A Depolarizing Chipless RFID Tag with Humidity Sensing Capability

ShangBin Fan[1], Yi Fan[2], TianHai Chang[1], XiongYing Liu[1], Manos M. Tentzeris[3]

[1]School of Electronic and Information Engineering,
South China University of Technology,
Guangzhou 510641, China
liuxy@scut.edu.cn

[2]School of Electronic and Information,
Guangdong Polytechnic Normal University,
Guangzhou 510665, China

[3]School of Electrical and Computer Engineering,
Georgia Institute of Technology,
Atlanta, GA, 30332–0250, USA

***Abstract*—A novel compact depolarizing chipless RFID tag is investigated for humidity sensing. The proposed chipless tag is based on three nested scatterers with the resonant frequencies in the band covering from 4 GHz to 7.5 GHz. The innermost scatterer is used to monitor humidity variation, while the outer two resonators are introduced to encode 6-bit data through using frequency shift encoding method. Polyvinyl alcohol (PVA) film is deposited on the surface of the sensing resonator, making it sensitive to the humidity. The relative humidity information is encoded in the deviation of the resonant frequency. In addition, the tag has a compact size of 15 × 15 × 0.8 mm^3 with depolarizing characteristic which can increase the robustness of detection in complex environments.**

Keywords—Chipless RFID; depolarization; humidity sensor; radio frequency identification (RFID)

I. Introduction

Radio frequency identification (RFID) is an automatic identification technology that uses radio frequency signals to transmit information through electromagnetic coupling. In recent years, chipless RFID sensor possessing the functions of RFID tag and passive sensor node has aroused the attention of researchers. Chipless RFID tags require no integrated circuit (IC) or on-board power supply and can work for a long time as they are not limited by battery life [1]. Hence, the chipless RFID sensor has benefits over traditional sensors because of its lower cost and longer working life [2]. According to the sensing target, different kinds of chipless RFID sensors have been studied, such as temperature sensors [3], humidity sensors [4], and displacement sensors [5].

In this paper, a depolarizing chipless RFID humidity sensor is introduced. When interrogated by an RFID reader, the proposed sensor can provide relative humidity information of the environment together with 6 bits coding data. Moreover, the humidity sensor possesses depolarizing characteristic, improving its detection robustness in harsh environments.

II. Tag Design And Sensing Principle

A. Tag Structure

The configuration of the proposed chipless RFID sensor is shown in Fig.1, which is manufactured on the substrate of Taconic TLX-8 with a relative permittivity of ε_r = 2.55, a loss tangent of $tan\delta$ = 0.0019 and a thickness of h = 0.8 mm. The designed chipless tag consists of three set of nested concentric square rings with chamferings on the main diagonal and splits on the vice diagonal. Each ring works as a resonant scatterer. As the tag is excited by a vertical polarized wave, its radar cross section (RCS) will generate three resonant peaks in the

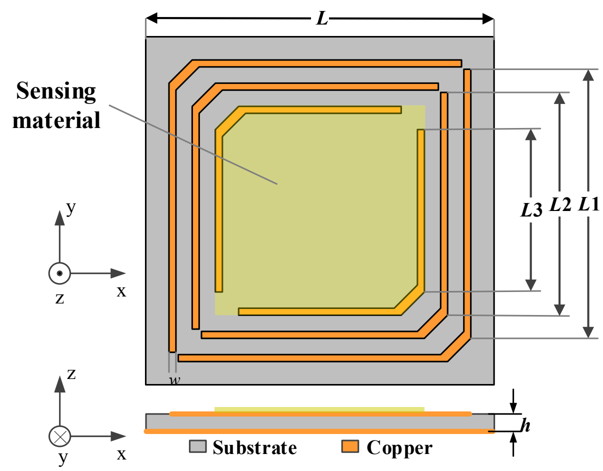

Fig. 1 Geometry of the proposed sensor. Dimensions are L = 15 mm, $L1$ = 11.6 mm, $L2$ = 9.6 mm, $L3$ = 7 mm, w = 0.3 mm, and h = 0.8 mm.

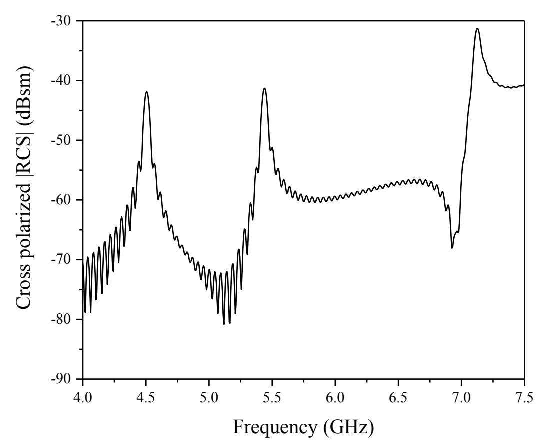

Fig. 2 Simulated RCS magnitude in cross polarization.

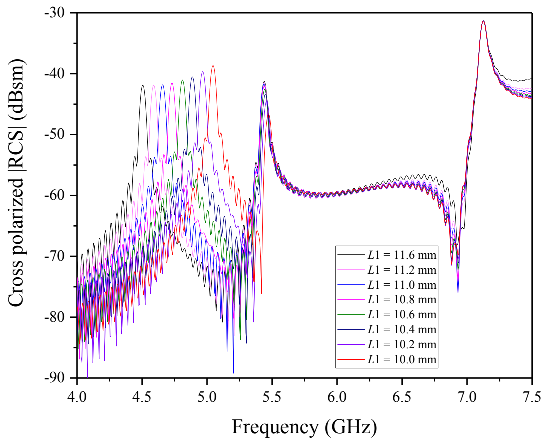

Fig. 3 Simulated RCS magnitudes in cross polarization corresponding to different length of $L1$.

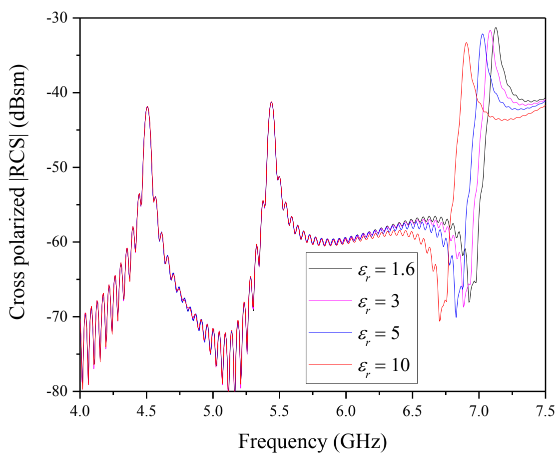

Fig. 4 Simulated RCS magnitudes in cross polarization for different relative permittivity ε_r of PVA.

horizontal direction, i.e., cross polarization, as shown in Fig.2. The proposed tag operates in the frequency range of 4–7.5 GHz and the innermost scatterer is used to monitor humidity variation.

In order to improve the coding capacity, the frequency shift encoding method is adopted on two resonators outside. With reference to Fig. 3, obvious frequency shift can be realized by changing the geometrical dimensions, such as the length of $L1$. It can be seen that the resonator can provide eight distinguishing resonant frequencies without affecting the adjacent resonator and the frequency offset is about 60 MHz. Thus, it can reliably encode 3-bit data. Similar results can be obtained by adjusting the length of $L2$. Therefore, the total coding capacity of the proposed tag is 6 bits. The tag is simulated and the cross polarized RCS magnitude is computed in CST MWS.

B. *Humidity Sensing Principle*

In this designed tag, the sensing part is constructed through covering a thin PVA film on the inner resonator. As the environmental humidity changes, the relative permittivity of PVA shows obvious variation [6]. Hence, the resonant frequency shifts are caused, representing different humidity level. Consequently, the relative humidity information is encoded in the frequency shift of the resonant peaks.

To verify the sensing principle, a simulation is performed in CST MWS. The variation of humidity is imitated by changing the dielectric constant of the material deposited on the tag. As shown in Fig. 4, when the relative permittivity ε_r increases, the resonant frequency shifts towards lower frequency.

III. Conclusions

A compact depolarizing chipless RFID tag with humidity sensing capability has been presented. The proposed sensor can monitor humidity variation of the environment while providing 6-bit coding data. Besides, the tag possesses depolarizing characteristic, improving its detection robustness in complex environments.

In future research, the tag will be fabricated and measurements in humid environment will be carried out to validate the sensor operation. Also, a calibration curve for the sensor will be determined through enough experiments.

Acknowledgment

This work was supported in part by the National Natural Science Foundation of China under Grant 61372008, in part by the Science and Technology Planning Project of Guangdong Province under Grant 2014A010103014, 2015B010101006, and in part by the China Scholarship Council (CSC) under Grant 201706155018.

References

[1] S. Preradovic and N. C. Karmakar, "Chipless RFID: bar code of the future," *IEEE Microw. Mag*., vol. 11, no. 7, pp. 87–97, Dec. 2010.

[2] N. C. Karmakar, E. M. Amin, and J. K. Saha, *Chipless RFID Sensors*, John Wiley & Sons, 2016.

[3] T. Noor, A. Habib, Y. Amin, J. Loo, and H. Tenhunen, "High-density chipless RFID tag for temperature sensing," *Electron. Lett.*, vol. 52, no. 8, pp. 620–622, Apr. 2016.

[4] A. Vena, E. Perret, S. Tedjini, D. Kaddour, and T. Barron, "Toward a reliable chipless RFID humidity sensor tag based on silicon nanowires," *IEEE Trans. Microw. Theory Techn.*, vol. 64, no. 9, pp. 2977–2985, Sep. 2016.

[5] E. Perret, "Displacement sensor based on radar cross-polarization measurements," *IEEE Trans. Microw. Theory Techn.*, vol.65, no.3, pp. 955–966, Mar. 2017.

[6] Z. Abbas, Y. K. Yeow, K. Khalid, and M. Z. A. Rahman, "Improved dielectric model for polyvinyl alcohol-water hydrogel at microwave frequencies," *Am. J. Applied Sci.*, vol. 7, pp. 270–276, 2010.