Design of a Battery-less Micro-scale RF Energy Harvester for Medical Devices

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This paper presents a micro-scale RF (radio frequency) energy harvesting circuit that can be used for RF signals for milliwatt to microwatt scale DC power units. Both at hospitals and homes, radio waves are always present in our daily lives in the form of signals transmitted from TV, Radio and Mobile base stations. There are many signals of different frequencies in our surroundings that can be reclaimed via a harvester. Even though these signals carry a small amount of energy, the possibility of using that to energize devices is promising. The methodology of this work is to analyze the RF energy spectrum to identify the most available RF energy sources. Based on that we design an appropriate antenna to capture that spectral power and replicate a circuit that can convert micro-scale RF energy received via the antenna into usable electrical power. Finally, the harvester circuit is used to feed power to a table clock and successfully demonstrated. The limitations are noted along with how the system may be improved through better antenna design. This harvester design is unique in not using a battery

Keywords – RF energy harvesting, Micro scale energy harvesting, Voltage multiplier circuit

1. Introduction

The green technology behind RF energy harvesting is an emerging technology under extensive discussion in order to power low power devices. The ambient RF energy so widely spread across the world is absorbed by all living and lifeless things and ends up as wasteful heat energy contributing to global warming on a very small scale. Efforts to reduce global warming to any degree are an enormously welcome contribution.

Energy harvesting using spatial electromagnetic (EM) energy, specifically at RF, is presenting itself as a viable source of energy [1]. This is based on the notion that the level of transmitted and received signals and powers over the RF spectrum of frequencies has dramatically increased. Intel and Nokia are two market giants interested in research in this direction.

One of the fundamental challenges in achieving RF energy harvesting is that even though the energy transmitted from RF sources is high, only a small amount can be scavenged in a real environment; the rest is dissipated as heat or absorbed by other materials. The next challenge is using the harvested energy to power up existing circuits, especially in devices over long periods of time [1-3]. In most of the recent work, RF energy is stored in a battery which then powers a device. However, we have designed our system without using the battery. This makes harvested power utilizable when it is needed the most – when there is no battery.

Wireless medical devices are bound to increase as the population grays, and the pressure to avoid sending senior citizens to institutions increases so that their health and well being can be monitored and treated in their homes through the use of technology. RF energy harvesting that could yield power levels of 0.1 $\mu W/cm^2$ will be important to operate wireless medical devices without the use of batteries. The challenge that faces RF energy harvesting is to harvest energy at low transmission power and small sized harvesting devices [4]. Wearable medical devices and sensors run on RF energy harvesting devices is an attractive alternative to much of the battery dependent medical devices, including the heart pacer.

2. System design

Our investigations into the RF energy spectrum and the recognition of available RF energy sources within Sri Lanka**.** For the task of analyzing the RF energy spectrum to design the relevant receiving antenna, information on power density values with respect to their frequency values and the most suitable frequency band with respect to location was collected. It was thereby identified that the highest average power exposure occurs due to GSM signals. Thus a half wave dipole antenna for 900 MHz was preferred. Also a resonant circuit is designed to match the impedance. A Villard Voltage Doubler was designed as the multiplier with *n* stages as shown in Fig.1. Theoretically, the open circuit output voltage V_0 of the Villard voltage multiplier with *n* stages in terms of its input voltage V_i is given

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$$V_0 = 2nV_i \tag{1}$$

However, under the loading condition the output voltage drop ΔV_0 is given in terms of the output current I.

$$\Delta V_0 = \frac{I}{fC}\left(\frac{2n^3}{3} + \frac{n^2}{2} - \frac{n}{6}\right) \tag{2}$$

Since there is no control over the input frequency, the value of the stage capacitors had to be selected to minimize the voltage drop. Also the number of stages could not be increased indefinitely because of the decrement in the output current caused by rise of the output voltage and the rise of voltage drop as n increases. Using simulation, for the current of 1 mA, the voltage was optimized for different values of capacitor and number of stages (Fig. 2) and it was found that the most suitable circuit is a two stage voltage multiplier with 1nF stage capacitors. Also the transient characteristic of the number of stages and the open circuit output voltage was also simulated using Ansoft in order to check the rise time of the circuit as shown in Fig. 3.

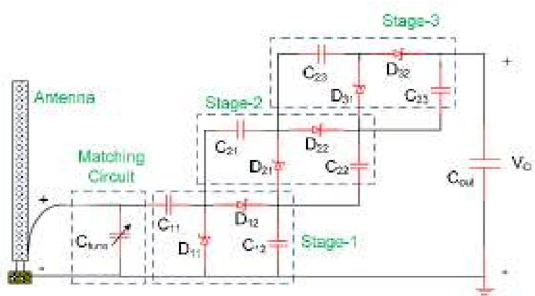

Fig.1: Voltage multiplier circuit

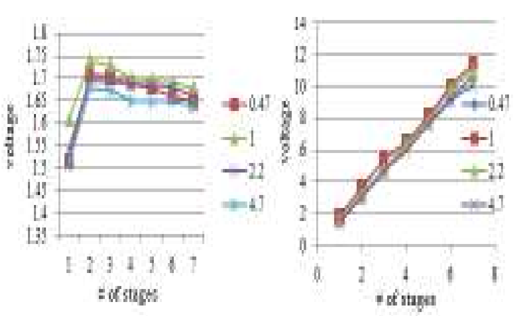

Fig.2: The output voltage with load (left) and without (right) for different capacitances in nF

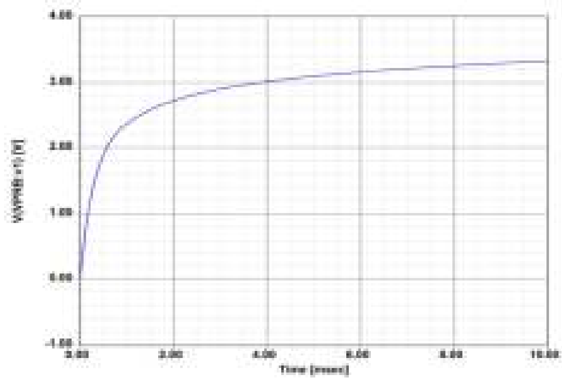

Fig. 3: Ansoft Simulation: Rise time of 5-Stage, 0.47 nF Voltage Multiplier

3. Implementation

The circuit was implemented and used to power an alarm clock. The physical setup may be found in Fig. 4.

Fig.4**:** Alarm clock operated by RF energy

4. Conclusions

The harvester unit is tested with the simulation results and its designed parameters are verified. We have powered an alarm clock with the RF energy of the GSM frequency band. Ambient RF energy harvesting may be improved to a higher level by improving the aperture area of the receiving signal. Using meshes, arraying elements and directing RF beams are the other possible ways of yielding better performance. Although the application of this energy source is limited by its low power output, it can be used to power at no running cost many devices that require low power.

5. References

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