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On energy harvesting for augmented tags

Récupération d'énergie pour tags augmentés

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ABSTRACT

In this paper, the harmonic signals generated by UHF RFID chips, usually considered as spurious effects and unused, are exploited. Indeed, the harmonic signals are harvested to feed a supplementary circuitry associated with a passive RFID tag. Two approaches are presented and compared. In the first one, the third-harmonic signal is combined with an external 2.45-GHz Wi-Fi signal. The integration is done in such a way that the composite signal boosts the conversion efficiency of the energy harvester. In the second approach, the third-harmonic signal is used as the only source of a harvester that energizes a commercial temperature sensor associated with the tag. The design procedures of the two "augmented-tag" approaches are presented. The performance of each system is simulated with ADS software, and using Harmonic Balance tool (HB), the results obtained in simulation and measurements are compared also.

RÉSUMÉ

Dans cet article, les signaux harmoniques générés par les puces RFID UHF, généralement considérés comme des effets parasites et non utilisés, sont exploités. En effet, les signaux harmoniques sont collectés pour alimenter un circuit supplémentaire associé à un tag RFID passif. Deux approches sont présentées et comparées. Dans la première approche, le signal harmonique $3f_0$ est combiné avec un signal Wi-Fi externe à 2,45 GHz. L'intégration se fait de telle manière que le signal composite augmente le rendement de conversion du circuit de récupération d'énergie. Dans la seconde approche, le signal harmonique $3f_0$ est utilisé comme seule source d'énergie alimentant un capteur de température commercial associé au tag. Les procédures de conception des deux « tags augmentés » sont présentées. Les performances de chaque système sont simulées avec le logiciel ADS, en utilisant l'outil

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Harmonique Balance (HB) ; les résultats obtenus au moyen de simulations et de mesures sont aussi comparés.

1. Introduction

With the emergence of the Internet of Things and its 50 billion connected objects expected for 2020, the RFID (Radio Frequency Identification) technology, well known in the areas of traceability, logistics and security, presents promising enabling perspectives [1,2]. Indeed, UHF (Ultra High Frequency) RFID, with its huge and relevant features (standardized, mature wireless and passive technology), is rapidly evolving to new types of tags, the so-called "augmented tags", which provide more than ID by incorporating not only the unitary identification function, but also new capabilities such as localization and sensing. The idea of the sensor-tag approach is to associate new tag information capture capabilities while still enjoying the identification functionality and obviously, also the remote power supply and wireless transmission. A wide variety of RFID Sensors have been demonstrated in the literature, among them sensors for temperature [3,4], pressure [5], humidity [6,7], deformation [8], crack width [9], curvature monitoring [10], Open/Close [11], chemical [12], food quality [13], etc. The previous references give some examples of the cited functionalities, but the list is not exhaustive.

To transform a passive RFID tag into a passive RFID sensor tag, there are two types of implementations. In the first type, one can exploit the sensitivity of the tag antenna to its environment, in particular when the antenna is made or loaded by sensitive material [14] or to profit from the nonlinear RFID chip properties. In the second type, the tag integrates an external sensor, which requires some additional energy consumption [15–20]. In this second case, when using the chip rectifier, the difficulties reside on the energy supply of the attached sensor to the detriment of tag performance. Another alternative is the use of energy-recovery devices that leverage energy from other sources such as solar, thermal, kinetic or electromagnetic sources [21,22]. Besides, the integration of the sensor in the RFID chip is also an interesting alternative, even if it leads to a reduction in the read range due to the degradation of the backscattering signal. This is why some recent studies focus on the co-optimization of communication and sensing characteristics. These new approaches aim to divide and/or modify the encoding of the information returned by the tag in order to combine the advantages of each; for instance, using a phase modulation for the sensor functionality and an amplitude modulation for the communication [9] or carrying the sensor information through a modulation frequency [23]. Another approach is a hybrid analog–digital backscatter platform that uses digital backscatter for addressability and control, but switches to analog backscatter mode for high data rate transmission sensor data [24]. It is also worth citing the widely used Wireless Identification and Sensing Platform (WISP), which is a programmable, microcontroller-based sensor tag compliant with the EPC Class 1 Generation 2 UHF RFID standard [25]. Furthermore, tags with battery-assisted passive (BAP) mode are now available and enable longer read-range sensing and several commercial BAP Gen2 integrated circuits have a serial port [19].

This paper focuses on the case where the RFID tag integrates one or several specific sensors. In this context, offering new sensing capabilities in RFID is synonym of additional energy needs in order to preserve the performance, and especially, the hallmark of passive tags. Some works demonstrated that it is possible to exploit green energy sources such as solar, thermal or mechanical sources. Electromagnetic energy (EM) sources present either in the environment of tags or within them (so unexploited and classically lost) are here used, and in this sense the proposed solutions could be considered green too. Indeed, the harmonic signals generated by the UHF RFID chips, and especially, the third-harmonic signal, which is the dominant harmonic [26,27], becomes useful in order to (*i*) significantly improve the EM harvesting operation via an external source or (*ii*) directly provide energy source for a sensor associated with the tag.

This work, which strongly mixes energy and radio science (i.e. power supply and wireless sensors-tags) in terms of new proposed concepts and technological solutions, constitutes a relevant brick for this dossier devoted by URSI France to "Energy and Radio Science". The paper is organized as follows. In section 2, some considerations on the use of nonlinear circuits and associated applications are summarized with a focus on the RFID context in order to better highlight the proposed concept. Section 3 presents the two envisaged system configurations exploiting the nonlinear behavior of UHF RFID chips. Section 4 explains the fundamental steps of the design and highlights the methodology. The modeling of the UHF RFID chip taking into account the impedances at operating frequencies and the harmonics generation is detailed. The two harvesting circuits, which are distinct according to the application, are described, justifying the choice and highlighting the main characteristics. The coupling with a three-port matching network between reader, chip and harvesting section, which is a critical design step, is detailed, comparing notably the performance of lumped and distributed solutions. Section 5 demonstrates the proposed concepts and shows the performance results in simulation and measurement. Finally, section 6 draws the conclusion and perspectives.

2. Considerations on the use of nonlinearities in radar, sensing and RFID applications

The signal generation by nonlinear behavior (i.e. harmonics or/and intermodulation products) is a well-known phenomenon that has been extensively studied in active antennas and circuit literature. Harmonic radar (also called secondary

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