Ambient Energy Harvesting from 2-way Talk-Radio Signals for "Smart" Meter and Display Applications

Jo Bito, Sangkil Kim, Manos Tentzeris
School of Electrical and Computer Engineering
Georgia Institute of Technology
Atlanta, GA Unites States of America
Jbito3@gatech.edu

Symeon Nikolaou
Department of Electrical Engineering
Frederick University
Nicosia, Cypres

***Abstract*—A ambient wireless energy harvesting prototype made of a compact antenna and an optimized RF-DC converter circuit is designed to convert the wireless signal emitted by a 2-way radio into usable DC power at which many low power electronics and displays used in sensors and smart meters could operate. The output DC power of -4.75dBm is achieved with 1 M-ohm load resistance at 13 cm away from the 2-way radio whose transmitting power is 2W. Measurements show electronics with operating voltage of 18 V as well as capacitive LCD display can be powered on using ambient RF signals eliminating the need for batteries.**

I. Introduction

Since the 90s, wireless signals have become prevalent in the air in most of the urban areas. In addition to TV and mobile communication signals, wireless LAN hotspots and smart meters used in residential and industrial areas have inundated the air with electromagnetic waves in different frequencies with in the HF, VHF and UHF bands. While most of the ambient microwaves are communication signals for voice, video and data communication and leakage from home appliances, they can also be used as a pervasive source of power in powering large scale, wireless and wired sensors for a range of applications such as structural, environmental and human health monitoring [1][2].Wireless power transfer/harvesting has been the focus of the research community in recent years. This technology already has been applied in near and far field RFIDs for logistics under the ISO 18000 standards, and for powering smart-phones under the NFC-based Qi standard. Compared to the other ambient energy sources such as solar and mechanical energy, the power density of RF waves is fairly low. However, it is superior to other sources in its ability to penetrate opaque walls and being available over a wide area [3]. In recent years, a number of works have focused on the use of ambient wireless signals such as long range TV and cellular signals as a power source for sensors and beacons [3]. This work differs from the aforementioned efforts because instead of using ambient power from a cellular or TV base-station or a dedicated wireless transmitter such as RFIDs it uses the signals emitted by commercially used 2-way talk radios as potential power source for industrial sensors, wearable biosensors, "smart" meters.

II. Energy Harvesting System Design

In this paper, a Motorola RDU2020 2-way business radio with a Motorola UHF linear polarized antenna, RAN4033, is used as the source of wireless power. In talk or transmit mode, the radio transmits 2W of wireless power in a narrow frequency band around 464.6 MHz. The composition of the energy harvesting system is shown in Fig.1. The energy harvesting system shown in Fig.1, consists of a receiving antenna, an RF-DC conversion circuit and a matching circuit between the antenna and the RF-DC conversion circuit which are all fabricated on standard 1.6 mm thick FR-4 substrate. This energy harvesting system does not require high directivity antennas and can generate higher power compared with other energy harvesting systems utilizing communication signals/waves, that have been previously reported [1][3].

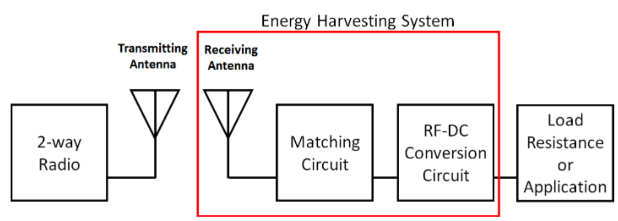

Fig. 1. Composition of energy harvesting system.

A. Antenna Design

To harvest power from the radio, a folded dipole antenna is designed in planar form to allow easy handling and mounting. The antenna is connected with an 1:1 impedance transformer that served as a balun for balanced feeding to minimize losses due to the differential to common mode transition between the antenna and RF-DC charge pump circuit. The physical dimension of the folded dipole antenna and the measured reflection coefficient of the antenna with the balun from 300 to 600 MHz are shown in Fig.2 and Fig.3 respectively.

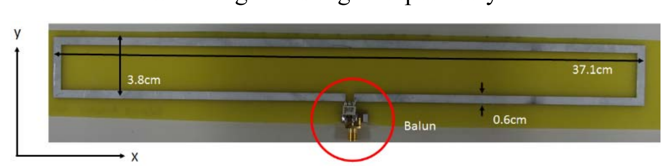

Fig. 2. Physical dimension of folded dipole antenna

The antenna was designed using the full wave 3D electromagnetic solver, ANSYS HFSS v13.0. The input matching network consisted of a series 100 pF capacitor and a shunt 4.7 nH inductance was utilized to match the non-50 ohm antenna impedance to the RF-DC conversion circuit at 464.6 MHz. The antenna has a simulated peak gain of 3.23 dBi which is 0.78 dB lower than the maximum directivity of 4 dBi which is known to be theoretically possible using a loop antenna [4]. E-plane and H-plane radiation patterns are shown in Fig. 4.

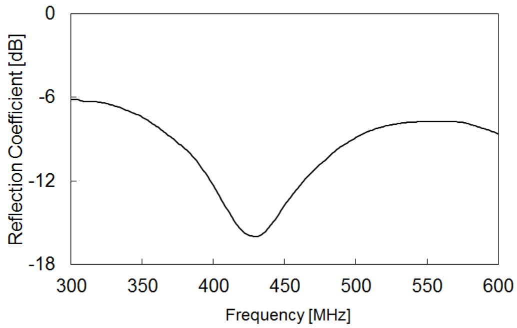

Fig. 3. Reflection coefficient of folded dipole antenna from 300 to 600 MHz

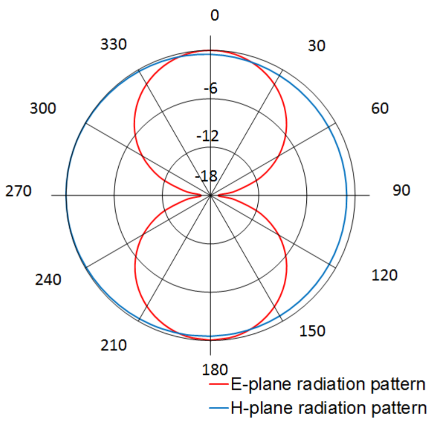

Fig. 4. E-plane and H-plane radiation pattern of folded dipole antenna

B. RF-DC Power Converter Design

In order to convert the RF signal induced across the antenna into a usable DC power, a 5-stage Dickinson voltage-multiplying RF-DC converter circuit was designed and matched to the antenna. The RF-DC charge pump circuit is composed of Avago HSMS 282C schottky diodes, and 18pF and 22pF capacitors. The RF-DC charge pump circuit was optimized to have the most sensitivity in the UHF bands between 400 and 500 MHz. The DC output power as a function of input RF power at 464.6 MHz is depicted in Fig.5. The RF-DC conversion circuit requires 0 dBm of input power to turn on without matching to a signal generator.

III. System Performance

The system performance of the power harvester when placed 13 cm away from the radio power source is shown in Fig. 6. The distance is chosen because 13cm is the transition from near field to far field at 464.4 MHz [4]. With a 1 M-ohm load resistance placed at the output of the RF-DC charge pump, a DC output voltage of 18.32 V and the output DC power of -4.75dBm is achieved. The power harvesting system can successfully power a capacitive load of a 6cm by 3cm low power LCD display for mobile applications, altering its shade in the process using just the wireless power from the radio 13 cm away.

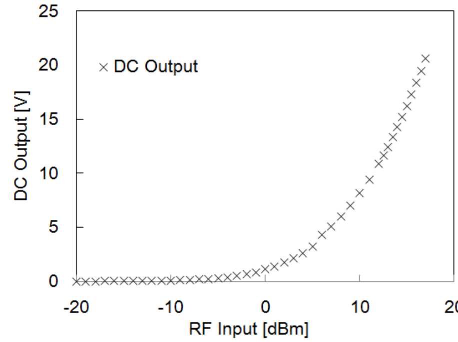

Fig. 5. DC output voltage of RF-DC charge pump circuit for different input power levels

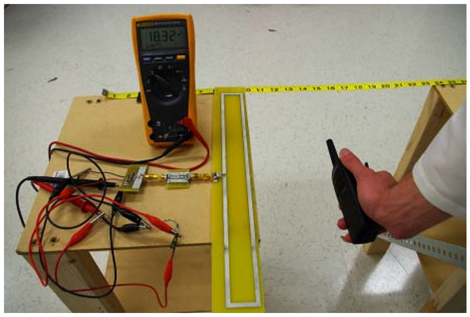

Fig. 6. Prototype harvesting ambient wireless power from a Motorola RDU2020 radio 13 cm away and giving 18.32V DC output voltage across 1 M-ohm load .

IV. Conclusion

We have presented a novel ambient energy harvesting topology that can power up "smart" meters, wearable biosensors and LCD displays using the available power of a 2-way talk radio at a distance of 10-15cm. With a 1 M-ohm load placed at the output of the RF-DC charge pump, a DC output voltage of 18.32V and the output DC power of -4.75dBm are obtained utilizing transmitted signals from commercially used 2-way talk radio.

References

[1] Visser, Hubregt J., and Ruud JM Vullers. "RF Energy Harvesting and Transport for Wireless Sensor Network Applications: Principles and Requirements." (2013): 1-14.

[2] Kawahara, Yoshihiro, Xiaoying Bian, Ryo Shigeta, Rushi Vyas, Manos M. Tentzeris, and Tohru Asami. "Power harvesting from microwave oven electromagnetic leakage." In Proceedings of the 2013 ACM international joint conference on Pervasive and ubiquitous computing, pp. 373-382. ACM, 2013.

[3] Pinuela,M.etal.,"AmbientRFEnergyHarvestinginUrbanand Semi-Urban Environments," Microwave Theory and Techniques, IEEE Transactions on, vol.61, no.7, pp.2715,2726, July 2013.

[4] C.Balanis,AntennaTheory.:Wiley,1997,ch.11,pp.569-588.