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Chipless Wireless Temperature Sensor Based on C-like Scatterer for Standard RFID Reader

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Abstract

This summary presents a proof of concept for a passive chipless wireless sensor for temperature range detection. The temperature range information is encoded in a binary format using dual C-like scatterers operating at two different frequencies. The sensing principle is based on resonance shift of the Radar Cross Section (RCS) peaks of the backscattered signal from the two adjacent scatterers. This shifts the reflected power maximum in or out of the bands mapping it to logic ‘1’ or logic ‘0’. The European and ISM bands are chosen for wireless sensor compliance with commercial RFID readers communication standards. This is an attempt to use the conventional RFID standards reader for chipless sensing.

1. Introduction

The conventional radio frequency identification (RFID) systems where the tag antenna is connected to an IC chip are well developed technology and widely available for different applications [1]. An alternative to conventional RFID systems is the chipless RFID technology, where the tags are made of an antenna or scatterer only. This has the advantage of being realizable in a single fabrication process on different types of substrates [2, 3]. Chipless RFID technology [4] appears as a young field of research because in the past several years, most chipless RFID systems found in literature are either in their early prototyping phase or have existed for period of couple of years. This keeps an open door for research and development for novel chipless RFID system with improved or new functionalities [4].

Chipless temperature sensing is a topic of recent interest in RFID research community. Different structures have been realized and tested [5, 6, 7, 8]. However, reading chipless tags have many constrains concerning the usage of reading impulses which do not exist in commercial readers. The challenge in this work is to propose a solution based on standard RFID system to read chipless sensor-tags. This work addresses a proof of concept for a passive chipless wireless sensor interrogation using commercial RFID readers for temperature information in dual commercial frequency bands. The sensor operating principle is based on encoding temperature ranges in a binary format using two C-like resonant scatters. The two scatters are designed on a temperature sensitive dielectric substrate where one scatter resonates in the ETSI UHF RFID band, while the other scatter resonates in 2.4 GHz ISM band. Temperature variation introduces a shift in the position of the resonance and anti-resonance peaks of the RCS of the backscattered signal. Depending on the position of the peaks, the power level of the scattered signal shifts from maximum which corresponds to (logic ‘1’) to minimum which corresponds to (logic ‘0’). Using this coding, the desired temperature range information is encoded in a two bits value.

2. Sensor Structure & Simulation

Figure 1 represents the structure of the proposed temperature sensor. It consists of two C-like resonators on a temperature sensitive dielectric substrate. Resonator 1 has a resonance frequency of 0.862 GHz while resonator 2 has a resonance frequency of 2.43 GHz. The choice of these frequencies is made in order for the proposed sensor to be used in commercial allocated frequency bands (ETSI & ISM bands).

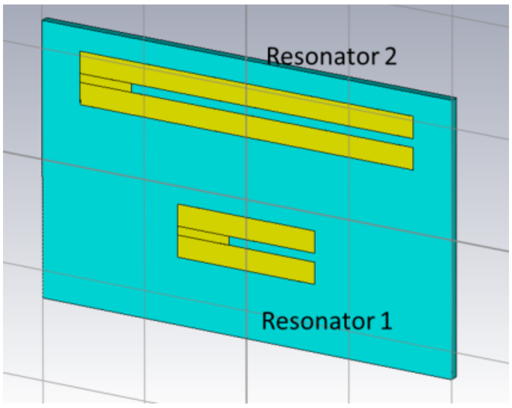

Figure 1. Temperature sensor structure based on the two C-like resonators on temperature sensitive dielectric substrate.

The operation principle is based on a resonance frequency shift of RCS peak due to the permittivity variation as a function of temperature. The substrate has been chosen to have high dielectric constant for sensor size reduction as well as high coefficient of dielectric constant for significant frequency shift under temperature variation. To study the effect of temperature variation on the backscattered RCS frequency shift, the structure has been simulated with substrate parameters ($\varepsilon_r = 30$, h = 1 mm, $\tan\delta = 0.001$) and coefficient of dielectric constant of $-370\times10^{-6}/^{o}C$. Simulation results are shown in Figures 2 and 3. C-like scatter exhibits a resonant frequency and an anti-resonance frequency. The specific geometry of the C-like allows obtaining resonance of an open/shorted structure leading to $\lambda/4$ resonator. It is worth noting that the same configuration shows an anti-resonance frequency slightly different. In this design we exploit the resonant frequency as the RCS level associated to that frequency is more suitable for detection and therefore practical implementation of the measurement. Typical RCS response of the C-like is shown on Fig. 2

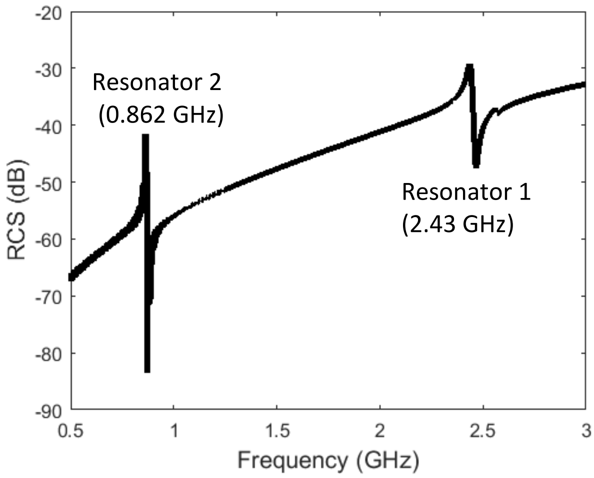

Figure 2. RCS simulation results of the sensor structure for resonance in two frequency bands.

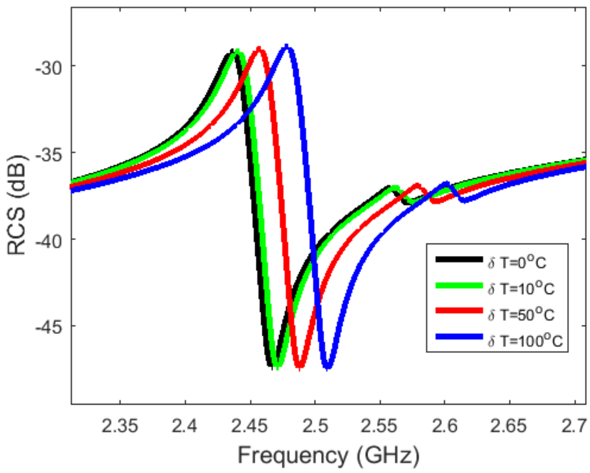

Figure 3. RCS simulation results for resonance under different temperature values in the ISM band.

3. Operation Principle and Coding

The two C-like scatters act as two bits encoder for a temperature range. Logic '1' is represented by a resonance lies within the band, while logic "0" is represented by a resonance outside the band. The encoding depends on the band width and the amount of resonance shift due to temperature variations. Since the ETSI and ISM bands do not have the same band width, one expect that the resonance shift will not be the same and hence allowing different combination of binary code to be assigned to ranges of temperatures. Fig. 4 (a) shows the ranges of temperatures in the ETSI band while Fig. 4 (b) shows the temperatures range in the ISM band.

Table I summarizes the different bit combinations that could be used to represent the desired temperature ranges.

It is worth noting that the proposed principle of encoding is for indicating temperature ranges and not a specific temperature value. For instance, the code "01" indicates a temperature range less than 10°C but not a given exact value.

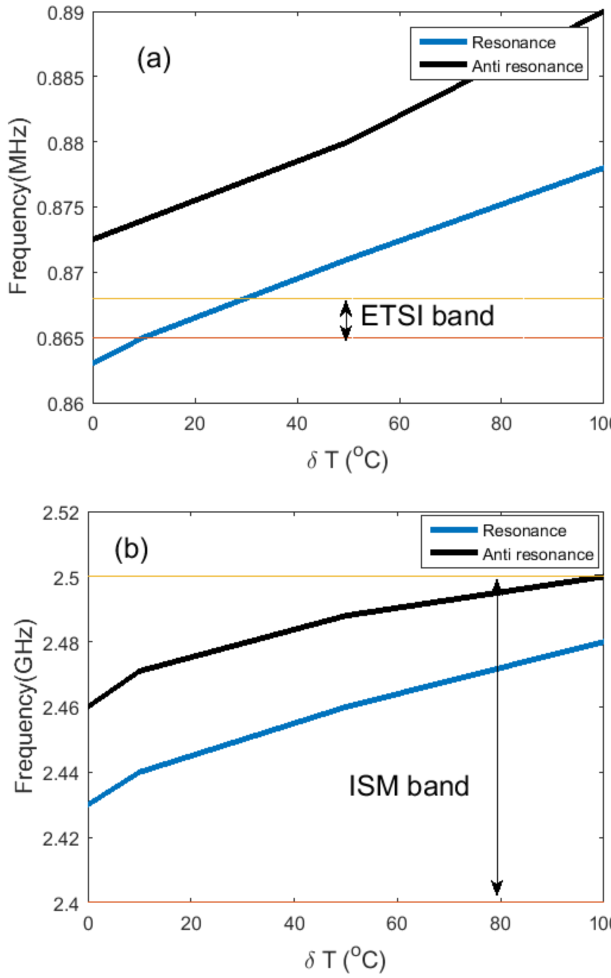

Figure 4. Simulated resonance frequency shift due to temperature variation from 0 to 100 °C(a) for the 0.862 GHz peak. (b) for 2.43 GHz peak.

TABLE 1: The different bit combination representing the temperature range

EU band	ISM 2.4-2.5 GHz band	Condition	Peak type
'0'	'1'	T < 10 °C	Resonance
'1'	'1'	10 < T < 30 °C	Resonance
'0'	'0'	T > 100°C	Anti-resonance

4. Conclusion

In this paper we presented a proof of concept for the design of temperature sensor using chipless configuration and exploiting the variation of the substrate permittivity with the temperature. A specific design based on C-like scatterrers geometry can lead to frequency response in the ESTI RFID UHF and the 2.4GHZ bands, which allows the use of conventional RFID readers as chipless sensor interrogator.

5. Acknowledgements

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7. References

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