



**HAL**  
open science

# A Miniature and High-Efficiency Rectenna in ISM 868 MHz Frequency Band

Alassane Sidibe, Alexandru Takacs

► **To cite this version:**

Alassane Sidibe, Alexandru Takacs. A Miniature and High-Efficiency Rectenna in ISM 868 MHz Frequency Band. 2020 IEEE International Symposium on Antennas and Propagation and North American Radio Science Meeting, Jul 2020, Montreal, Canada. pp.1509-1510, 10.1109/IEEECONF35879.2020.9330401 . hal-04873395

**HAL Id: hal-04873395**

**<https://hal.science/hal-04873395v1>**

Submitted on 8 Jan 2025

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

# A Miniature and High-Efficiency Rectenna in ISM 868 MHz Frequency Band

A. Sidibe<sup>1</sup>, A. Takacs<sup>1</sup>

<sup>1</sup>LAAS-CNRS, Université de Toulouse, CNRS, UPS, F-31400 Toulouse, FRANCE  
 asidibe@laas.fr, atakacs@laas.fr

**Abstract**— In this paper, a compact three-dimensional (3D) configuration rectenna with high efficiency is presented. Its dimensions are 56 mm x 32 mm x 10 mm that is only 0.0004 of cubic wavelength at the operating frequency (865 MHz). This rectenna uses a miniaturized 3D folded dipole antenna with a maximum gain of +1.54 dBi at 865 MHz. The rectenna is optimized to operate at a low power level with high efficiency (71.6% max). This one can harvest a dc voltage greater than 1 V from illuminating radiofrequency power densities greater than 1.6  $\mu\text{W}/\text{cm}^2$ .

**Keywords**—Wireless Power Transmission; Rectenna; Energy Harvesting; Compact Antenna.

## I. INTRODUCTION

Nowadays, with the quick development of wireless systems and batteryless devices, more research investigations are done on the Energy Harvesting (EH) and Wireless Power Transmission (WPT) techniques. Rectenna (RECTifying anTENNA) system is the core of these techniques and is commonly used in wireless remote supply applications. However, its miniaturization is a huge challenge for researchers and extensive efforts have been made concerning antenna miniaturization aspects [1-4]. The objective of our researches is to keep a good trade-off between the size and the efficiency of the proposed rectenna.

In the following, we present a compact rectenna design for ISM 868 MHz band. The rectenna design including the miniaturization methodology of the antenna is presented in Section II. The experimental results are then presented and discussed in Section III.

## II. RECTENNA DESIGN

This paper addresses a typical rectenna topology as proposed in [1]. It consists of a compact dipole antenna connected to the

rectifier circuit through a dedicated matching network. The rectenna was simulated and fabricated on the FR4 substrate (thickness: 0.8 mm, dielectric constant: 4.4; and dielectric loss tangent: 0.02).

### A. 3D Folded Dipole Antenna design

An original topology of 3D folded dipole antenna (3DFDA) operating at ISM 868 MHz frequency band with a good trade-off between its size and gain (more than +1 dBi) was selected for our rectenna. The miniaturization of this dipole antenna can be implemented by using a meander line structure [3] or by adding an annular ring around it [4]. The miniaturization of the 3DFDA is illustrated in Fig. 1 and is achieved by the following four steps: (i) first the dipole arms are folded to form D1 antenna (Fig. 1 a); (ii) then a T-match stub is added in order to improve the input matching of D2 antenna (Fig. 1 b); (iii) the antenna size is down-scaled (scaling factor: 0.76) and consequently, its resonant frequency has increased at approximately 1.13 GHz for the D3 antenna (Fig. 1 c), (iv) two vertical rectangular arms (size 10 mm by 32 mm) are added in order to set the resonant frequency of the D4 antenna in the ISM 868 MHz frequency band (Fig. 1 d). The position of the electrical short-circuit transmission line between the folded dipole antenna (FDA) and the vertical arms impact the resonant frequency of the antenna and was carefully optimized by using electromagnetic simulation performed with HFSS software from ANSYS. Fig. 2 shows a comparison of the return loss at different steps of the miniaturization procedure. The radiation pattern of the fabricated D4 antenna was measured in an anechoic chamber and the measured gain is depicted in Fig. 4. The differences between simulated and measured S11, presented in Fig. 3, are mainly due to the manual soldering of the metallic vertical arms to the short-circuit transmission line.

However, Fig. 4 shows a good correlation between the measured and simulated gains in the E-plane ( $\Phi = 0^\circ$ ). The maximum measured gain is +1.54 dBi.

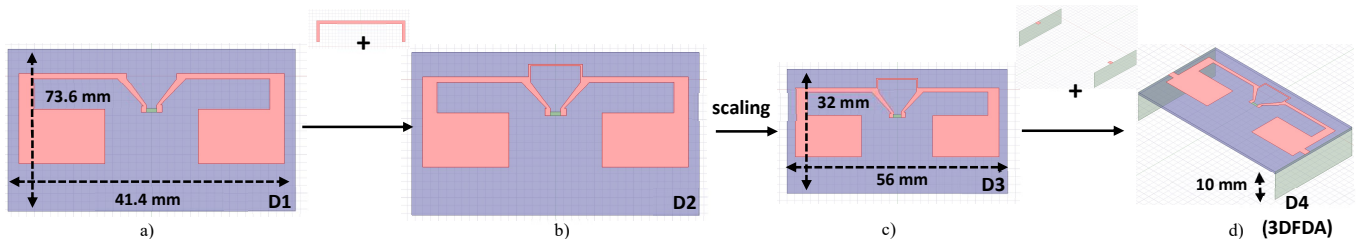


Figure 1: Design procedure of the 3DFDA.

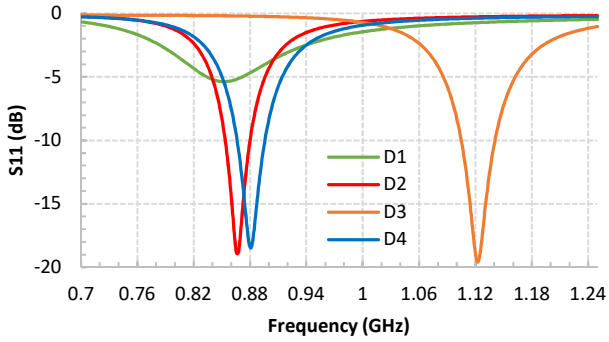


Figure 2: Comparison of the simulated return loss during miniaturization procedure of the antenna.

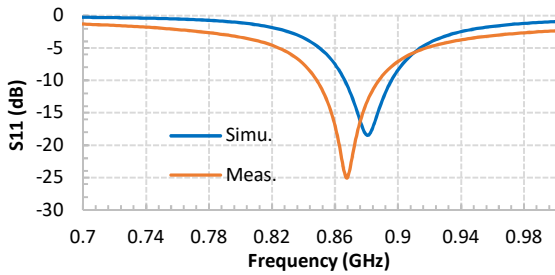


Figure 3: Measured (orange line) and simulated (blue line) of the return loss ( $S_{11}$ ) of the 3DFDA (D4) antenna.

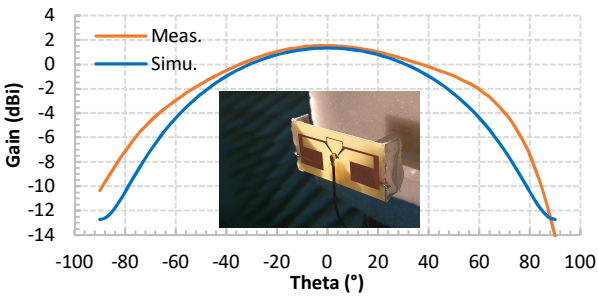


Figure 4: Radiation pattern (gain in dB) at 865 MHz in the E-plane: experimental (orange line) and simulation (blue line) results and photo of the manufactured 3DFDA (D4) antenna in anechoic chamber.

### B. RF-to-dc Rectifier

The RF-to-dc rectifier stage is composed of a matching network, diodes and a low pass filter, all designed with a dedicated load. A doubler rectifier topology implemented by using coupled differential microstrip transmission lines was adopted. The rectifier uses series pair Schottky diodes (SMS7630-005LF) and the L matching network is composed of a serial inductance of 33 nH (LQW15AN33NJ00D) and a shunted capacitor of 4 pF (GRM1551X1H4R0CA01D). The rectifier was designed, simulated and optimized on ADS (Advanced Design System software by Keysight) for a 10 k $\Omega$  load (that is the typical input impedance of a standard power management unit such as bq25504 from Texas Instrument).

### III. EXPERIMENTAL RESULTS AND DISCUSSION

The rectifier designed to operate at 865 MHz, was integrated into the 3DFDA (D4) antenna leading to a compact rectenna (overall size: 56 mm x 32 mm x 10 mm). The

measurements were performed in an anechoic chamber using a standard patch antenna connected to an RF wave's generator in order to create the desired incident power density on the rectenna under test. As shown in Fig. 5, the rectenna harvests its maximum dc voltage of 1.93 V at 865 MHz when illuminated by a radiated power density of 3.3  $\mu\text{W}/\text{cm}^2$ .

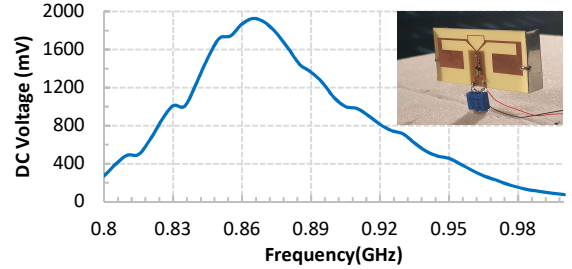


Figure 5: Measured dc voltage as function of the frequency with a power density of  $S=3.3 \mu\text{W}/\text{cm}^2$ . The inset shows a photo of the manufactured prototype.

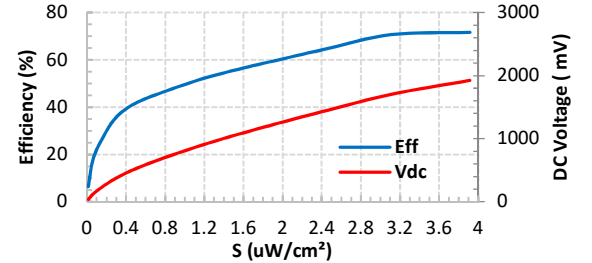


Figure 6: Measured efficiency (blue line) and dc voltage (red line) as function of the power density at 865 MHz.

The maximum conversion efficiency (the ratio between the measured dc power and the RF power derived from the antenna effective surface and the incident electromagnetic power density [2]) reaches 71.6 % at 865 MHz from a power density between 3.9  $\mu\text{W}/\text{cm}^2$  (Fig. 6). As expected, the rectenna exhibits good performances in terms of efficiency.

### IV. CONCLUSION

This paper addresses a miniature rectenna, which is about 0.0004  $\lambda^3$  at 865 MHz. The miniaturization procedure was described and the antenna was fully characterized. The rectenna can reach an RF-to-dc conversion efficiency of 51% and a dc voltage of 800 mV with a power density of 1  $\mu\text{W}/\text{cm}^2$  while the maximum conversion efficiency is 71.6 % for a power density of 3.9  $\mu\text{W}/\text{cm}^2$ .

### REFERENCES

- [1] A.Okba, A. Takacs, H. Aubert, "Compact Planar Integrated Rectenna for Batteryless IoT Applications", 48<sup>th</sup> European Microwave Conference (EuMW), Sept. 2018.
- [2] A. Sidibe, A. Takacs, A. Okba, H. Aubert, "Design and characterization of a compact rectenna for structural health monitoring applications", 2019 IEEE International Symposium on Antennas and Propagation and USNC-URSI Radio Science Meeting, July 2019.
- [3] Adi M. J. Marindra, P. Pongpaibool, W. Wallada and S. Siwamogsatham, "An optimized ink-reducing hollowed-out arm meander dipole antenna structure for printed RFID," International Journal of Microwave and Wireless Technologies, January 2016.
- [4] A. Okba, A. Takacs, H. Aubert, "Compact Flat Dipole Rectenna for IoT Applications" Progress In Electromagnetics Research C, Vol. 87, 39–49, 2018, pp.42–43.