Poster Abstract: radio frequency power transfer for wireless sensor networks

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***Abstract*—The technology for wireless power transfer has recently gained increased attention because one of the main advantages is allowing ubiquitous and pervasive systems, such as wireless sensor networks, to be continuously charged losing the constraint of battery capacity. This paper describes the design and implementation of an energy harvester which scavenges energy from radio frequency (RF) waves in Ultra High Frequency (UHF) range. The harvester accumulates energy in capacitors or supercapacitors to supply wireless sensor nodes with no batteries. The RF design consists of an antenna module, matching network and a four-stage voltage multiplier.**

I. Introduction

Recently, radio frequency power transfer have registered a growing interest as energy harvesting techniques, allowing the development of autonomous systems, such as wireless sensor networks which must operate for long intervals of time without human intervention and maintenance [1]. Power scavenged from the environment can be used as an alternative power source in order to extend the lifetime of wireless sensor networks applications, especially if they require low energy.

Differently from classic environmental energy harvesting techniques which convert energy from natural sources, the scenario of wireless powered sensor networks (WPSN) is to exploit a specific power source device *(Radio spot)* which transmits a continuous-wave (CW) RF signal to several sensor platforms deployed in a region. Each node of the WSN is enabled to harvest the spread energy and to replenish the local energy reservoirs. In an electromagnetic wave system, the main problem to tackle is the optimization of conversion efficiency. In fact, in a RF transmission, the energy is usually scattered in several directions through free space propagation and a large part of it is unused. Therefore the goal is to increase the ratio of the power received by an antenna and converted into electrical power.

The circuit presented in this paper operates at 865,5-867,6 MHz, a range where RFID systems are allowed to transmit with higher power than common ISM bands. Thus we employ a dedicated antenna for harvesting process which makes the scavenger flexible and completely independent from the powered platform and from the radio used for communication. Differently from RFID systems [2], communication is not constrained by the power of the RFID reader signal and does not used backscattered technique allowing sensor nodes to communicate with each other and not only to the *Radio spot*.

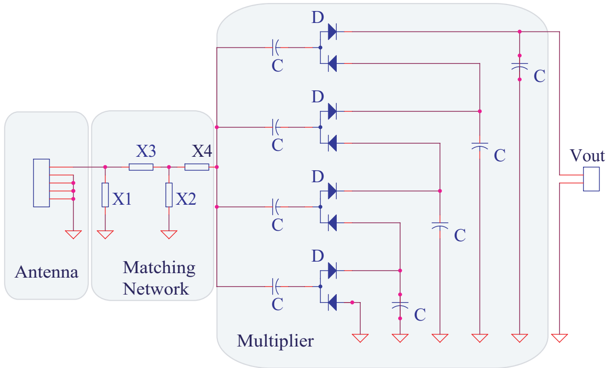

Figure 1. Schematic of the RF design

II. Harvester Design

The three crucial parts of the circuit are the antenna module, the matching network and the final voltage multiplier used as rectifier as depicted in Figure 1.

The rectifier module adopts a cascaded Cockroft-Walton voltage multiplier circuit [3] with multiple cascaded sections in order to convert the extremely low input voltage up to a level sufficient for replenishing the energy reservoirs and for powering the sensor node. According to the expected power received by the antenna and the operating frequency of the scavenger (865,5-867,6 MHz), the design of the multiplier can be completely determined. The optimum number of stages can be calculated using the following formula:

$$N_{opt} = \frac{3 \cdot V_{out}}{4 \cdot E_{PK}} = 3.989 \quad (1)$$

where E_{PK} is the peak input voltage after the matching network and V_{out} is the expected output voltage. We opted for a four-stage multiplier and the value of the capacitor can be computed according to:

$$C(N_{opt}) = \frac{I_{load}}{f} \cdot \frac{-N_{opt} + 3N_{opt}^2 + 4N_{opt}^3}{12E_{PK} \cdot N_{opt} - 6V_{out}} = 99.5pF \quad (2)$$

where I_{load} is the output current. We adopt Schottky diodes as rectifier elements for their low threshold which makes them

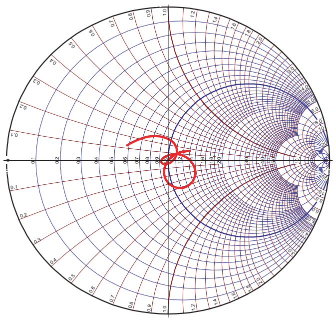

Figure 2. Input impedance varying the input power from $-15\,dBm$ to $10\,dBm$.

suitable for low input level rectifier applications and for low losses.

The input impedance looking in to the rectifier circuit is usually capacitive. The goal is to achieve an input impedance of $50\ \Omega$ in order to maximize the power transferred to the multiplier. We used lumped reactive components to create the matching network. Usually RF designers deserve a lot of attention to the development of the layout and the placement of the components which may remarkably influence the performance of the harvester. Simulations and measurements help to design the optimal layout.

Using a small-signal diode model, we use smith chart methods to find the optimal matching network elements at a given frequency. Figure 2 is a plot of the input impedance of the matching circuit measured by varying the input power from $-15\,dBm$ to $10\,dBm$. It shows that the input impedance is always close to the desired matching point allowing an optimal power transfer from antenna to the multiplier in any condition of the input signal.

III. Experimental Results

The most important figure of merit is the *Power Conversion Efficiency* (PCE) of the rectifier circuit, which can be defined as

$$PCE = \frac{P_{out}}{P_{in}} \qquad (3)$$

In other words, Power Conversion Efficiency is the ratio between the power dissipated by the sensor node P_{out} and all the power consumed by the resistive elements in the whole circuit P_{in}. Higher PCEs mean that a great portion of all the energy is directly used by the node. Figure 3 depicts the characteristic curves of the harvester. We fixed the input power at the antenna at $5\,dBm$ and changed the load value. The Maximum power transferred to the sensor node is $2,8\ mW$ with $PCE = 0,8$.

Figure 4 shows the multiplier output voltage with different input power at the antenna. It is worth noting that as soon as the input power is enough to reach the forward voltage of the Schottky diode, the output voltage increases quickly reaching values which are enough to charge an energy reservoir such as a capacitor or supercapacitor.

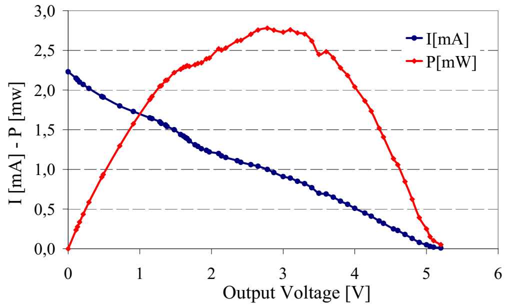

Figure 3. Characteristic of the harvester with $5\,dBm$ of input power

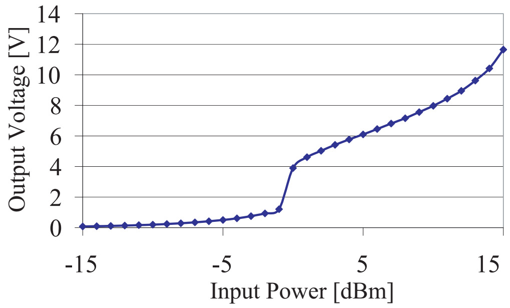

Figure 4. Output voltage over input power.

Finally, Figure 5 shows charging characteristic of a capacitor directly connected to the output of the RF harvester. The *Radio spot* was set with 1 W output RF power and the scavenger was deployed in the environment at a distance of 3 m from the radio source. The antenna can receive up to $5\,dBm$ from the continuous wave (CW) signal, and we used different values of capacitor as energy buffer. The charging time depends mainly from the value of the reservoirs; in particular, for the used capacitor, the measured charging time is less than 150 s.

References

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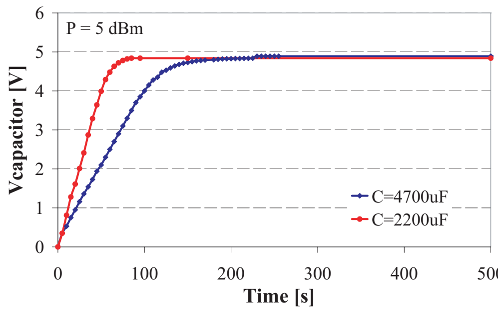

Figure 5. Charge of $4700\,\mu F$ and $2200\,\mu F$ energy buffer with $5\,dBm$ of input power at antenna.