

Multiparameter chipless RFID sensor tag for humidity and NO₂ determination

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Summary:

This paper reports a chipless RFID sensor tag to be used for the simultaneous determination of both humidity and NO₂ concentration in the environment. The tag is based on the use of functionalized ELC resonators with two different sensitive materials. The detection strategy allows for a wireless determination of both environmental parameters because the resonators work at different frequencies and react differently to the selected environmental parameters.

Keywords: Environmental sensor, microwave sensor, chipless RFID sensor, multiparameter sensor, reduced SnO₂

Introduction

Chipless RFID solutions are an emerging technology compared to their chipped counterparts and are intensively studied for their advantages related to the absence of electronics in the tag. This quality makes chipless RFID tags very attractive due to their low price, mechanical stability, very low energy consumption and suitability in harsh environments. Furthermore, the sensing capability can be added to the more traditional identification function in a very simple and unified way by adding sensing resonating structures to the ID geometries [1,2]. This is achieved by adding a sensitive layer on top of the selected resonator [3], which interacts with a specific chemical or physical parameter present in the environment and modifies the intensity and the frequency of the resonance peak accordingly. This characteristic of chipless RFID sensors gives the possibility to exploit gas sensing materials already used in established wired sensing approaches combining them seamlessly with wireless detection strategies ⁴.

In this work, we focus on the sensing function to be implemented in a chipless RFID tag, addressing simultaneously two environmental parameters, namely NO₂ concentration [4] and relative humidity (RH) [5]. The detection is performed wirelessly with antennas located 20 cm from the tag. The two selected sensing materials are Nafion NRE 212 (commercially available) and reduced SnO₂ for humidity and NO₂, respectively. It will be shown how the detection can be efficiently performed, how the two pa-

rameters can be determined by combining the response of the two sensors and what is the role of the co-sensitivities. This work paves the way for the ambitious goal of multiparametric chipless RFID detection where all the relevant environmental parameters are monitored simultaneously with a single ID tag at room temperature, with negligible energy consumption and in a completely passive way

Experimental Details

The chipless sensor cell includes two sensors fabricated by microlithography and wet-etching processing on the 17 μm copper layer of a commercially available 168 μm-thick RO4350 substrate. The resonator geometry is an electric inductive capacitive (ELC) resonator. The two sensors have a resonance frequency which is given by their geometrical dimensions and is expected in the range 1.5-2.5 GHz from the simulation of the bare resonators. The geometries of the resonators are reported in Fig. 1.

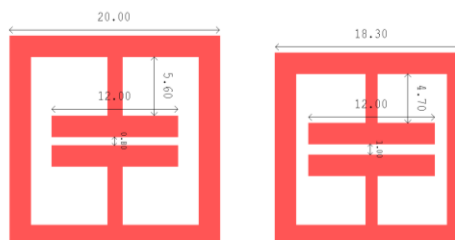


Fig. 1. Geometry of the chipless tag with two resonators. All dimensions are in mm.

The sensitive materials are Nafion NRE 212, which is commercially available and reduced SnO₂, prepared as described in ⁴. The reader is

composed of two directional E-plane linearly polarized Vivaldi Horn antennas connected with low-losses RF cables to an Agilent ENA series E5061B VNA.

The magnitude of the S21 signal is measured as a function of the environmental parameters in the range 1.5-3 GHz. The climatic chamber where the tag is introduced for the measurements has a volume of 500 cm³. It is custom-made with dielectric materials to enable the reading inside the chamber and reduce its interference with signal detection. Humidity and NO₂ levels are controlled inside the chamber through connections with calibrated mass-flow controllers.

The distance between the tag inside the chamber and each antenna is 20 cm.

Results and Discussion

In Fig. 2 the resonance peaks of the two sensing resonators are reported at 0% RH and 0 ppm NO₂, after baseline subtraction. The peak at 1.75 GHz is functionalized with Nafion NRE-212 and the peak at 2.25 GHz with reduced SnO₂. The response to increasing relative humidity in both sensors is reported in Fig. 3.

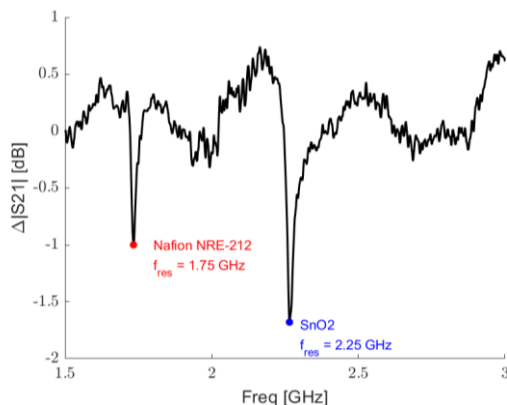


Fig. 2. Resonance peaks of the two resonators at 0% RH and 0 ppm NO₂.

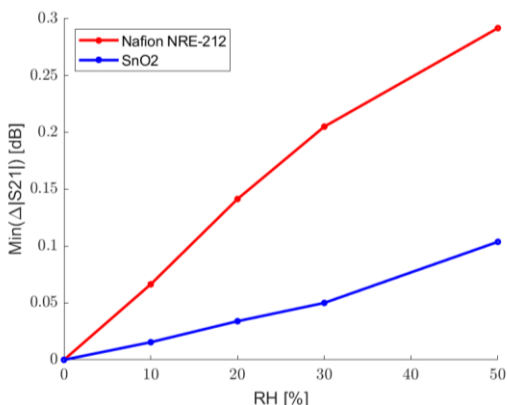


Fig. 3. Variation of |S21| as a function of relative humidity for both sensors.

As expected, the resonator covered with Nafion 212 NRE shows a high sensitivity to humidity.

However, also the response of the resonator covered with SnO₂ is not negligible and needs to be taken into account.

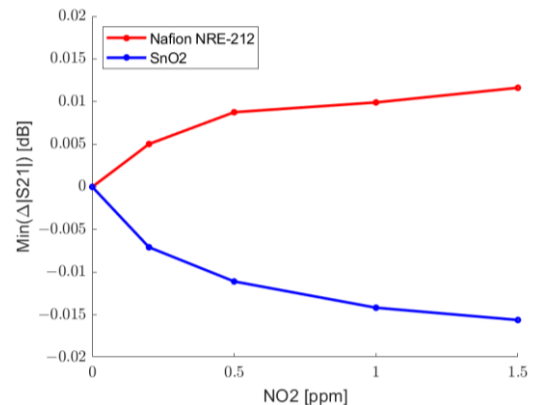


Fig. 4. Variation of |S21| as a function of NO₂ concentration for both sensors.

The variation with increasing concentrations of NO₂ in both sensors is reported in Fig. 4. Again, both sensors are responding to the environmental parameter, but the sensor functionalized with reduced SnO₂ shows a higher variation as expected. However, in this case, the direction of the variation is not the same, suggesting a quite different reaction mechanism in the two cases. Typical response and recovery times are also notably different for the two sensors (data available but not shown in this abstract). Despite the cross-sensitivities, the combined output of the two sensors allows for the determination of both environmental parameters. (1)

References

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