Enhanced Chipless RFID Tags for Sensors Design

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***Abstract*— Chipless technology is based on the modulation of the backscattered signal. The challenge in designing chipless RFID sensors is how to perform data encoding without the presence of a chip and adding the sensing capability. The aim of this work is to investigate chipless RFID design able to face these challenges.**

Keywords—chipless RFID tag; chipless RFID sensor; RCS.

I. INTRODUCTION

The pervasive nature of the Internet-of-Things requires the development of novel, reliable and low-cost wireless solutions. A promising research area regarding this topic deals with Radio Frequency Identification (RFID) systems that employ chip-based RFID tags with sensing capabilities. RFID tags usually comprise an antenna and an integrated circuit (IC) that performs all of the data processing and is powered by extracting energy from the interrogation signal transmitted by the RFID reader. It has been proven that it is possible to add sensing capability to RFID tags in order to estimate physical parameters or chemical substances [1]. However, a rectifier circuit followed by a charge pump circuit is required to extract DC power from the reader's transmitted signal. At his purpose, the level of the signal available from the tag antenna must reach a critical threshold level of approximately -22 dBm for most sensitive RFID chip. Despite the great interest of conventional RFID, the need for an all passive sensing solution is highly desirable in order to fulfill important practical requirements such as: real-time sensing, potentially infinite lifetime, green technology compliant and last but not least low-cost to allow a massive use of tags for environmental monitoring. It is therefore a challenging and necessary task to investigate on chipless RFID technology to reduce the unit cost and provide innovative solutions for realizing a ubiquitous wireless sensor network.

Chipless technology is based on the modulation of the backscattered signal and it has recently gained great attention in the logistic field for tracking objects. The challenge in designing chipless RFID tags is how to perform data encoding without the presence of a chip and a great research effort is ongoing to propose more and more clever encoding, both in frequency as well as in time domain. In addition to this, the sensing capability has to be added and the chipless RFID tag has to provide an estimate of an environmental entity. Numerous state-of-the-art designs of chipless sensors can be found in the open literature although the reliability and reproducibility of most of them is critical.

Several challenges still wait to be faced and efficiently solved. First of all, the sensing capability relays on Chemical Interactive Materials (CIMs) and in particular to their permittivity variation once integrated in the sensor. The permittivity variation is in fact at the basis of the sensing mechanism of the changing physical parameter. Therefore, modeling the relation between the sensed parameter and the change in the sensor response is of the utmost importance. In this sense, some promising designs of chipless RFID tags have been further investigated in order to provide a tag that can also perform sensing operation.

II. CHIPLESS RFID SENSORS EXPLOITING PERIODIC SURFACES

A chipless RFID sensor can be realized by exploiting the permittivity variation of a CIM placed on a frequency-based chipless RFID [2]. The changing permittivity of the superstrate material determines a variation of the frequency response of the chipless RFID tag. As an example, a chipless RFID tag that can be transformed in a humidity sensor is investigated. The proposed configuration is illustrated in Fig. 1. The CIM is placed on the periodic surface printed on a grounded dielectric superstrate (FR4 substrate 2mm-thick). In the reported example, a sheet of paper has been adopted as the CIM superstrate. The permittivity of the dry paper has been considered equal to 3.5. A progressive increment of the 10% of the initial permittivity has been estimated because of humidity absorption. It is apparent that the increasing water content of the paper layer determines a shift of the absorption peak of the chipless RFID tag (Fig.2). In this case, the information is encoded in the frequency shift with respect to the reference values of the dry paper and it is not related to the peak deepness. Ongoing investigation are focusing on linking the change in permittivity to the relative humidity (RH).

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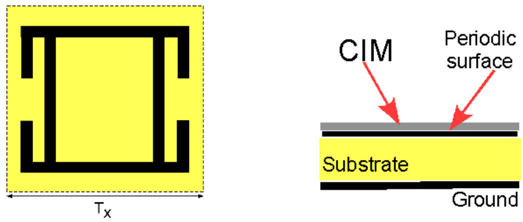

(a) *(b)*

Fig. 1. Top view of the unit cell of the periodic surface a) and stackup of the employed configuration b).

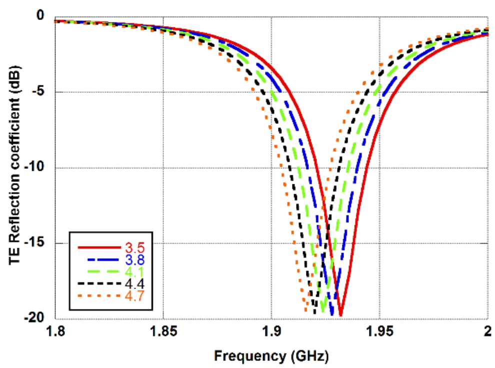

Fig. 2. Shift of the absorption peak as a function of the increasing CIM permittivity.

III. Chipless RFID based on Radiofrequency Elementary Particle (REP)

One of the most effective approaches to code chipless tags is to define a single scattering shape that exhibits a well predictable and controlled electromagnetic signature. This single scattering shape can be seen as a coding REP. The association of several REPs, with different sizes to provide orthogonal electromagnetic signatures, can be used to build chipless tags. It is worth noting that the RF characteristics of the REPs govern the performance of the designed tag, in particular the coding capacity and potential read range. In practice, the definition of the shape of the REP should consider three main parameters: selectivity, read-range and size of the REP [3]. A very promising configuration is represented by a C-like extended shape provides the better compromise in terms of size, frequency selectivity and RCS level. An example of chipless tag is shown in Fig. 3a. It is based on 5 REPs having different sizes to cover different parts of the UWB band. A bandwidth of 1 GHz is associated to each REP and a frequency step of 100 MHz is considered. These data allow a coding capacity of 16 bits. Higher coding capacity can be reached by using more REPs [4]. Last but not least, this chipless tag can be transformed into chipless sensor by adding some sensitive material inside one of the REPs. Based on chipless technology, the idea here is to add on a sensor function [5]. The tag-sensors presented here use a material sensitive to humidity, with the idea of making it interact directly with the wave, which will question the tag and the backscattered part of which must also contain its identifier. One simple solution consists of using one of the resonators to measure humidity (see Fig. 3a) [5]. Since each resonator has a different resonance frequency, we are certain that it will always be possible to separate the information pertaining to the ID from that pertaining to the physical value. Fig. 3b shows the variation in resonance frequency of the largest resonator (see Fig. 3a) according to humidity: the other resonances remain constant provided that the humidity-sensitive material has only been deposited on the element resonating at 2.54 GHz.

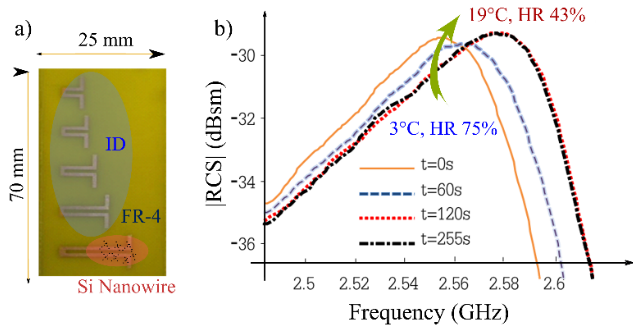

Fig. 3. a) Photograph of a chipless RFID tag integrating the sensor function. b) Influence of humidity on the EM response of a resonator containing a deposit of Si nanowire.

In this approach, the properties of the sensitive material that will determine those of the sensor. For our chipless tags, a variation in conductivity undeniably causes a change in the response of the signal of a resonator in the tag, while a change in permeability or permittivity will result in a gap in its resonance frequency. To do this, silicon nanowires have been deposited in the slot of a resonator (Fig. 3a). The deposit has been done manually; the nanowires are placed in an aqueous solution and then, using a pipette, several drops have been placed on precise spots on the structure (see Fig. 3a). As Fig. 3b shows, measurements taken with a classic chipless test bench have revealed the sensitivity of the sensor to humidity. Measures are taken every 15 seconds to supervise the variation of the tag's RCS as a function of time. As we will see, measurements taken at fixed humidity and then fixed temperatures—with the other value being variable—have made it possible to isolate the source of the variations observed.

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