IJCSI International Journal of Computer Science Issues, Vol. 7, Issue 5, September 2010
ISSN (Online): 1694-0814
www.IJCSI.org

Efficient 2.45 GHz Rectenna Design with high Harmonic Rejection for Wireless Power Transmission

Zied Harouni[1], Lotfi Osman[1] and Ali Gharsallah[1]

[1] Department de physique, Faculté des sciences de Tunis, Laboratoire d'Electronique
El Manar,2092 , Tunisia

Abstract

The purpose of this work is to propose an efficient microstrip rectenna operating on ISM band with high harmonic rejection. The receiving antenna with proximity coupled feeding line implemented in a multilayer substrate. The rectenna with integrated circular sector antenna can eliminate the need for an low pass filter (LPF) placed between the antenna and the diode as well as produce higher output power, with maximum conversion efficiency of 74% using a 1300 Ω load resistor at a power density of 0.3 mW/cm².

Keywords: *WPT, Rectenna, Rectifying circuit, Proximity coupled antenna, Defect ground structure.*

1. Introduction

Rectifying antenna (rectenna) which can convert RF energy to DC power plays an important role in free space wireless power transmission (WPT). Over the last century, the development of rectenna for space solar power transmission (SSPT) [1] as well as WPT [2] had great achievement with specific functions; and the applications e.g., actuator [3] or wireless sensors [4].

The typical rectenna in the prior literatures [5]–[7] basically consists of four elements: antenna, low pass filter (LPF), diodes, and DC pass capacitor. The initial development of rectenna focuses on its directivity and efficiency for great power reception and conversion, hence, large array [8] was usually adopted for microwave power reception. Afterward, many functions were added to enhance the performance of the rectenna array, such as arbitrary polarization [9], dual-polarization [10], CP [11], and dual band [12]. Besides, for the antenna integrated with nonlinear circuits, such as diodes and FETs, it is well known that harmonics of the fundamental frequency would be generated. The unwanted harmonics cause problems of harmonics re-radiation and efficiency reduction of rectenna; then the LPF is required to suppress harmonics to improve system performance and prevent harmonics interference. For size reduction and cost down, the antenna with harmonic rejection property was proposed to eliminate LPF [13]. In this paper, a microstrip rectenna with harmonic rejection property is proposed it shown in figure 1.

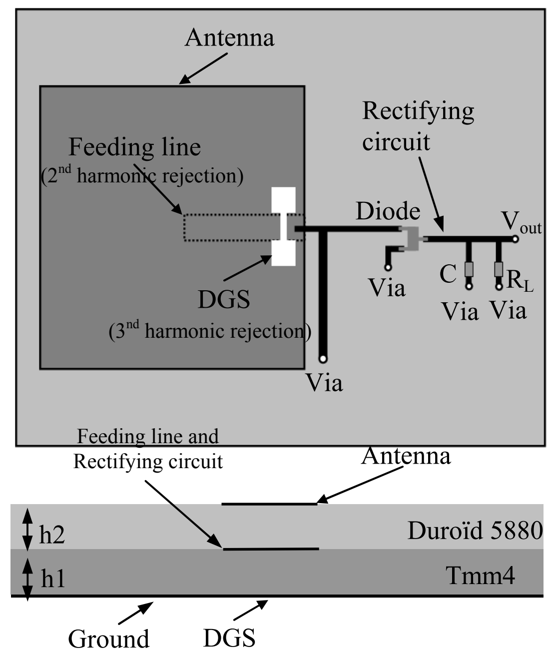


Figure 1. Proposed rectenna with harmonic rejection

2. Antenna design

The rectangular radiating patch is printed on the side of the first substrate while the microstrip feed line is on the upper side of the second substrate, the ground plane, and the dumbbell shape slot, are on lower side of the second substrate. The relative permittivities and the thickness are ε_{r1}=2.2, ε_{r2}=4.5, h_1=1.575 mm and h_2=1.524 mm. We should emphasize that the value of ε_{r1} has been chosen small to enhance the patch radiation. Similarly, the quantity ε_{r2} has been chosen so high to reduce the size of microstrip feed line compared to the radiating element. The line is dimensioned for 50Ω characteristic impedance and a bandwidth of 2.845 mm.

The length and width of the patch are 34.2 mm and 34.9 mm respectively, which are dimensioned to resonate at 2.45GHz frequency. The slot in the ground plane, whose dimensions are given on the Figure 2. The electromagnetic energy is coupled from the microstrip feed line to the patch, the slot avoid a frequency stop band.

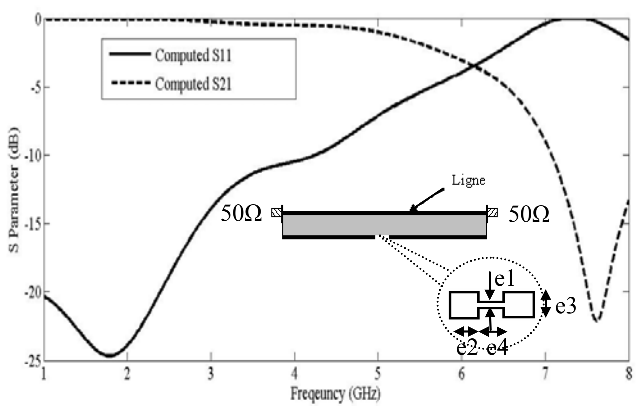


Fig. 1 S-parameters and side view of the DGS used to reduce the third harmonic in the proposed design, e1=0.255mm, e2= 2. 95mm, e3=2.1mm, e4=2.84mm

The use of a DGS allows the apparition of a stop band controlled by tuning the dimensions of the slot. The S parameter result of the DGS is shown in figure 2.

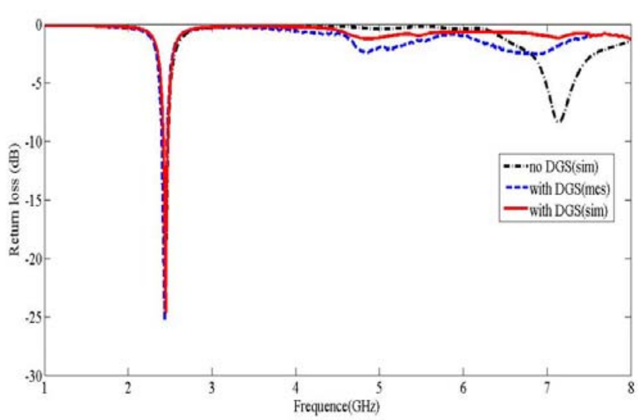


Fig. 2 Simulated and Measured reflection coefficient versus frequency.

The measured return loss impedance bandwidth is about 2.6% for a 6.4 dB gain at 2.45GHz operating frequency. It can be noted that the mismatches at the harmonics frequencies 4.9GHz and 7.35GHz are -1.95 dB and -1.75 dB respectively.

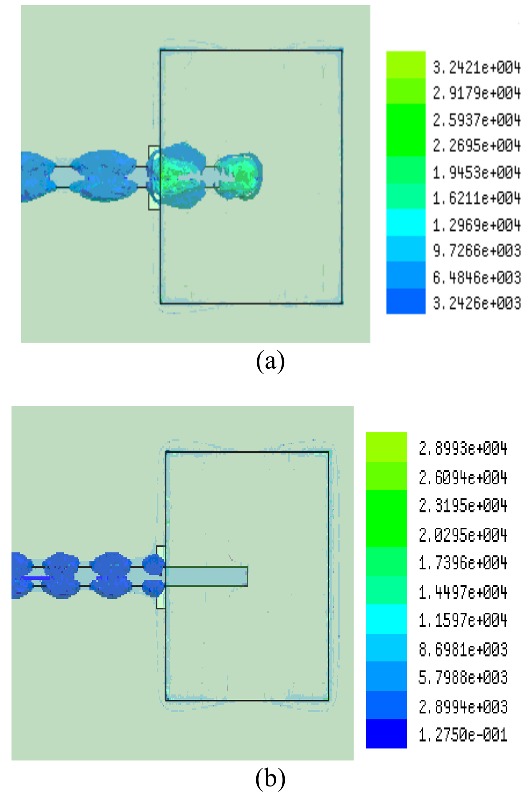


Fig. 3 Field distribution (V/m) at 4.9 GHz (a) and 7.35 GHz (b).

Figure 3 shows the current distribution at 4.9 GHz and 7.35 GHz

3. Rectenna measurements

The receiving antenna and rectifying are connected by SMA connectors as shown in Fig. 4. It contains a linearly polarised patch antenna designed at 2.45 GHz by using HFSS software[14]. The rectenna contains one HSMS2860 commercial Schottky diodes in a SOT23 package. The zero bias junction capacitance Cj0 is 0.18 pF and the series resistance Rs is 5 V.

Fig. 4 Photograph of the proposed rectenna

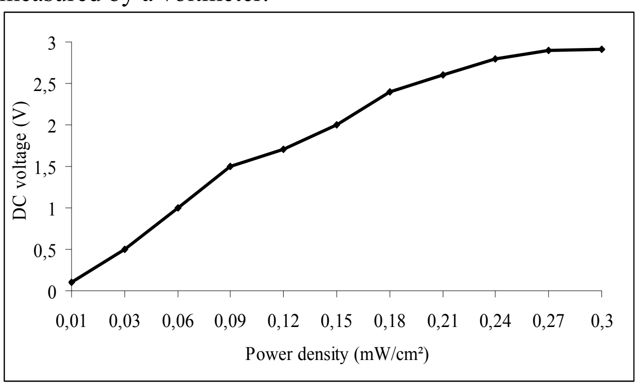
The experiments have been carried out in anechoic chamber. The transmitting antenna is a standard linear polarized horn with gain Gt of 12 dB. The rectenna is located at the distance *r* of 70 cm, which is the far region of the horn. The output DC voltage and overall efficiency have been measured against power density from the Friss transmission equation(1).

$$P_r = \left(\frac{\lambda}{4\pi r}\right)^2 P_t G_t G_r \quad (1)$$

where Pt is the transmitting power; Gr is the receiving antenna gain; ¸ is the free space wavelength at 2.45 GHz. So the RF-DC conversion efficiency is calculated by formula (2).

$$\eta_r = \frac{\frac{(V_{out})^2}{R_L}}{P_r} \quad (2)$$

The rectenna is illuminated by a linearly polarised incident plane wave of 20 V/m (0.10 mW/cm²) at its broadside. On the transmitter side, we have used a 30 dB gain power amplifier at 2.45 GHz connected to a signal generator. The output DC voltage across the resistor load has been measured by a voltmeter.



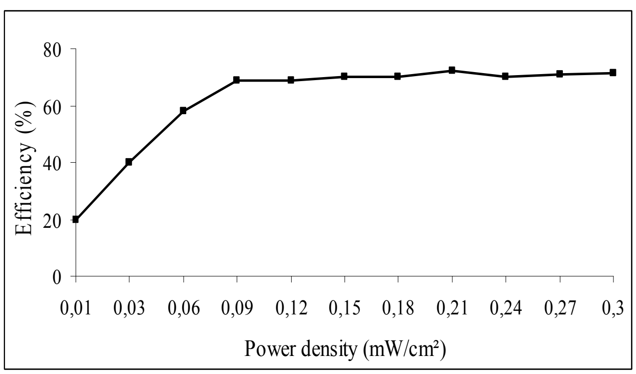


Fig. 5 Measured DC voltages and rectenna efficiency against power density

The measured output DC voltages and overall efficiency are shown in Fig. 5. In the power density range (0–0.3 mW/cm²), the measured rectenna efficiency is above 74% from 0.3 mW/cm² power density and the corresponding output DC voltage is 2.9 V over a 1300 Ω optimised load resistance. The measured results show that the output voltage and efficiency increase when the power density increases.

In applications, the antenna and rectifying circuit can be integrated directly on one substrate by omitting SMA connectors. Without the loss of SMAs, the efficiency would be higher.

4. Conclusion

An efficient rectenna design, based on a series diode circuit topology is proposed. An optimised length of the feeding line and defect groud structure are used to reject the second and the third harmonics. No input low pass filter is needed, thus reducing the insertion losses and the dimensions of the circuit. The rectifying circuit has been optimised at 2.45 GHz for an input power of 10 dBm. The rectenna exhibits a measured efficiency of 74 % at 0.3 mW/cm² power density and an output DC voltage of 2.9 V.

5. Acknowledgment

We thank D. Delcroix and the Esycom laboratory of University of Marne-La-Vallée in Paris.

References

[1] P. E. Glaser, “An overview of the solar power satellite option,” *IEEE Trans. Microw. Theory Tech.*, vol. 40, no. 6, pp. 1230–1238, Jun. 1992

[2] W. C. Brown, “The history of power transmission by radio waves,” *IEEE Trans. Microw. Theory Tech.*, vol. 32, no. 9, pp. 1230–1242, Sep.1984.

[3] Epp, L.W., Khan, A.R., Smith, H.K., and Smith, R.P.: ‘A compact dualpolarized 8.51-GHz rectenna for high-voltage (50 V) actuator applications’, IEEE Trans. Microw. Theory Tech., 2000, 48, (1), pp. 111–120

[4] Farinholt, K.M., Park, G., and Farrar, C.R.: ‘RF energy transmission for a low-power wireless impedance sensor node’, IEEE Sensors J., 2009, 9,(7), pp. 793–800

[5] H. Takhedmit, L. Cirio, B. Merabet, B. Allard, F. Costa, C. Vollaire and O. PiconEfficient 2.45 GHz rectenna design including harmonic rejecting rectifier device, Electronics letters 10th June 2010 Vol. 46 No. 12

[6] Tzong-Chee Yo, Chien-Ming Lee, Chen-Ming Hsu, and Ching-Hsing Luo, Compact Circularly Polarized Rectenna With Unbalanced Circular Slots, IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION, VOL. 56, NO. 3, MARCH 2008

[7] M. Ali, G. Yang, and R. Dougal, Miniature Circularly Polarized Rectenna With Reduced Out-of-Band Harmonics, IEEE antennas and wireless propagation letters, vol. 5, 2006

[8] R. M. Dickinson, "Performance of a high-power, 2.388-GHz receiving array in wireless power transmission over 1.54 km," in *IEEE MTT-SInt. Microw. Symp. Dig.*, Jun. 1976, vol. 76, no. 1, pp. 139–141.

[9] J. A. Hagerty and Z. Popovic, "An experimental and theoretical characterization of a broadband arbitrarily-polarized rectenna array," in *MTT-S Int. IEEE Microw. Symp. Dig.*, May 20–25, 2001, vol. 3, pp. 1855–1858.

[10] J. O. McSpadden and K. Chang, "A dual polarized circular patch rectifying antenna at 2.45 GHz for microwave power conversion and detection," in *IEEE MTT-S Int. Microw. Symp. Dig.*, May 1994, vol. 3, pp. 1749–1752.

[11] Y.-Y. Gao, X.-X. Yang, C. Jiang, and J.-Y. Zhou, A circularly polarized rectenna with low profile for wireless power transmission, *Progress In Electromagnetics Research Letters, Vol. 13, 4-49, 2010*

[12] Y. H. Suh and K. Chang, "A high-efficiency dual-frequency rectenna for 2.45- and 5.8-GHz wireless power transmission," *IEEE Trans. Microw. Theory Tech.*, vol. 50, no. 7, pp. 1784–1789, Jul. 2002

[13] Ji-Yong Park, Sang-Min Han,Tatsuo Itoh, A Rectenna Design With Harmonic-Rejecting Circular-Sector Antenna, IEEE Antennas and wireless propagation letters, vol. 3, 2004.

[13] ANSOFT CORPORATIONS, HFSS V.11- Software based on the finite element method.

Zied Harouni was born in France in 1980, he received his master's degree in electronic from the Faculty of Sciences of Tunis, Tunisia, in 2006, where he prepare his PhD degree. His research interests microwave transmission power.

Lotfi Osman he received his PhD degree, He is currently working at the Ecole supérieur de telecommunication de Tunis. His research interests antennas and modelling in microwave integrated circuits.

Ali Gharsallah Professor in the faculty of Sciences of Tunis, he received the engineering's degree in radio-electrical from the Ecole Supérieure de Telecommunication de Tunis in 1986 and the PhD degree in 1994 from the Ecole National d'Ingénieurs de Tunis. Since 1991, he was with the Department of Physics at the Faculty of Sciences, Tunis. His current research interests include antennas, multilayered structures and microwave integrated circuits.