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SENSORS, ENERGY HARVESTING, WIRELESS NETWORK AND SMART OBJECTS
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RF ENERGY HARVESTING AND REMOTE POWERING AT 900MHZ AND 2.4GHZ

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1) Context / Study motivation

With the growing popularity and applications of large-scale sensor-based wireless networks, the need to adopt inexpensive, green communications strategies is of paramount importance. To address such purpose the top most challenge concerns the supply and management of the energy required to operate the system. One approach is to deploy a network comprising self-powered nodes extracting their power from a variety of natural (sunlight, thermal...) and/or man-made (propagating radio waves, mechanical vibration...) sources for sustained network operation [1], [2]. Thus there is a strong motivation to enable off-the-shelf wireless sensor devices with energy harvesting capability that would allow sensor nodes to fill part or all of its energy costs. The propagating radiofrequency (RF) waves allow low cost, compact and adaptable solutions for energy harvesting [3]. Among the most popular frequency allocations exploited for Wireless Power Transfer (WPT) are the 900MHz and 2.4GHz ISM bands. Since the attenuation of the RF waves is inversely proportional to the frequency, the 900MHz band yields lower loss in the power transmission. On the other hand the 2.4GHz band makes the implementation of the antenna, and so RF harvesters, more compact.

2) Description of approach and techniques

Three building blocks are required to develop a RF harvester: an antenna to harvest the electromagnetic energy, a high frequency AC to DC converter and a storage element. Two types of antenna have been used: 900MHz commercial whip dipole antenna (Fig.1a) and 2.4GHz micro-strip patch antennas on printed circuit board (Fig.1b). To transfer a maximum of the power available at the antenna output, P_{rf}, to the rectifier, the impedance of each block must be matched. As the collected power, P_{rf}, is low, the rectifier is based on Cockcroft-Walton Voltage Doublers [4]. This topology is well suited to low power rectification since it further provides voltage amplification during the AC to DC conversion (Fig.2). The performances of the diodes featuring the rectification are of major importance. Considering the threshold voltage, the saturation current and parasitic capacitance, the Avago's HSMS2852 serie exhibits good characteristics to operate up to 2.4GHz. The analytic expression of the rectified voltage, V_{REC}, is reported in the equation (1). It depends on the number of cascaded stage, N, and the input power, P_{rf}, since the diode type and the antenna design respectively impose R_{dbl}, V_d and R_{ant}. According [5], if P_{rf} ranges from -25dBm to -10dBm, the optimum number of stage for maximum sensitivity is 4:

$$V_{REC} = 2N\left[\sqrt{8.P_{rf}.\left(\frac{R_{dbl}}{N} - R_{ant}\right)} - V_d\right] \qquad (1)$$

With R_{dbl}, the input resistance of a single stage doubler, R_{ant} is the antenna resistance at the operating frequency and V_d is the voltage drop across the diode.

3) Results / Conclusions / Perspectives

Printed Circuit Boards (PCB) including matching networks, a 4-stage rectifier, a storage capacitor and an antenna were developed on a 1.5 mm FR4 substrate. COTS devices such as HSMS diodes and capacitors are reported by heat treating (Fig.3). Each PCB is dedicated to an ISM Band, 900MHz and 2.4GHz respectively. The unloaded rectified voltage, V_{REC}, is presented in Figure 4 versus the input power P_{rf}. We observe that the 900MHz PCB exhibits a larger rectified voltage than the 2.4GHz PCB above -20dBm. This difference comes from the diode whose the performances decrease with the frequency. The sensitivity is defined as the minimum input power (P_{sens}) required to achieve V_{REC} =1V. P_{sens} is -18dBm at 900MHz, and -14dBm at 2.4GHz (Fig.4).

RF Energy harvesters have been tested according two scenarios of application. The first presents the measurement results in the context of Wireless Power Transfer (WPT). The WPT has been experienced with the remote powering of a clock in a furnished room of the lab. A schematic of the scenario is proposed in Figure 5.a and a picture of the scene is represented in Figure 5.b. The clock is directly connected to the RF harvesters and its nominal supply conditions are 0.9V/5µA. With a radiated power of 27dBm at 2.4GHz the clock can be powered up to 3.5 meters. At 900MHz the covered distance increases to 14 meters with a radiated power of 30dBm. The second scenario focuses on an opportunistic collection, namely scavenging, of any RF energy available in the harvester environment such as a smartphone and a tablet (Fig.6). The first experimentation is the download of a video with a cell phone in EDGE mode, Fig. 7.a. Located at 16cm of the cell phone, the 900MHz harvester supplies the clock by rectifying a 1.45V voltage during the downloading process. The second experimentation embeds a tablet broadcasting some music to a pair of speakers by a wireless Bluetooth connection. The 2.4GHz RF harvester is located close to the tablet, 8 cm, as illustrated in the Fig. 7.b. The rectified voltage is 1.3V and the clock is properly powered.

This work addresses the issue of energy harvesting with the development of COTS based RF harvesters. Two harvesters dedicated to the two most popular ISM bands, 900MHz and 2.4GHz, are realized. Sets of measurements lead to the remote powering of a 0.9V/5µA clock at 3.5m and 14m at 2.4GHz and 900MHz respectively. Such kind of Wireless Power Transfer is dedicated to the remote powering of sensors in home or industrial applications. The second scenario demonstrates the clock powering by harvesting the energy from a cell phone during a GSM data download at 900MHz. We also supply the clock by gathering the power from a 2.4GHz Bluetooth connection between a tablet and a pair of wireless speakers. This approach namely RF energy scavenging, aims to demonstrate the opportunistic collection of power from our surrounding RF environment.

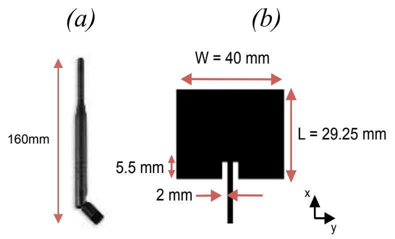

Figure 1: 900MHz/2.4GHz whip dipole antenna (a) 2.4GHz Micro-strip patch antenna on 1.5mm FR4 substrate (b)

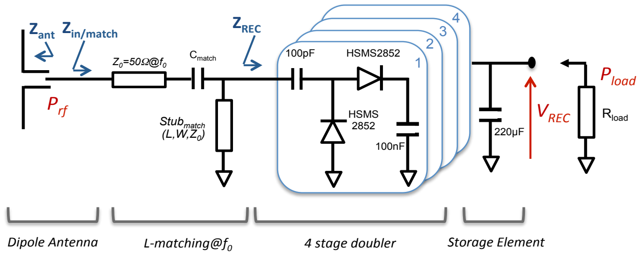

Figure 2. Schematic of the RF Energy harvesting module

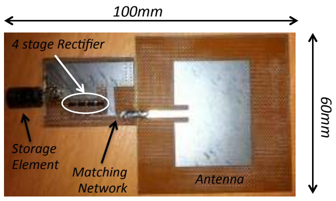

Figure 3. 2.4GHz RF Harvester on 1.5mm FR4 board

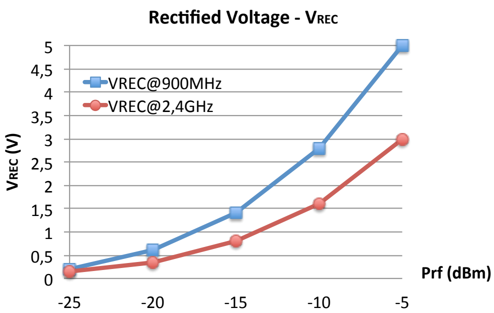

Figure 4. Unloaded Rectified Voltage at 900MHz & 2.4GHz

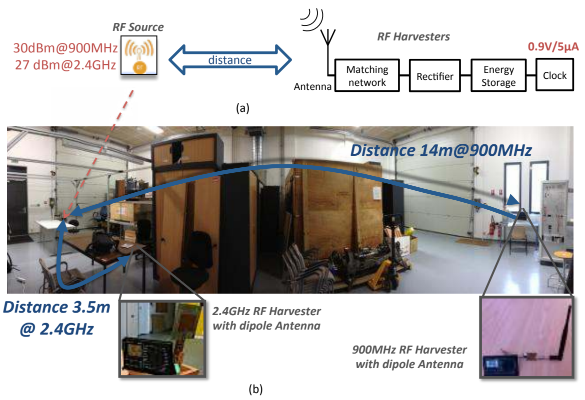

Figure 5. Remote powering of a 0.9V/5µA clock at 900MHz and 2.4GHz: schematic of the scene (a) picture (b)

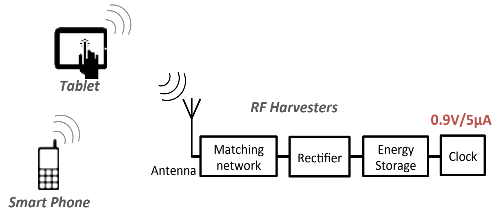

Figure 6: RF Energy scavenging scene from common wireless devices

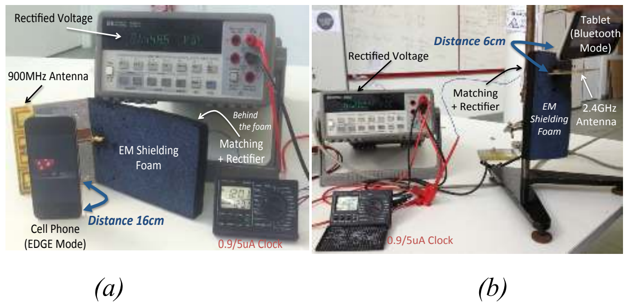

Figure 7: Scavenging scenario of RF energy for clock powering at 900MHz with a cell phone in GSM/EDGE mode (a) at 2.4GHz with a tablet in Bluetooth connection (b)

REFERENCES:

[1] K. Lin, J. Yu, J. Hsu, S. Zahedi, D. Lee, J. Friedman, A. Kansal, V. Raghunathan, and M. Srivastava, "Heliomote: Enabling long-lived sensor networks through solar energy harvesting," in 3rd Int. Conf. Embedded Networked Sensor Syst., Nov. 2–4, 2005, p. 309.

[2] J.A. Paradiso and T. Starner, "Energy scavenging for mobile and wireless electronics," IEEE Pervasive Computing, Vol. 4, Issue 1, pp. 18- 27, Jan-March 2005.

[3] K. Finkenzeller, RFID Handbook: Fundamentals and Applications in Contactless Smart Cards and Identification, 2nd ed. Chicester,Sussex, U.K.: Wiley, 2003.

[4] T. Le, K. Mayaram and T. Fiez, "Efficient far-field Radio-Frequency Energy Harvesting for Passively Powered Sensor Networks" IEEE J. of Solid State Circuit, vol.43, N°5, pp. 1287-1301, May 2008.

[5] T. Taris, L. Fadel, L. Oyhenart, V. Vigneras, "COTS-Based Modules for Far-Field Radio Frequency Energy Harvesting at 900MHz and 2.4GHz", IEEE New Circuits And Systems conference (NEWCAS), Paris, France, June 2013, pp. 71-74.