RADIO FREQUENCY ENERGY HARVESTING

T.A. YULDOSHEV M.O. SULTONOVA
Tashkent university of information technologies named after Muhammad Al-Xorazmiy

This thesis is devoted to energy harvesting from radio waves in Urban and Semi-Urban Environments, and analyzes the characteristics of antennas used, as well as the results of the experimental experiments.

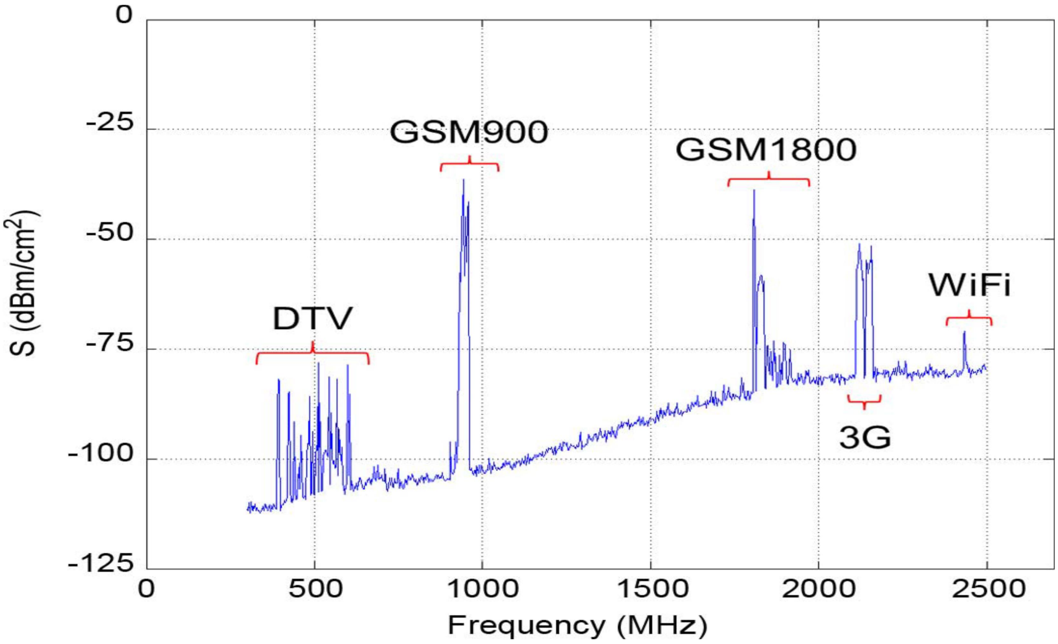
Key words: ambient energy, rectennas' antennas, linear polarized folded, Rectenna, Ansoft HFSS environment.

The use of renewable energies to power electronics devices is not a new concept. The process of extracting energy from the ambient environment to generate electricity is termed as energy harvesting or energy scavenging. This energy can be harvested from various sources available in the ambient environment such as thermal energy, mechanical energy, and radiant energy. In Table 1, properties of widely utilized ambient energy sources are introduced. Among the available ambient energy sources, RF energy has greatly grown due to the preponderance of wireless signals, such as mobile base stations and Wi-Fi networks, radio and TV transmitters, and microwave radios and mobile phones. Compared to the other energy sources, RF energy provides a relatively low energy density of 0.2 nW/cm2–1 μW/cm2. Energy harvesters for low power devices, including applications related to wireless sensor networks (WSNs), extend significantly the operating lifetime and present a new challenge as the harvesting system has to be comparable in size with sensor nodes. This technique could be especially useful for powering up the wireless networks deployed in harsh environment, charging batteries, or storing energy in super capacitors. In this paper, we focus on ambient RF energy harvesting technology that will have an important potential to impact sensors located in harsh environments or remote places, where other energy sources as wind or solar sources are impracticable. This technique attracted significant attention and multiple RF energy harvesting systems including receiving antennas, matching circuits, and rectifying circuits which have been developed for green supply of low consumption electronics. The general structure of a typical RF energy harvester, comprised of receiving antenna along with a circuit capable of converting RF signals into DC voltage. The antenna picks up the RF power sent out by the network controller, the impedance matching network ensures maximum power transfer in the system, and the rectifier converts the RF power to a DC voltage. The components of the energy harvesting system (antenna, matching network, and rectifier) are usually known as a Rectenna or a RF/DC, which is able to harvest.

Table 1: Characteristics of various energy sources and harvested power.

Band	Frequencies (MHz)	Average S_{BA} (nW/cm^2)	Maximum S_{BA} (nW/cm^2)
DTV (during switch over)	470-610	0.89	460
GSM900 (MTx)	880-915	0.45	39
GSM900 (BTx)	925-960	36	1,930
GSM1800 (MTx)	1710-1785	0.5	20
GSM1800 (BTx)	1805-1880	84	6,390
3G (MTx)	1920-1980	0.46	66
3G (BTx)	2110-2170	12	240
WiFi	2400-2500	0.18	6

From our RF survey, DTV, GSM900, GSM1800, 3G, and Wi-Fi were identified as potentially useful ambient RF energy harvesting sources, although DTV appears to be heavily dependent on line-of-sight and sudden changes in atmospheric conditions (e.g., temperature inversion) and Wi-Fi is very dependent on user traffic. It should be noted that the mobile phone base-station TXs employ vertically polarized antennas, placing a constraint on harvester orientation in deployment.



Figur. 1. Input RF power density measurements urban areas.

Since our harvesters are intended to operate within a general (semi-)urban environment, where the exact location of the TX source is unknown, the rectennas' antennas need to be as close to omnidirectional as possible, avoiding the need for beam-pointing during deployment. This is at the obvious expense of limited antenna gain, and therefore, the corresponding levels of that the rectifier can receive. Conversely, if the location of the TX is known, then it may be tempting to use a high gain antenna, but this would require an appropriate level of beam-pointing and polarization matching that can be established and maintained.

Another requirement is that the antennas need to be easily scalable across all frequency bands since one important objective for this work is to compare and contrast different banded harvesters. Finally, the antennas need to be easily fabricated. For all these reasons, a linear polarized folded dipole was selected, although a monopole would also be suitable. To simplify impedance matching between the antenna and rectifier, a modified folded dipole was used to obtain the required 50- reference input impedance. A balun does not need to be employed, as there is no significant degradation in performance for this particular application, even with the use of an unbalanced micro strip rectifying circuit. Furthermore, the antenna was not integrated onto a substrate, to give the additional freedom to embed the harvester on windows or within walls, furnishings, fixtures, or fittings. To this end, two different antennas were fabricated for each band; one made using a 560- m diameter copper wire and the other with 75- m-thick 25-mm-wide copper tape. The fabricated antennas are shown in Fig. 3. Since the copper tape was not rigid enough to retain its shape, it was placed on a Perspex substrate, to represent a flat panel.

The antenna design required the best choice of the substrate dielectric constant, length and width of the antenna, and the ground plane. The properties and performance of the proposed antenna have been predicted and optimized through electromagnetic simulation software in Ansoft HFSS environment. The size of the proposed RF energy harvester can be reduced by miniaturizing the antenna. An antenna is one of the few components, the size of which is related to the operating frequency. In general,microstrip antennas are half-wavelength structures, with a resonant frequency given , where C is the speed of light, L is the patch length of the antenna, and ε_r is the relative permittivity of the grounded microwave substrate.The dielectric constant of the substrate has a considerable role in the antenna overall performance, the width, the length, and the resonant frequency.

$$f = \frac{C}{2*L\sqrt{\varepsilon_r}}$$

Simulations Results. With the overall objective of RF efficient energy harvesting, we focused on the development, fabrication, and characterization of a dual-band antenna designed to serve as our receiving antenna. The reflection coefficient of the proposed antenna is measured between 1GHz and 6GHz. From the result it is observed that the antenna is resonating at 2.47GHz, 4.93GHz, and 5.69GHz with return loss below 14 dB.

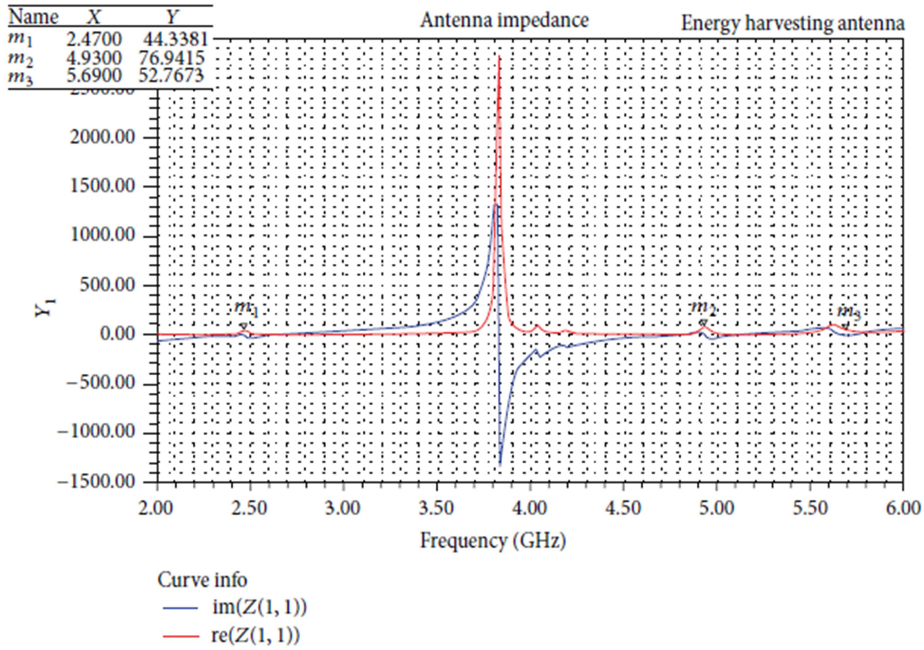


Figure 2. Simulated input impedance of antenna.

The results of the simulated impedance are shown in Figure 2. The real part of the impedance at the resonant frequencies is close to 50Ω, ($m1$) 44.33Ω, and ($m3$) 52.76Ω for 2.4GHz and 5.69GHz, respectively. The imaginary part of the impedance is almost negligible in the desired range of frequency band.

RF energy harvesting is a key technology due to its potential to provide power indefinitely. It is a green technology suitable for a wide range of wireless applications such as RFID tags, implantable electronics devices, and wireless sensor networks. In this paper, a novel receiving antenna capable of dual-band operation has been proposed for RF energy harvesting system. A dual-band with wide bandwidth characteristics is observed which covers Wi-Fi bands. The results obtained indicate a good overall performance of the proposed antenna at the required frequency range: return loss better than 20 dB with impedance close to 50Ω and quasi-omnidirectional radiation patterns.

References

1. «Demonstration of microwave power transmission, Pract.» Wireless, pp. 835–835, 1965.
2. T. Salter, G. Metze, and N. Goldsman, «Parasitic aware optimization of an RF power scavenging circuit with applications to smartdust sensor networks,» in IEEE Radio Wireless Symp., 2009, pp. 332–335.
3. «SENSIMED Triggerfish®—Continuous IOP monitoring,» SENSIMED, Lausanne, Switzerland, Mar. 2012. [Online]. Available: http://www.sensimed.com/S-Trig-glaucoma.htm.
4. H. B¨ottner, J. Nurnus, A. Gavrikov et al., "New thermoelectric components using microsystem technologies," Journal of Microelectromechanical Systems, vol. 13, no. 3, pp. 414–420, 2004.

Information about the authors

Yuldoshev Temur Abdumo'min o'g'li — Muxammad al-Xorazmiy nomidagi Toshkent axborot texnalogiyalari universiteti "Radio va Mobil aloqatexnalogiyalari" fakulteti 1-kurs magister, yoldoshevtemur7@gmail.com

Maxbuba Sultonova — Muxammad al-Xorazmiy nomidagi Toshkent axborot texnalogiyalari universiteti "Mobil aloqa tizimlari kafedrasi» dotsenti