



RF ENERGY SCAVENGING

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Abstract- RF energy is currently broadcasted from millions of radio transmitters around the world including mobile phones, radios, mobile base stations, and television/radio broadcast stations which may affect the human brain and can damage DNA leading to cancer development. On the positive side, the ability to harvest RF energy, from ambient sources, enables wireless charging of low-power devices and has ensuing benefits to product design, serviceability, and dependability.

In this paper, we present a study of ambient RF energy Scavenging techniques. The measurement of the ambient RF power spectral density is presented. The average of the density in broadband (1GHz-3.5GHz) is in the order of -12dBm/m². Two systems have been studied to recover the RF energy. The first is a broadband system without matching circuit. The second one is a narrow band system (1.8-1.9GHz) with a matching circuit. The rectifier circuit RF / DC and the choice of the load to optimize the DC power recovered are presented.

Index Terms—RF energy, Scavenging Energy, Spiral Antenna, WPT System.

I. INTRODUCTION:

Energy scavenging techniques are emerging as environment friendly energy sources, which form a hopeful alternative to existing energy resources. These include energy harvesting from solar power, wind power, vibrational sources and also passive human power. Here another source is introduced from which energy could be harvested – RF/Microwaves in air.

In recent years the use of wireless devices is growing in many applications like mobile phones or sensor networks. This increase in wireless applications has generated an increasing use of batteries. Many research teams are working on the autonomy of the batteries by reducing the consumption of the devices. Others teams have chosen to recycle ambient energy like in MEMS. The charging of multiple applications is easy because the user can do it easily, like for mobile phones. But for other applications, like wireless sensor nodes

located in difficult access environments, the charging of the batteries is becoming a big problem. when the number of devices is large and are distributed in a wide area or located in inaccessible places. The uses of the Wireless Power Transmission (WPT) allow the overcoming of these problems.

The rectification of microwave signals to DC power has been proposed and researched in the context of high-power beaming since the 1950s. It has been proposed for helicopter powering, solar power satellite (SPS), the SHARP System, and recently for RFID system. In this paper we focus on ambient RF energy. We propose to use the energy from commercial RF broadcasting stations like GSM, TV, WIFI or Radar to supply energy for wireless sensor nodes or other applications.

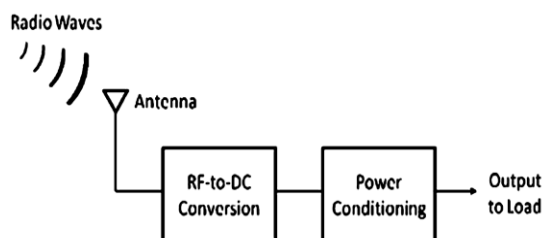


Fig.1: Conceptual View of WPT System

In this paper we focus on ambient RF energy. We propose to use the energy from commercial RF broadcasting stations like GSM, TV, WIFI or Radar to supply energy for wireless sensor nodes or other applications. This powering method can be especially interesting for sensor nodes located in outlying places, where other energy sources like solar or wind energies are not feasible. The DC power depends on the available RF power and conversion efficiency RF/DC. The choice of antenna and frequency band is very important to optimize the DC power harvested. In this paper we focus on ambient RF energy. We propose

This problem to enhance the use of Commercial RF broadcasting stations like GSM, TV, WIFI or Radar to supply energy for wireless sensor nodes or other applications. This powering method can be especially interesting for sensor nodes located in outlying places, where other energy sources like solar or wind energies are not feasible.

The DC power depends on the accessible RF power and conversion efficiency RF/DC.

$$P_{dc} = \eta_{RF/DC} \cdot P_{RF}$$

The selection of antenna and frequency band is very important to optimize the DC power harvested. In the section 2 of this paper we present the measurements of the ambient RF power density. The evolution of this density is studied as a function of the frequency and time. The section 3 discusses the design of the broadband rectenna without a matching circuit. The section 4 presents a study of the rectenna with a matching circuit.

II. MEASUREMENTS OF DENSITY POWER:

Multiple sources of different frequencies are radiating power in all directions in a rich scattering environment (Fig. 2).

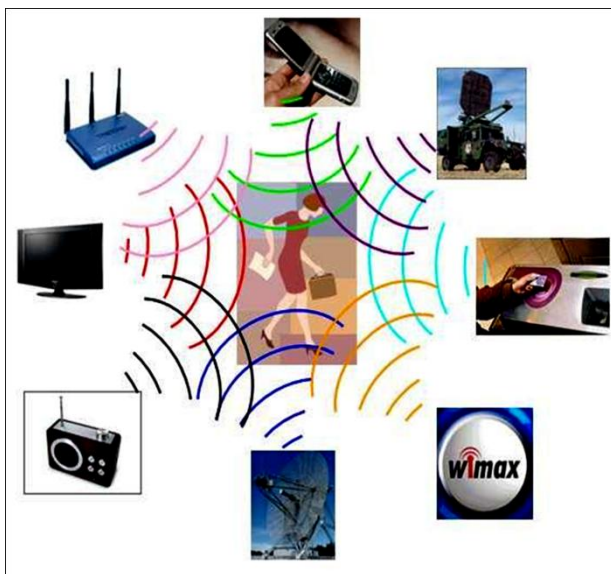


Fig.2: examples of the different radiating sources.

We have measured the RF power density in the different points in the urban environments. The variation of this density in dBm/m² depends on the frequency and time in the 680MHz-3.5GHz band and is represented in the Figure.3. The power density variation is found to be between - 60dBm/m² and -14.5dBm/m² (1nW/m² and 35.5:W/m²) and is constant over time. The maximum of this power spectral density has been measured in the 1.8GHz-1.9GHz band. The summation of the power density of all the measured signals (Fig.3) provides a greater power density around 12dBm/m².

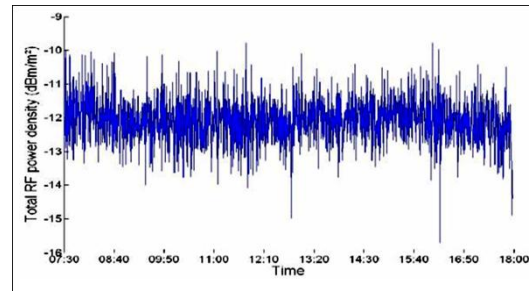


Fig.3 Measured RF power density versus Time (680MHz-3500MHz)

The RF energy harvesting system principle is presented in the Fig.4

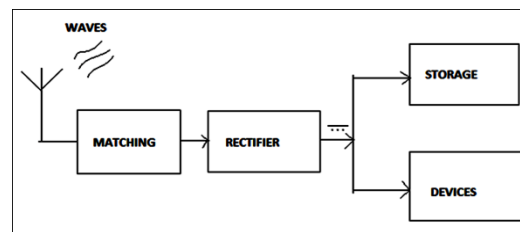


Fig.4. Principle of RF energy harvesting system.

III. BROADBAND SYSTEM:

The broadband system consists of two parts; the rectifier without matching circuit and the broadband antenna. The goal of the system is to maximize the DC power harvested and is designed to recover all signals available. For this issue we must use an Omni-directional broadband antenna.

A. Rectifier:

The RF/DC converter is a voltage doubler and has been designed and simulated by using the MULTISIM 10.1 software, which uses the harmonic-balance method.

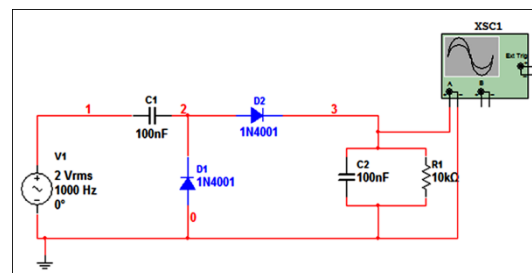


Fig.5: Schema of the rectifier.

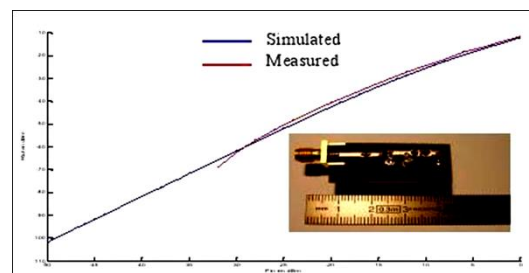


Fig.6: Simulated and measured DC power as a function

of RF power (1.5GHz).

Fig.6 shows the variations of the output DC power versus the input RF power at 1.5GHz. The simulation and measurement results are in good agreement for RF power more than -32dBm.

The impedance of the antenna affects the DC power recovered. In Fig.7, the DC power as a function of resistance of antenna for a wide band frequency is presented. For resistances lower than 50ohms the DC power is very low. The optimum resistance value to increase the DC power over the entire frequency range (1GHz-3GHz) is about 100ohms.

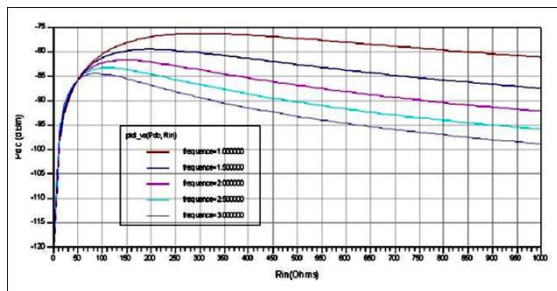


Fig.7: Simulated result of the DC power as a function of the antenna endurance. The input RF power is $P_{in} = -40\text{dBm}$.

B. Spiral Antenna:

As seen in the previous section, the major problem in broad-band rectenna design is linked to the matching circuit. For maximal power transfer, the antenna impedance must be matched to the optimal diode impedance for all frequencies. Our approach is to present a constant impedance of 100ohms to the diode by using a frequency-independent antenna. An equiangular spiral with dimensions shown in Fig.8 was chosen for the following reasons:

- 1) Uni-planar with convenient feed point for diode connection.
- 2) Possible dual polarization.
- 3) Broadband antenna.
- 4) Omni-directional radiation pattern.

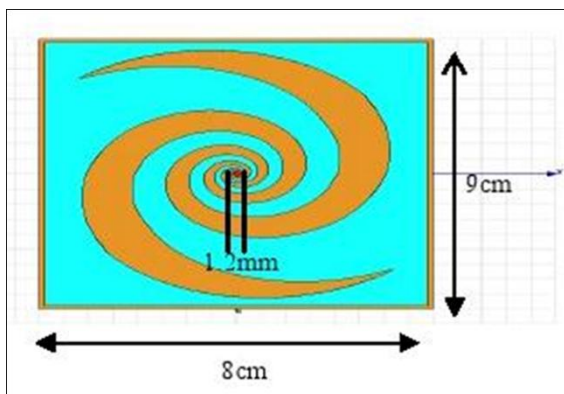


Fig.8: Spiral Antenna

Measured and simulated return losses are in good agreement in Spiral Antenna. In all band (1GHz-3GHz) the return loss is lower than -10dB.

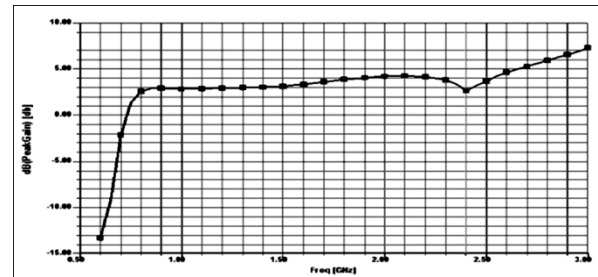


Fig.9 Maximum gain.

The utmost RF power that the spiral antenna can capture in the order of -42dBm (63nW).

In Fig.10, the DC power as a function of load RL for a wide band frequency is presented. The optimum load to maximize the DC power is 18Kohm. With this load the DC power is estimated between 5pW and 10pW (-83dBm - 80dBm). The rectenna is presented in Fig.11. The measured power in environment is around -79dBm (12.5pW). It is in the range of estimated DC power.

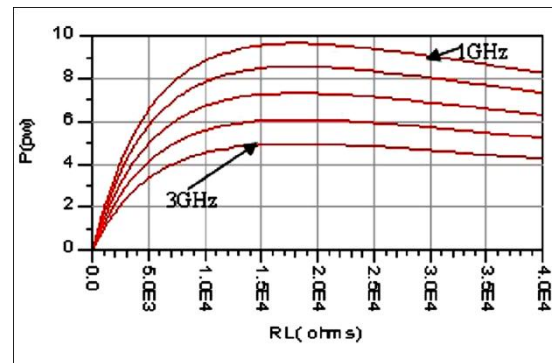


Fig.10: Output power as function of RL load for $P_{in} = -42\text{dBm}$ (63nW).

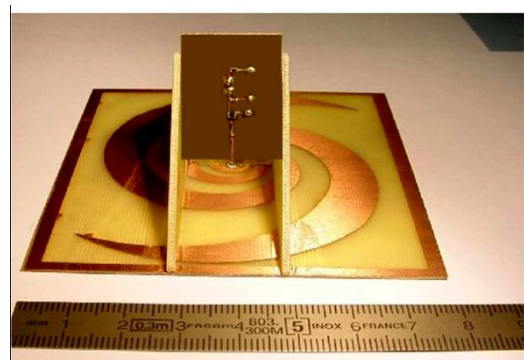


Fig.11 Rectenna prototype

The Dc power harvested with broadband system is very low. The level of RF energy and the mismatching of the antenna to rectifier are the causes of this low level DC power. To increase the DC power harvested and the efficiency of conversion RF/DC we can use the special RF source to feed the devices (WPT). The use of

antenna arrays can increase the RF power and the DC power but for attended the significant DC level the size of the array become very large.

4. Narrow band system:

As seen in the section I, the maximum of the power density in the urban environment has been measured in the 1.8GHz- 1.9GHz band. This power density is -14.5dBm/m² and is constant over time. It is nearly equal to moiety of the total power density (Fig.11)

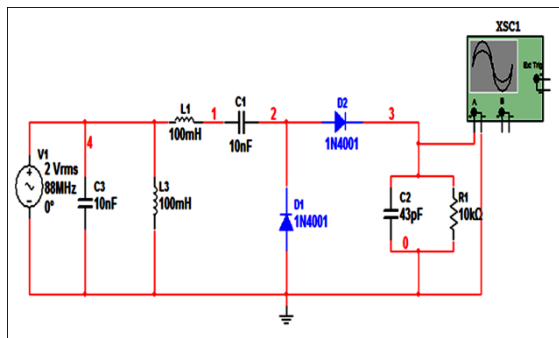
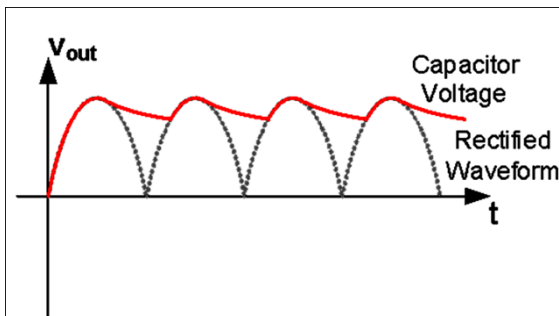


Fig.11: Schema of the rectifier with matching circuit.



The estimate DC power scavenged with the narrow band system is presented in Fig.12. The input RF power recovered with antenna is estimated around -42dBm (63nW). The efficiency of rectifier is estimated in order of 0.6% (Fig.13). The DC power can be attended the 400pW.

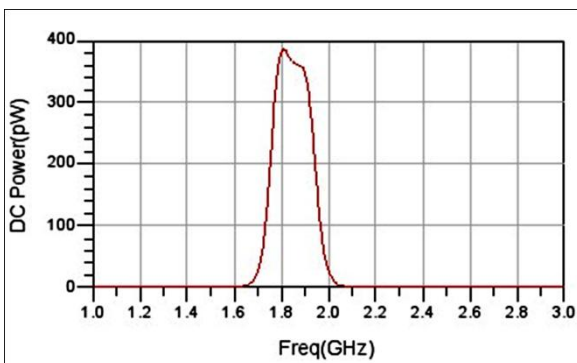


Fig. 12: estimated of DC power scavenged with a narrowband system

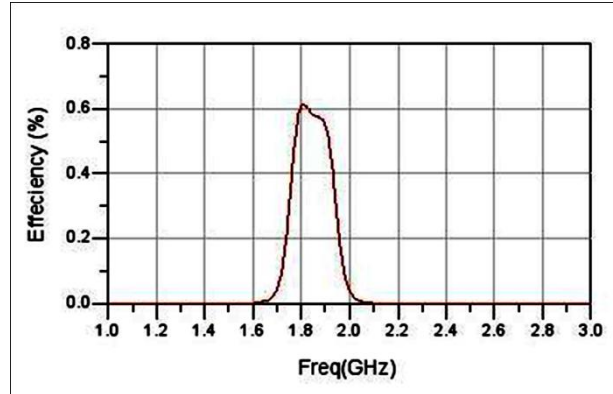


Fig.13: Estimated efficiency as function frequencies

The use of the matching circuit has increased the DC power. But the efficiency of conversion RF/DC is very low (0.6%). This is due to characteristics of the diodes at low power and the voltage junction ($V_j=0.35V$ for HSMS2850). To increase the DC power harvested and the efficiency of conversion RF/DC we should be use the diodes more sensitive than HSMS2850 with a junction voltage near 0V and use an antenna arrays to increase the input RF power.

V. CONCLUSION:

In this paper we have presented a study of feasibility to harvesting the ambient RF energy. The measurement of the RF power density available in urban environment shows the RF power is very low and is distributed in a large wide band frequency. To scavenge a maximum of DC power we have presented a wideband system when able to deliver a DC power around 12.5pW. A narrowband system is also presented. The first study for this system show the attended DC power can be about a 400pW. For the two systems the scavenged DC power is very low to ensure autonomous operation of devices. But this energy harvesting can be store in micro-battery or super capacity. To increase the DC power scavenged we can increase the RF input power by using for example an antenna arrays.

VI. REFERENCES:

- [1] www.google.com
- [2] www.energyharvestingjournal.com.
- [3] www.rfwirelessensors.com/tag/ambient-energy-harvesting.
- [4] www.scribd.com Research > Internet & Technology

