Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 139 (2017) 55–60

Energy Procedia

www.elsevier.com/locate/procedia

International Conference On Materials And Energy 2015, ICOME 15, 19-22 May 2015, Tetouan, Morocco, and the International Conference On Materials And Energy 2016, ICOME 16, 17-20 May 2016, La Rochelle, France

Design and simulation of dual-band RF energy harvesting antenna for WSNs

Asma Bakkali[a,b,]*, José Pelegri-Sebastia[b], Tomas Sogorb[b], Antonio Bou-Escriva[b], Abdelouahid Lyhyaoui[a,]*

[a]*Laboratory of Innovative Technologies, Abdelmalek Essaadi University, Tangier 1818, Morocco*
[b]*Research Institute for Integrated Management of Coastal Areas, Universitat Politecnica of Valencia, Grao de Gandia, 46730 Valencia, Spain*

Abstract

Radio frequency energy harvesting is attracting an increasing deal of attention in order to provide power to the electronic devices, including Wireless Sensor Networks. In this context, we focus on ambient radiofrequency energy available in the ambient environment. The receiving antenna is the main element of radiofrequency harvester, as it has to capture the RF energy from the radiating sources. Our work provides a new design of the receiving antenna to harness RF energy more effectively. Several simulations and optimizations are performed in order to maximize the antenna gain around the Wi-Fi bandwidth (2.45 GHz and 5 GHz). Variation of the return loss passes below -29 dB for 5 GHz frequencies and the radiation shape shows a quasi-omnidirectional pattern in Wi-Fi bands. The dual band antenna proposed is very interesting for the RF harvesting energy system, meeting the desired criteria to maximize the ambient harvested RF energy.

Peer-review under responsibility of the scientific committee of ICOME 2015 and ICOME 2016.

Keywords: Receiving Antenna; Energy Harvesting; Radio frequency; Radio Frequency Energy; Harvesting; Renewable Energy Sources; Wireless Sensor Networks

* Corresponding author. Tel.: +33627746820; fax: +34-96-284-9309.
E-mail address: asma.bakkali@yahoo.fr

Peer-review under responsibility of the scientific committee of ICOME 2015 and ICOME 2016
10.1016/j.egypro.2017.11.172

1. Introduction

Energy harvesting is the process of collecting the energy from environment and converting it into usable electrical energy for power electrical devices. This technology is also known as power harvesting and energy scavenging [1, 2]. A variety of sources and techniques are available in order to power devices or store energy, including radiofrequency (RF) energy and ocean waves, solar and wind powers, thermal energy and mechanical vibrations [3, 4, 5]. In this paper, we focus on ambient electromagnetic energy available from commercial RF broadcasting stations such as GSM, TV, Radio, especially that from Wi-Fi networks. RF energy harvesting holds a promise future for generating a small amount of electrical power for electronics devices. Such harvesters enable a battery-less operation and extend significantly the operating lifetime of the Wireless Sensor Networks (WSNs). Numerous papers have been published on RF energy harvesting as a feasible alternative to batteries. The RF energy-harvesting system is composed of three primary subsystems. The first subsystem is the receiving antenna responsible for capturing the RF energy that will later be used to power electronics devices such as sensor nodes. The other main subsystems are the matching network and the rectifier or rectification circuit [6, 7, 8]. In [9], authors propose a novel antenna structure for RF energy harvesting. The proposed antenna is composed of two individual radiators, the main radiator and the parasitic radiator. The energy-harvesting antenna is designed to be operated in the frequency band 2.13-2.15 GHz. The proposed antenna presents an interesting performance, therefore it can be used as an auxiliary DC power means in various wireless communication transceivers. In [10] the authors designed present a hexagonal microstrip patch antenna array that operates at 915 MHz in order to achieve the maximum possible of the RF energy and converts into DC power to light an LED. The authors in [11] propose a harvesting energy system using an omnidirectional broadband spiral antenna directly connected to the rectifier in order to avoid losses in the matching circuit. Results obtained indicate the insufficiency of the energy recovered to ensure the autonomous devices power. However, the harvested power could be stored in super-capacitors or micro-batteries.

The choice of antenna and frequency band is very important to optimize the DC power harvested. The concept for RF Energy Harvesting needs an efficient antenna along with a circuit capable of converting alternating-current voltage to direct-current voltage. The efficiency of an antenna is related to the shape and impedance of the antenna. This paper presents a new design of the receiving antenna as a main part in the RF harvesting energy system operating in Wi-Fi bands.

2. RF harvesting energy system

RF energy harvesting enables the capture of electromagnetic energy from available ambient RF energy sources. The energy that can be recovered from RF sources is relatively limited. It requires an energy harvesting system with a large cross section (antenna) and very close to the transmitter. Generally the energy harvested is very low, a specific application is the sensor supply when approaching a communicating device, which leads the sensor to wake up, measure and transmit information, then return to standby. As shown in Figure 1, the energy harvesting system consists of collection elements, conversion hardware, and conditioning control electronics. The harvested energy must be converted to electricity and conditioned to an appropriate form for charging batteries or storing energy. The antenna is in charge of capturing all the Wi-Fi signals. Impedance matching between the collectors and storage components is necessary in order to maximize the harvested energy, while the rectifier circuit will extract the power and convert it in DC voltage efficiently.

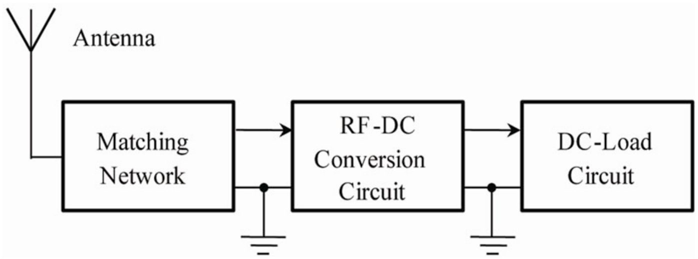

Fig. 1. Conceptual view of RF harvesting system

3. RF harvesting energy antenna

The antenna choice is very important in the design of an electromagnetic energy harvesting system. Several criteria can be defined to facilitate this choice. The most important requirements are: the operating frequency, the gain of the antenna, the efficiency of the circuit and its cost. The frequency bands of interest lead to the configuration of the patch antennas. In fact these antennas cannot only collect more power but also to make more compact structure.

The topology of the proposed antenna was designed for harvesting the Wi-Fi frequencies. For the antenna shape, different topologies were tested in order to reach the resonating frequencies with good performances. The antenna part is designed to resonate around 2.45 GHz and 5 GHz. The proposed antenna in this paper is printed on a Rogers RT/ Duroid 5870 substrate with thickness of 1.6 mm, relative permittivity of 2.33, and dielectric tangent of 0.0012 above a ground plane of cooper. The key property of Rogers RT/Duroid 5870 relates to the qualities of the material, comparing with other materials. Rogers RT/Duroid 5870 has lower loss tangent of 0.0004 at 1 MHz compared to 0.025 at 1 MHz for FR4. While using FR4 for example, with relative permittivity of 4.4 and dielectric tangent of 0.02, results obtained were not promising for this type of antenna especially for frequency resonating. The power is provided by a microstrip line of 50 Ω characteristic impedance, and the slots have been introduced to ensure the adaptation. The geometry of the proposed antenna is shown in Figure 2.

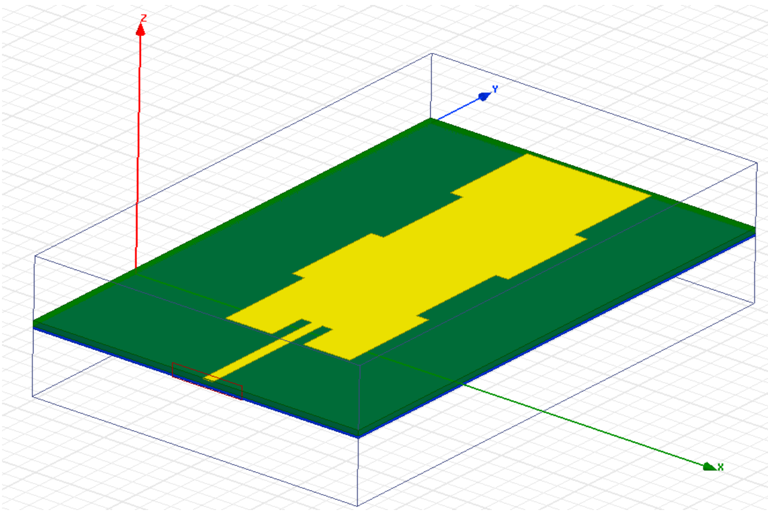

Fig. 2. Geometry of the proposed dual-band antenna

The main specifications chosen in simulation for this design are: the thickness of substrate 1.6 mm, the thickness of copper 0.035 mm and the loss tangent 0.0012. The antenna is designed and optimized to capture the energy from the ambient at Wi-Fi frequency bands of 2.45 GHz and 5 GHz. HFSS was used to simulate the presented antenna and to find the correct capacitive and inductive components for frequency tuning before fabrication of the optimized design. We present in this work a dual band antenna suitable for possible supply for wireless sensor networks. The results achieved are presented in the following paragraph.

4. Results and discussion

The features and performance of the proposed antenna have been predicted and optimized through electromagnetic simulation software HFSS environment. Several simulations and optimizations are performed on the geometrical parameters of the antenna in order to maximize gain around the Wi-Fi bandwidth (2.45 GHz and 5 GHz). The variation of the return loss (S11) as a function of frequency is shown in Figure 3. It is observed that the antenna is resonating at 2.4 GHz and 5 GHz, with return loss of -29.19dB. The simulation results of the impedance show that the real part of the impedance at the resonant frequencies is close to 50 Ω in the desired range of frequency bands. Figure 4 shows the simulated maximum gain of the proposed antenna. The antenna radiation simulations show that the maximum gain of the antenna increases with the frequency up to 2.5 GHz, and then constantly fluctuates beyond this frequency.

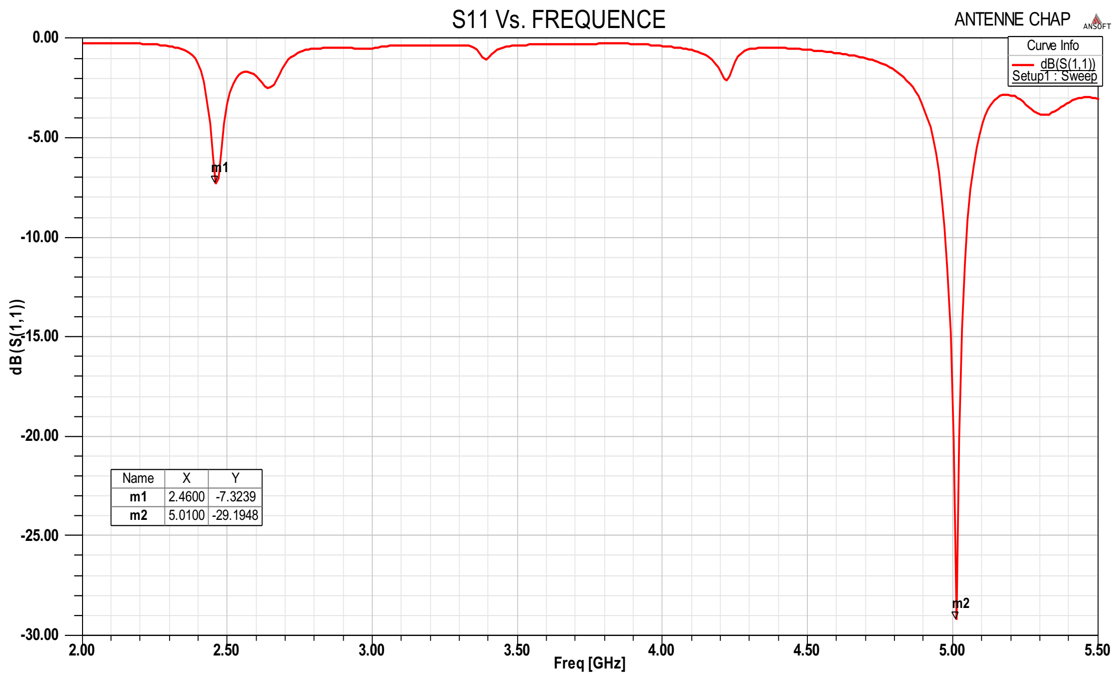

Fig. 3. Simulated return loss S11 versus frequency

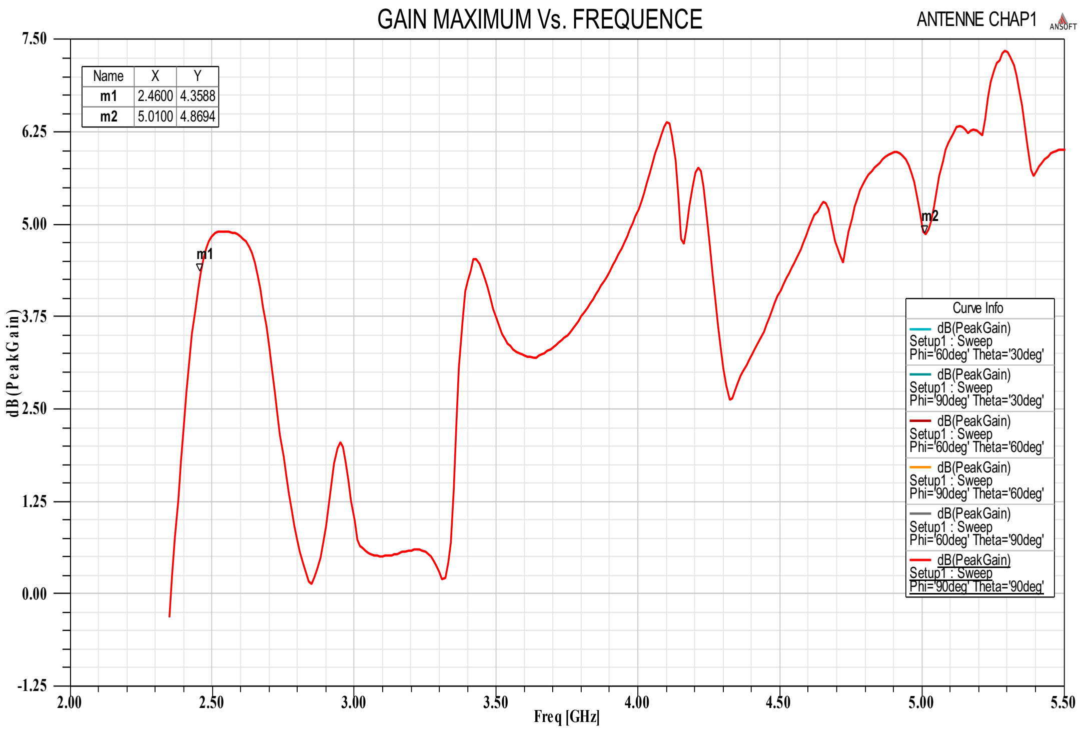

Fig. 4. Maximum gain versus frequency

The aim of this work is successfully achieved by finding new design to harvest ambient energy from high frequencies and providing solution to increase the efficiency of the RF harvesting system.

5. Conclusions

RF energy harvesting technology presents a promising future in low power consumer electronics and wireless sensor networks. The antenna proposed in this paper provides the input for the rectification circuit and it is based on a patch antenna in order to capture the radio frequency energy at 2.45 GHz and 5 GHz. The distribution of the energy radiated in the space shows the radiation shape in 2.4 GHz and 5 GHz operating frequencies as a quasi-omnidirectional pattern. The antenna proposed is very interesting for the RF harvesting energy system, meeting the desired criteria to maximize the captured RF energy. The antenna is under test was placed in the field for the test measurement. All measurements will be conducted in an anechoic chamber environment in order to perform the results in real conditions.

Acknowledgements conclusions

This research was supported in part by EMMAG Program, 2014, funded by the European Commission.

References

[1] Chalasani S, Conrad JM, A Survey of Energy Harvesting Sources for Embedded Systems, In: IEEE Southeast Conference; 2008
[2] Sudevalayam S, Kulkarni P, Energy Harvesting Sensor Nodes: Survey and Implications, In: IEEE Communications Surveys & Tutorials; 2011.p. 443 - 461.
[3] Mitcheson PD, Yeatman EM, Kondala RG, Holmes AS, Green TC, Energy Harvesting from Human and Machine Motion for Wireless Electronic Devices, Proceedings of IEEE; 2008. p. 1457–1486.
[4] Chen X, Yang T, Wang W, Yao X, Vibration Energy Harvesting with a Clamped Piezoelectric Circular Diaphragm, Ceramics International; 2012. p. 271–274.
[5] Paradiso JA, Starner T, Energy Scavenging for Mobile and Wireless Electronics, Pervasive Computing IEEE; 2005. p. 18-27.
[6] Dolgov A, Zane R, Popovic Z, Power Management System for Online Low Power RF Energy Harvesting Optimization, IEEE Transactions on Circuits and Systems; 2010. p.1802–1811.
[7] Muramatsu M, Koizumi H, An Experimental Result using RF Energy Harvesting Circuit with Dickson Charge Pump, In: IEEE Conference on Sustainable Energy Technologies (ICSET), Sri Lanka; 2010
[8] Jabbar H, Song YS, Jeong TT, RF Energy Harvesting System and Circuits for Charging of Mobile Devices, IEEE Transactions on Consumer Electronics; 2010. p.247-253.
[9] Moon JI, Jung YB, Novel Energy Harvesting Antenna Design Using a Parasitic Radiator, Progress In Electromagnetics Research; 2013. p. 545-557.
[10] Xie F, Yang GM, Geyi W, Optimal Design of an Antenna Array for Energy Harvesting, IEEE Antennas and Wireless Propagation Letters; 2013, Vol. 12.
[11] Bouchouicha D, Dupont F, Latrach M, L. Ventura, Ambient RF Energy Harvesting, In: International Conference on Renewable Energies and Power Quality, Spain; 2010