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5.8 GHz Rectenna for wireless powering battery-less sensors

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Abstract. —This work aims to develop an electromagnetic energy rectification system, or rectenna, which constitutes the main element of a wireless energy transmission. The goal of our research is to use electromagnetic waves to power remote sensors that are part of the internet of things. In order for these sensors to function properly, their batteries must be recharged when low. In this study, we have developed a rectification system sensitive to the frequency of 5.8 GHz. To realize this system, we have focused on the various parameters that affect the RF-DC conversion efficiency of a rectifier circuit. Then, we presented the design theory of a rectifier system in microstrip technology. We then optimized and validated our system for an input power of about 20 dBm. The proposed system has an energy efficiency of 42.56and can supply a load at 200 ohms with an output conversion voltage of 2.918 volts for this low-consumption systems.

1 Introduction

Electronic systems are now omnipresent in our daily lives, integrated into most of the objects we use every day, as well as in key sectors such as aeronautics, automotive, space, consumer electronics, telecommunications, energy distribution and rail transport. They are also rapidly expanding into new growth markets such as e-health, which amplifies their development potential. It is widely used to recharge electric vehicles, household appliances, etc. These innovative devices are generally compact and include a low-power computer, wireless sensors and an antenna, allowing them to communicate with their environment. They also have an on-board power source in the form of batteries, requiring periodic replacement or recharging, which may limit their mobility and large-scale deployment [15]-[16]-[17]. Indeed, the interest to improve their energy autonomy, with respect to on-board energy sources, is becoming more and more imposing. In this context, the concept of wireless energy transfer, which has been developed since the 20th century [ref], appears as an interesting alternative to provide clean and ecological energy. This principle consists in collecting ambient electromagnetic energy and transferring it to a receiver via radio frequency (RF) waves. Its low impact on the environment makes it a promising energy source to solve the problems related to the management of electronic waste and batteries, as well as to reduce greenhouse gas emissions.

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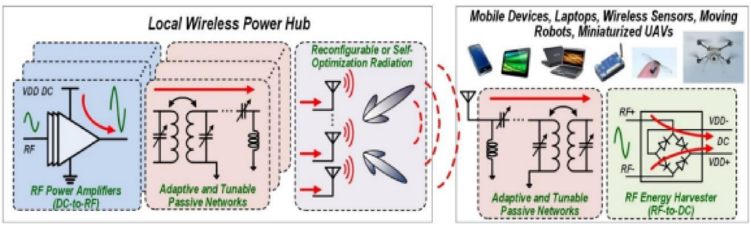
In addition, new wireless energy sources can be energetically integrated with other renewable energy sources. For example, wireless energy transfer systems can be combined with solar panels, wind turbines or other renewable energy sources, and several research works are directed towards this axis [22]. This approach of combining different renewable energy sources offers promising opportunities for sustainable and environmentally friendly powering of electronic systems, thus contributing to the transition to a cleaner and more sustainable energy future. According to Figure 1, ”power transmission” is a three step process that involves converting DC electrical energy into RF energy first, sending the RF energy over space to a distant location, and then gathering the power and converting it back to DC at the receiving site or charge. A WPT system will operate more efficiently if RF energy is transmitted effectively because overall efficiency is inescapably the sum of the individual efficiencies associated with the three system components.



Energy-harvesting system

2 ENERGY-HARVESTING TECHNOLOGY

2.1 The electromagnetic energy transfer technique

A technology known as wireless power transmission enables the transfer of electrical energy from one location to another through the atmosphere, a vacuum, or any other environment without the use of conductive materials. The wireless energy transfer using a microwave beam offers ranges from a few meters to several kilometers, with reasonable transmission loss, in contrast to inductive near-field transfer field [21], which is limited in range (of the order of a few centimeters), or to the transfer energy transfer by resonant magnetic coupling [22]. antennas that broadcast and receive. There are two types of power transfer:

- Near-field power transfer
- Far field power transfer

In the near field, low frequency systems (135 kHz and 13.56 MHz) use capacitive or inductive coupling to obtain the power required to communicate (system capacitive or inductive coupling in order to obtain the power required to communicate (RFID system). At these frequencies, the wavelength is very large compared to the distance (< 1 cm for capacitive coupling and < 1m for inductive coupling). However, for transmission distances exceeding a few meters, wireless power transfer generally uses energy propagation by electromagnetic radiation (far field zone). In this work, we will be interested only in the study of the RF wireless power transfer energy and particularly reception part, also called Rectenna.

2.2 Rectifying component of wireless power transfer energy

The main challenge for a Rectenna is efficiency in order to guarantee a long life for intelligent devices, particularly from the perspective of energy sustainability. A system like this is required to run these devices off of ambient energy, doing away with the need for batteries.Indeed, the performance of the rectifier is related to the RF power that is imposed on it, which in turn affects the efficiency of the conversion. The efficiency of the conversion circuit is expressed by the ratio of the output DC power to the input RF power:

$$\eta = \frac{PDC}{PRF} \tag{1}$$

$$PDC = \frac{VDC^2}{RL} \tag{2}$$

$$PRF = \frac{1}{2} \times \Re(URF * IRF) \tag{3}$$

Where PDC is the the power received by the receiving antenna.
Generally, Rectenna are designed in printed technology, for reasons of cost, compatibility and ease of cost, compatibility and ease of realization [1][2][3][4]. The block diagram of a Rectenna is shown in figure 3. For the antenna part, dipoles or printed patch antennas are used as the receiving element in the element in the design of Rectennas. The printed antennas are compact, of thickness, low manufacturing cost and can be shaped on non-planar surfaces. The radiation performance and polarization of the antenna are very important very important characteristics in the design of Rectennas [5][6]. For the rectifier circuit, different configurations can be used to convert RF energy to DC energy, such as diode bridges and half-bridges, as well as series and shunt diodes. series and shunt diodes. However, Schottky diodes are the most commonly used in this type of application [8] The role of the RF input filter is to carry out the matching between the antenna and the rectifier circuit at the working frequency and to The role of the RF input filter is to perform the matching between the antenna and the rectifier circuit at the working frequency and for a given nominal RF power. On the other hand it blocks the harmonics coming from the rectifier circuit (which is a non linear circuit). However, the DC output filter is a low-pass filter with a capacitor in parallel with the load. In parallel with the load. This filter lets the DC power pass and blocks the RF energy.

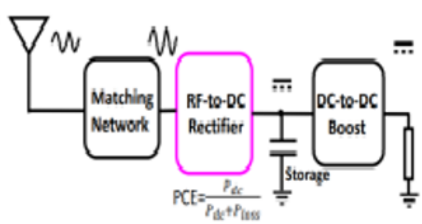


Figure 1. Rectenna systems for wireless power transfer

2.3 Rectenna design

Figure 4 illustrates the circuit's schematic layout for ADS (with scattered parts). The proposed circuit's impedance matching network is a T-junction with a radial stub at the end. Before the load, a Kuruda filter is applied as a DC filter to prevent the rectifier's high order harmonic frequencies.To guarantee impedance matching, various microstrip lines were employed in different locations. As shown in the figure 4, we designed a rectifier circuit in microstrip technology at 5.8 GHz.Based on a combination of series and parallel typologies, and HSMS-2860 and HSMS-286C Schottky diodes to achieve the best performance at 5.8 GHz, They are powered by a microstrip line with a characteristic impedance of 50 and printed on an FR4 substrate. In practice, The SMS-2860 and HSMS-286C Schottky diodes type is usually chosen depending on the intended application [10-12].

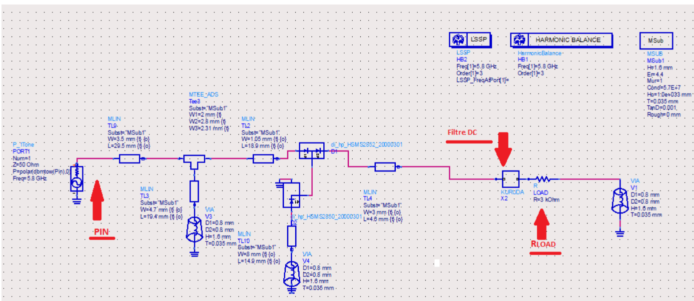


Figure 2. Structure of a rectifier at 5.8GHz

2.4 RESULTS OF SIMULATION AND DISCUSSION

In this section we report the different results of simulation. We notice that the proposed circuit is well adapted to 5.8 GHz and it presents a good S11 of about -11.843 dB (below -10 dB) for an input power of about 20 dB as illustrate at figure 5. The choice of load resistor was made to obtain the best value of the conversion efficiency. Figure 6 shows the simulated efficiency as a function of input power at 5.8 GHz. We can see that the proposed circuit can rectify high input power levels due to the high breakdown voltage (15 V) of the HSMS-2822 Schottky diode used. Moreover, we can notice that the conversion efficiency reaches a maximum value of 42.565% at 20 dBm for an optimal load resistance of 200. Figure 7 plots the simulated DC output voltage versus input power of the proposed 5.8 GHz circuit.

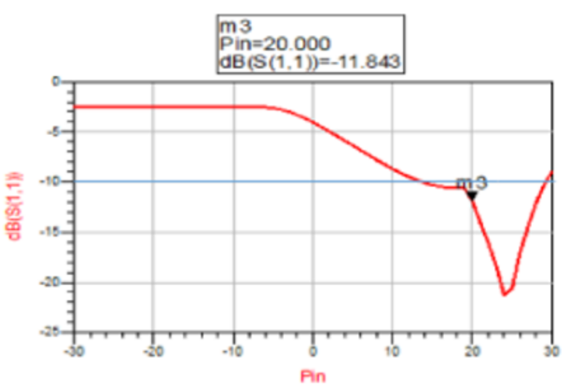


Figure 3. Simulated return losses S11

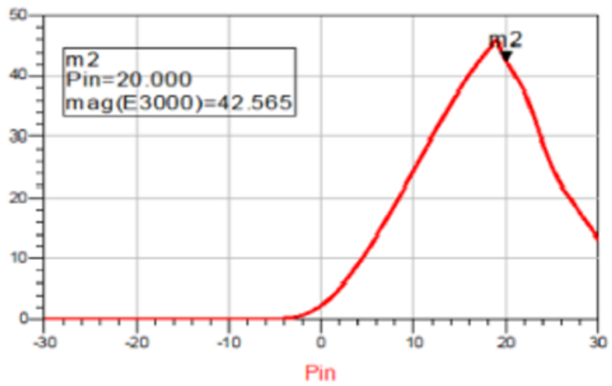


Figure 4. efficiency of conversion

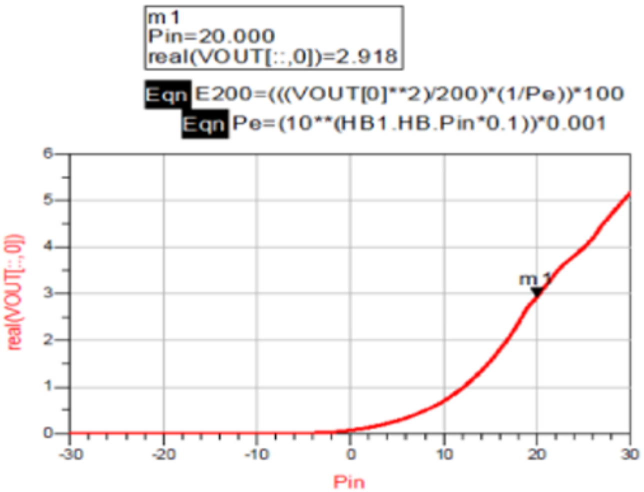


Figure 5. The simulated DC output voltage

We can clearly see that the proposed rectifier circuit at 5.8 GHz produces a significant output voltage of 2.918 V at 20 dBm.In terms of RF-DC conversion efficiency and DC output voltage, it is evident that our proposed circuit performs better at 5.8 GHz and 20 dBm.

3 CONCLUSION

This study builds and constructs an RF energy harvesting rectifier with a center frequency of 5.8 GHz, with a focus on microwave energy transmission and Wireless power transfer technology.This method can be used to maximize the autonomy of wireless sensors installed in challenging to reach locations.This paper presents a rectifier circuit used for wireless microwave energy transfer. A new circuit in microstrip technology has been proposed for 20 dBm input power applications. The optimized and successfully simulated circuit presents an energy efficiency of about 42.56% for an input power of 20dBm and allows to feed a 200 Ohm load resistor with an output voltage of about 2.918Volts.

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