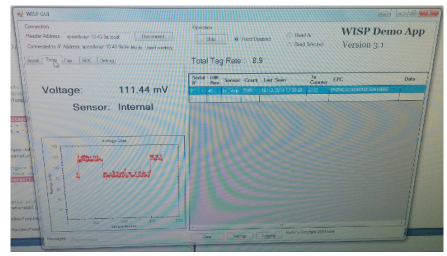
Fig. 4. Power detector output dc voltage versus distance at RF signal frequency of 2.38 GHz and transmit power of -5 dBm.

III. Communication

Finally, Fig. 5 shows the WISP type wireless sensor node operating as an RFID tag, and a screenshot of the read of the sensor node when interrogated by a commercial reader, where the jump in the reading is due to the presence of the metallic object.



(a)



(b)

Fig.5. Wireless sensor node (a), and (b) demonstration of sensing operation.

IV. Conclusion

The feasibility of an antenna based proximity sensor is investigated. The sensing operation is performed at 2.4 GHz, while communication is based on a UHF Gen 2 RFID system similar to a WISP node. It is verified that the presence of metallic objects in close proximity of approximately 4-5 cm can be easily detected, while the presence of objects in larger distances of approximately 40 cm may require careful calibration, additional signal processing or multiple frequency detection.

Acknowledgment

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