A Dual-Band Rectenna Without Impedance Matching Network for Wireless Power Transmission

Zhongqi He, Hang Lin, and Changjun Liu*
School of Electronics and Information Engineering, Sichuan University, China
*email: cjliu@ieee.org

***Abstract* – We proposed a facilitated design of a rectenna for dual-band wireless power transmission. This design introduces a co-design of a Schottky's diode and an antenna at 2.45 GHz and 5.8 GHz, in which their impedance are conjugate matching. The rectifying diode presents capacitive impedance, and a loop antenna presents inductive impedance. For validation, a rectenna at 2.45 GHz and 5.8 GHz was fabricated. The measurement results show a maximum conversion efficiency of 70% with a load resistance of 400 Ω was realized at 2.45 GHz. At 5.8 GHz, the peak efficiency is 61.5% with a load resistance of 200 Ω.**

***Keywords* — Conjugation impedance matching, dual-band, high efficiency, rectenna, wireless power transmission (WPT).**

I. INTRODUCTION

Recently, wireless power transmission (WPT) has attracted special attention since it is potential to charge the electronic devices which gain power hard through wires [1], such as wearable medical sensors, wireless sensors, and so on. In order to output more dc power, high efficiency and high power are required in a WPT system.

Rectenna can receive radio frequency (RF) power and convert it to dc power [2]. Thus, the RF-dc conversion efficiency of a rectenna is closely related to the performance of a WPT system. Some research teams have given serval methods to improve the performance of rectenna, such as dipole antennas [3] , loop antennas [4], dual-frequency antennas [5], fractal antennas [6], bent triangular antennas [7], and so on. When the input power varies, the RF-dc conversion efficiency of those designs becomes low, since the efficiency depends on the power level owing to nonlinear characteristics of rectifying diodes.

In this paper, a simple dual-band rectenna based on co-design of a Schottky diode's and a loop antenna's impedances to achieve high efficiency for WPT is presented. The design method for dual-band WPT is discussed in this letter. A rectenna operating at 2.45 GHz and 5.8 GHz is fabricated with an HSMS286 diode directly connecting into the loop antenna. The impedances of the diode and antenna are conjugate matching at the fundamental frequency to enhance power conversion efficiency. Neither microstrip line with 50 Ω characteristic impedance nor matching circuit network is employed between the antenna and rectifying diode. The proposed rectenna is simple without matching circuit stubs and filter.

II. PRINCIPLE AND DESIGN

Different from traditional dual-band rectenna, we proposed another topology for conjugate matching between the antenna and rectifying diode at dual-band, which removes the matching and filtering networks and dc-pass filter, as shown in Fig. 1(b). When the working frequency, input power, and dc load are determined, the input impedance of a Schottky diode can be given by Z_{RCT}=R-jX. According to transmission line theory, when the impedances of load and source are conjugate matching, the load can gain the maximum input power. Thus, in order to get more rectifying RF power, the impedance of antenna can be optimized to achieve Z_{ANT}= R+jX.

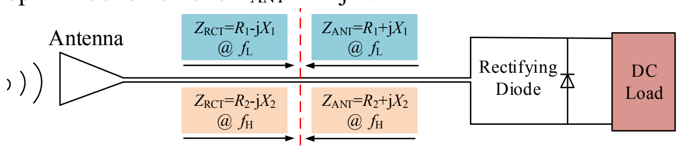

Fig. 1. Circuit configuration of the proposed rectenna.

A. Diode Impedance

The rectifying diode plays a crucial role in a WPT system, which can convert RF power to dc power. Since the implementation of WPT, Schottky diodes have been widely employed in rectifier circuit owing to their excellent performance in forward voltage, series resistance, and diode capacitance.

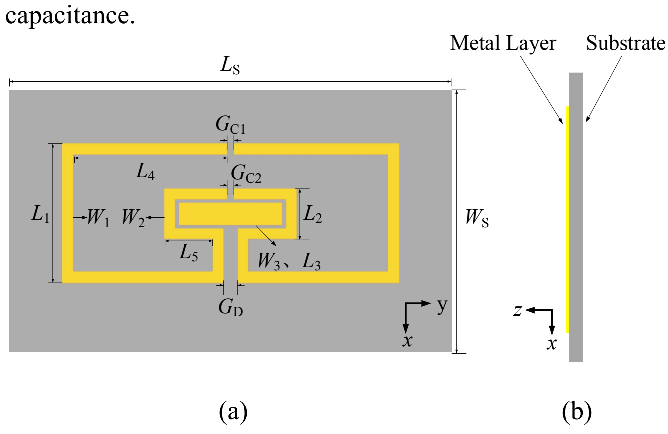

Fig. 2. Configuration of the proposed antenna. (a) Top view. (b) Side view.

The impedance of the HSMS286 at operating frequency of 2.45 GHz is 280-*j*110 Ω. When the input power is 17 dBm and dc load is 200 Ω at 5.8GHz, the impedance of the HSMS286 at fundamental frequency is 75-*j*49 Ω.

A dual-band loop antenna was also employed in this design as receiving antenna. The impedances of the antenna and rectifying diode are conjugate matching at 2.45 GHz

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and 5.8GHz, respectively, so the input impedance of antenna is determined by the diode. After optimization, the antenna's input impedances of 280+j110 Ω and 75+j49 Ω are obtained at 2.45 GHz and 5.8 GHz, respectively.

The proposed loop antenna is shown in Fig. 2. Two loops are used to receive RF power at different frequencies. The big one is for low frequency (2.45 GHz), and the small one is for high frequency (5.8 GHz). Three gaps are introduced in the loop antenna to weld capacitance (dc block) and rectifying diode, i.e. the top one and middle one marked as G_{C1} and G_{C2} for capacitances, and the bottom one marked as G_D for diode. The rectangle patch in the center can provide well tuning of the antenna's impedance by varying the parameters W_3 and L_3. The parameters of the antenna are listed in Table □.

TABLE □

PARAMETERS OF THE LOOP ANTENNA

L_S	W_S	W_1	W_2	W_3	G_{C1}	G_{C2}
60	33	1.5	1.4	3	1	1
G_D	L_1	L_2	L_3	L_4	L_5	
2	19	6.8	14	21	6.6	

III. EXPERIMENT RESULTS

In order to measure the proposed dual-band loop antenna, two baluns 2450BL15B100 and 5800BL15B100 are employed to fed the antenna, respectively. The proposed antenna is polarized along y-direction and has a maximum antenna gain of 3.2 dBi and 5.4 dBi at 2.45 GHz and 5.8 GHz, respectively.

Fig. 3 shows the fabricated rectenna. Two capacitances of 22 pF as dc block are inserted in the loop antenna, whose reactance are small at operating frequency of 2.45 GHz and 5.8 GHz. A Schottky diode HSMS286 is directly connected into the loop antenna. Two meander lines are used to output dc power, and they are not parallel to each other so as to avoid RF coupling in measurements.

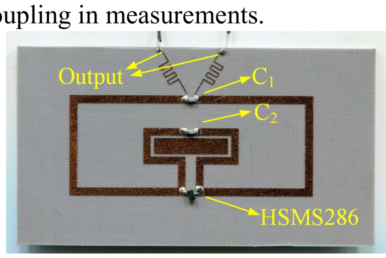

Fig. 3. Fabricated dual-band rectenna.

The rectenna operating at 2.45 GHz and 5.8 GHz has been measured at R_L = 200, 400, and 600 Ω, respectively. The output dc voltage as a function of the input power is shown in Fig. 4(a) and Fig. 5(a). The measured efficiency of the rectenna versus power is plotted in Fig. 4(b) and Fig. 5(b). The efficiency of the rectenna increases with the dc load and decreases after reaching the optimum load of 400 Ω at 2.45 GHz. The maximum efficiency of 70% is realized. At 5.8 GHz, the optimum load changes to 200 Ω with a peak efficiency of 61.5%.

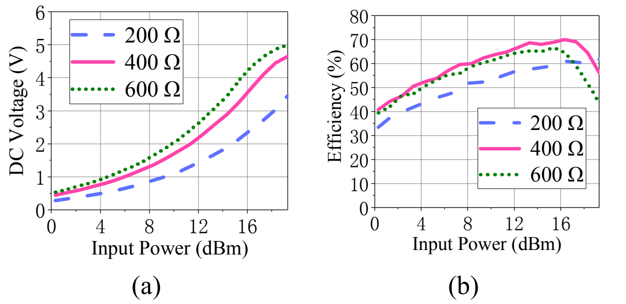

Fig. 4. Measured dc voltage(a) and efficiency(b) of the proposed rectenna as a function of input power at 2.45 GHz.

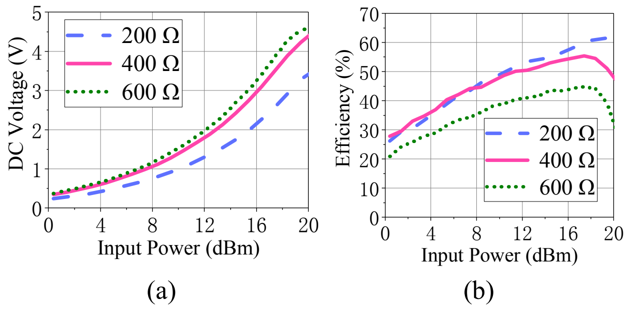

Fig. 5. Measured dc voltage(a) and efficiency(b) of the proposed rectenna as a function of input power at 5.8 GHz.

IV. CONCLUSION

A compact dual-band rectenna is designed, fabricated, and measured in this letter. The matching and filtering networks between antenna and rectifier in conversional rectenna have been removed by the simple design method, which leads a compact structure. Co-design of a Schottky diode's and a loop antenna's impedances is introduced to achieve them conjugate matching at operating frequency.

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