Energizing Low Power Circuits by Using an RF Signal Harvester

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***Abstract* — In this paper, a method of supplying voltage to a communication system through a wireless system is discussed. The main goal of this work is to propose a system that exploits RF signals (air signals) of 950-960 MHz to charge a small battery or to run a low power sensor. The work presented here will mainly focus on the modeling and simulations aspects of the project.**

***Keywords* —**Energy harvester, Low power circuits, RF signal, Sensor powering, wireless powering

I. Introduction

VARIOUS methods for wireless transmission of information have been studied for centuries and many good results have been achieved. Nowadays, different electronic devices such as Remote Terminal Units (RTUs), Sensors and Switches communicate wirelessly. In many applications, these devices are required to be independent, meaning that both wireless transmission of information and wireless powering are required while the system is mobile. Batteries are the main solution for empowering most wireless devices. However, there are some restrictions on the use of batteries, one of which is their limited charge. To overcome this issue, rechargeable batteries can be used, yielding the use of wires and power outlets.

At the same time, due to rapid technological improvements, power consumption of different electronic devices has decreased, which led to the potential of introduction of energy harvesters as the power source for low power consumption devices such as sensors. Basically, harvesters or "scavengers" are small devices that convert the free available energy of their surrounding into electrical power [1]. Depending on their type, harvesters utilize different energies such as solar, motion and vibration, temperature difference and ambient energy [1], [2].

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The other source for energy harvesters that is being considered is use of RF signals. Even though RF signals carry low energy, the power that can be achieved from them could be high enough to run a low power sensor or a low power circuit.

It worth's mentioning that the power of air signals can be as high as 30 dBm for GSM frequency which is relatively high and can be used for low power applications.

II. Arcitecture

High frequency signals' power is limited by regulations to avoid health concerns for human and battery drainage. Therefore there will not be enough power for triggering active element.

To achieve a passive circuit that can be adapted to harvest RF signals, the circuit of Figure 1 is suggested.

Figure 1: System Diagram of RF Harvester

Several signals of different frequencies are to be detected by this energy harvester, using embedded or a microstrip antenna. The main reason for using these types of antennas is their small size, ease of manufacture and low cost [3]. The antenna receives different modulated signals within its bandwidth.

To distinguish these different signals, a simple passive resonant circuit can be used. This type of resonant circuit consists of a capacitor and an inductor. The value of this capacitor and inductor is inversely proportional to the square of the frequency as shown in equation 1.

$$f_o = \frac{1}{2\pi\sqrt{LC}} \quad (1)$$

Furthermore, one of the main concerns in designing a resonant circuit is its quality factor which is defined as the ratio of its center frequency over its bandwidth (equation 2).

$$Q = \frac{fc}{Bw} \quad (2)$$

Therefore, the bandwidth, for a specific centre frequency, will decrease if the quality factor is increased. This yields a higher frequency selectivity which is of interest for the proposed harvester. Also, due to resonance phenomena, the higher selectivity results in an increase in the voltage level of the resonant circuit's output. However, there is a need for a voltage booster since the signals detected by the antenna carry low power. A Villard voltage multiplier is going to be used for this purpose.

Voltage multipliers can boost alternating input voltage to a higher level depending on the number of capacitor-diode stages used. The most common type of voltage multiplier is the half-wave series multiplier, which is known as the Villard cascade [5].

In order to add signals of different frequencies, the output voltage of the Villard voltage multipliers should be converted into DC voltage which can be done by the means of passive peak detectors.

The simplest peak detector circuit that can be used consists of a Schottky diode -which has a low built in potential of approximately 0.2 Volts [6], [7] - and a capacitor.

The overall circuit of the harvester is shown in Figure 2. In this circuit, capacitors of 1pF, 10pF and 22pF, and an inductor of 2.2 nH were used.

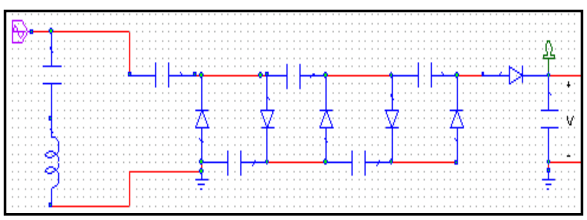

Figure 2: The circuit of the RF harvester

Even though the harvested signal is boosted by the multiplier, the output is not significant. To attain higher voltage at the output of the harvester several circuits, as that of Figure 2, can be merged together. In order to add the output DC signals of the peak detectors, a passive adder is needed [8].

III. Field Measurements

To inspect the level of available RF powers of air signals, which is variable and dependent on the surroundings, some environmental measurements were conducted. For this purpose, a spectrum analyzer (Rohde & Schwarz FSH3) and a monopole GSM antenna were used.

Figure 3 illustrates the spectrum of RF signals existing in frequency range of 100 KHz to 3GHz.

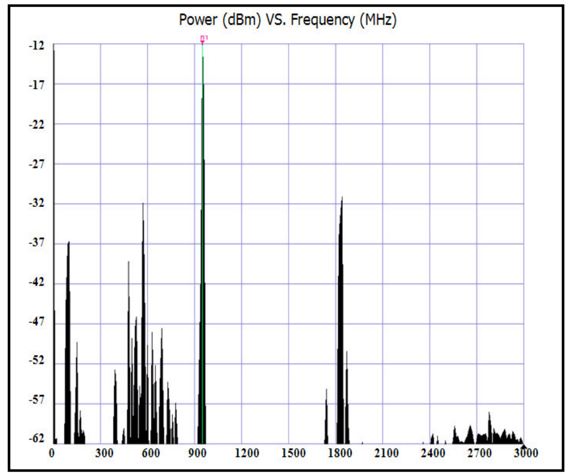

Figure 3: Spectrum of signals in the range from 100 KHz to 3 GHz

As it can be seen from the spectrum of Figure 3, there are different ranges of frequencies in which the power is adequate for the harvester introduced in this paper. The main challenge in getting power from signals is their continuous frequency hopping. However, after studying these signals, it was found that the signals with frequencies within the 950 MHz to 960 MHz range experienced less hopping. Moreover, these signals carry more power. Figure 4 shows one of the states of the signals in this range.

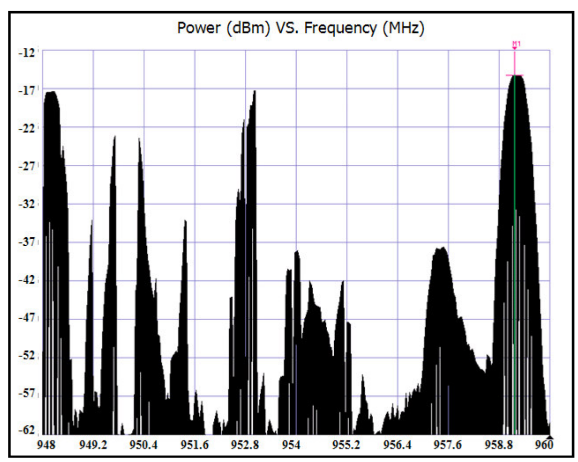

Figure 4: Spectrum of signals in the range from 948 MHz to 960 MHz

It can be seen that the RF signals can carry a peak value of -15 dBm. Nevertheless, some RF signals were found to have even a peak value of -10.5 dBm.

IV. SIMULATION

The circuit of this harvester was implemented and simulated in the AWR Analog Office software.

First, a single stage circuit (Figure 2) was implemented and its response to a signal of 1GHz with a power of -20 dBm was studied and its response is shown in Figure 5.

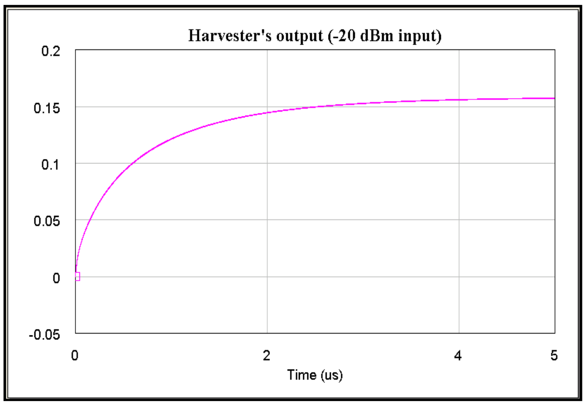

Figure 5: Response of the harvester to an input of -20 dBm

Also, the circuit was tested for two other input signals. For the first case, a signal with a power of -15 dBm was inputted to the system and the output was observed to be approximately 0.4 V. Then, the output for an input signal of -25dBm was observed to be almost 0.06 V. The difference in the output for the two cases of -25 dBm and -15 dBm input signals was observed to be large. This was also calculated using equation 3 [8].

$$V = \sqrt{P \times Z} \qquad (3)$$

Since the input impedance Z is constant, as the power increases by a small amount, the output voltage would increase by a considerable amount.

V. CONCLUSION and FUTURE WORK

In this paper, an RF signal harvester for powering low consumption electrical devices (such as sensors) was introduced. The required environmental studies and simulation for the purposed system were done and the results are shown in figures 3, 4 and 5. It was also found that some of the signals alter their frequencies continuously.

At the current stage of work, the design and implementation of a prototype is in process. Also, to improve the performance of the system in different environments, the use of a digital signal processor is under study. The DSP can also be used to overcome the problem of frequency hopping of signals. However, the DSP requires a power source and the main challenge at this stage would be powering up the DSP unit.

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