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A High-efficiency Circular Polarized Membrane Rectenna for Wireless Power Transfer

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***Abstract-* A high-efficiency circular polarized membrane rectenna for wireless power transfer at 2.45 GHz is presented. Its antenna's impedance is directly matched to a rectifier, and the thickness of the antenna is only 0.01 mm, which is a membrane structure. The rectenna is composed of a miniaturized CP membrane antenna and a rectifier with two Schottky diodes (HSMS-286C). The simulated results illustrate that the peak conversion efficiency 77% is achieved at 19 dBm. The results bring out a well application to powering electronic sensors.**

***Keywords-* antenna; circular polarized; rectifier; S-band**

I. INTRODUCTION

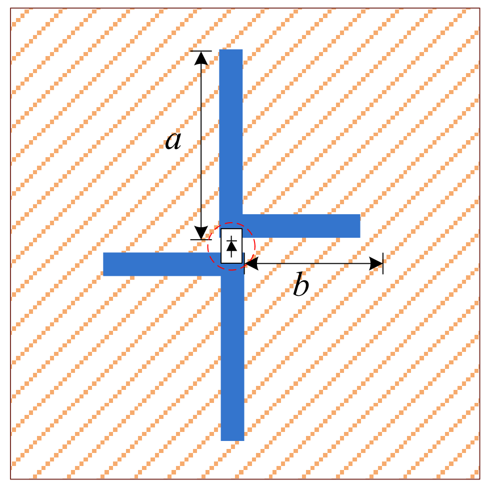
Microwave wireless power transfer (MWPT) as a portable charging way has received extensive attention to make people's life convenient. [1],[2]. In MWPT system, the rectenna is an important part of it. The rectenna consists of an antenna to capture the ambient electromagnetic energy and a rectifier to rectifying the microwave.

Recently, various rectennas have been reported to provide power for electronic sensors, such as dual-band aperture-coupled rectenna, dual-circular polarized rectenna, highly efficient differential rectenna, and reconfigurable rectenna, which are linearly polarized rectennas with high-efficiency in microwave power harvesting. However, the polarization direction of the microwave received by the antenna is suffer from variation. Therefore, CP rectennas are a better choice. There are various techniques for achieving circular polarization. In [3] -[4], the low-profile rectennas with a CP patch antenna is introduced, which realize circular polarization by using a quarter-wavelength microstrip line between the coupling points. Moreover, a wide-slot rectenna generates CP microwave by an L-shaped perturbation with circular patch. All of these circular polarized rectennas are fabricated on substrates.

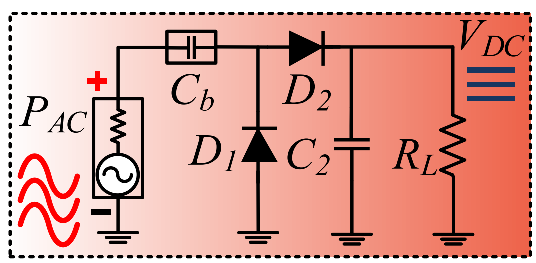
In this paper, a compact, CP membrane and high-efficiency rectenna without matching network is presented. A simple and compact rectifier with two Schottky diodes (HSMS-286) is placed between two dipoles without affecting the total size of the antenna. Compared with other reported rectennas, this membrane rectenna is more compact and lighter to satisfy the demand of WPT.

II. RECTENNA DESIGN

The geometry and configuration of this proposed rectenna are shown in Fig. 1. This antenna is designed on a thin substrate as a flexible printed circuit (FPC). It consists of a membrane antenna and a rectifier operating at 2.45 GHz. The antenna employs a pair of unequal dipoles to realize circular polarization. To improve the gain of this membrane antenna, a reflecting plane is employed and placed λ/4 away from the antenna plane. The simulated impedance of the proposed antenna is illustrated in Fig. 2. It can be seen that as the length of dipoles *a* and *b* increase, the real part and imaginary gradually decreases (range from 50 to 100 Ω) and increases (range from -10 to 70 Ω) at operating WiFi band, respectively. The impedance of the proposed antenna is (80+ j20) Ω at 2.45 GHz.



(a)



(b)

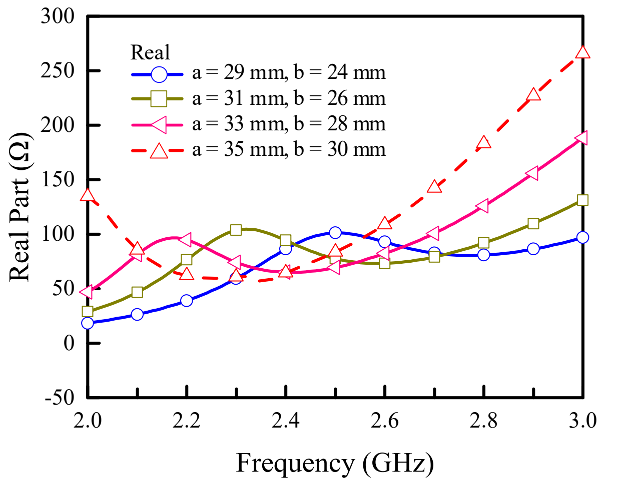
Figure 1. (a) Configuration of the compact rectenna with a=31 mm, b=26 mm and C2=100 pF; (b) Rectifier configuration.

A compact and high-efficiency rectifying circuit, which use two Schottky diodes of HSMS-286, is designed and simulated. Its input impedance can be expressed as:

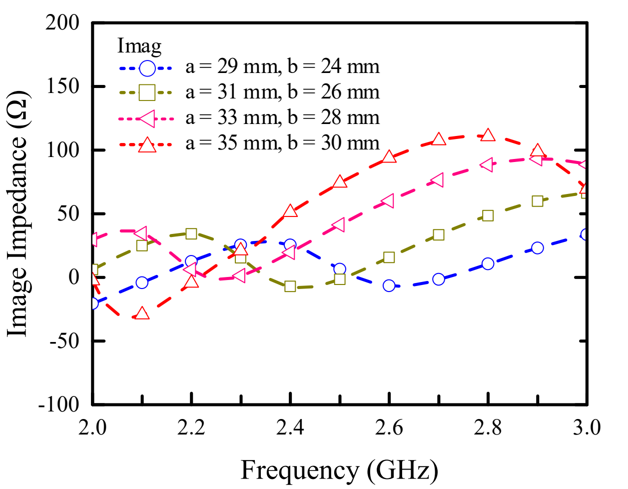
$$Z_{diode} = \frac{2\pi R_s}{\theta_i - \sin\theta_i + j2R_s\omega C_j\left(\pi - \frac{\theta_i}{2} + \frac{\sin\theta_i}{2}\right)} \quad (1)$$

where R_s is the diode series resistance, C_j is the diode junction capacitor, θ_i is the diode conduction angle.

The input impedance of the rectifier circuit is (88-j20) Ω at input power level 19 dBm (@2.45 GHz). It can be found that the impedances of antenna and rectifier can be conjugated matching each other. This design can decrease the power loss of extra transmission line. Meanwhile, its size is compact and weigh is light.



(a)



(b)

Figure 2. Influence of unequal dipoles dimension on the input impedance of antenna.

The proposed rectenna will be measured in an anechoic using a dedicated setup experiment depicted in Fig. 3. A horn is used as the transmitting antenna (peak gain=12.99 dBi) and a dimension D (21 cm). The far-field distance of MWPT is:

$$R_{\text{far}} = \frac{2D^2}{\lambda} \quad (2)$$

where λ is the wavelength.

The received power density of the rectenna S_R can be calculated as:

$$S_R = \frac{G_T P_{IN}}{4\pi D^2} \quad (3)$$

Then, the RF-to-dc conversion efficiency of the proposed rectenna can be calculated as:

$$\eta = \frac{V_{out}^2}{P_r R_{Load}} \times 100\% \quad (4)$$

where V_{out} is the dc voltage of the resistance load.

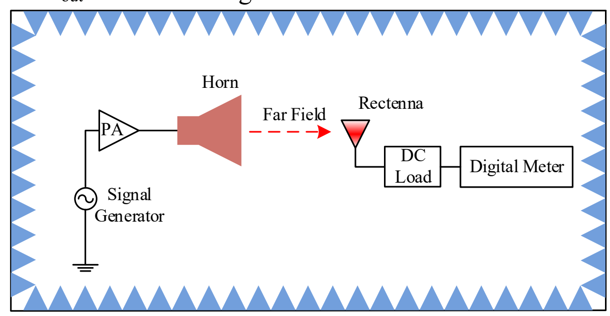


Figure 3. Setup measurement of the proposed rectenna.

Fig. 4 shows the simulated RF-to-dc conversion efficiency and the output voltage values with various input power levels at 13, 16, 19 and 22 dBm, respectively. As can be seen, the simulated results shows that the maximum conversion efficiency is achieved 77 % at received power level of 19 dBm with an optimal load of 400 Ω.

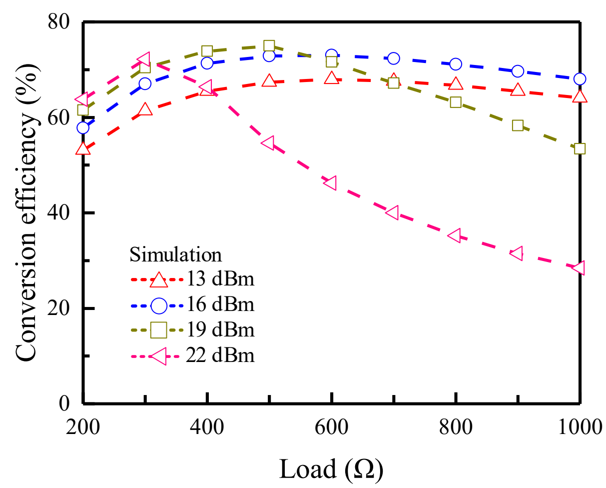


Figure 4. Simulated RF-to-dc conversion efficiency at various input power levels (13, 16, 19, and 22 dBm).

III. Conclusion

A compact, CP and high-efficiency membrane rectenna is presented in this paper. In order to obtain a more compact structure, the impedance of membrane antenna is conjugate matched to the rectifier. The maxmum RF-to-dc conversion efficiency is obtain 76.8 % at 19 dBm. Therefore, this rectenna design will provide a suitable method for the future MWPT.

Acknowledgment

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