

A Novel Broadband Rectenna for Energy Harvesting

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Abstract – This paper represents a broadband rectenna for wireless energy harvesting. First, a dual-polarization antenna has been proposed to receive RF energy from various directions. Then two broadband rectifier circuits with single-branch structure and two-branch structure have been designed. At -10dBm input RF power, The conversion efficiency of the single-branch rectifier is greater than 40% for the entire 1.75-2.5GHz band, and the efficiency of the two-branch rectifier is greater than 45% for the 0.85-0.95GHz and 1.7-2.45GHz band.

Index Terms — broadband rectifier, energy harvesting, rectenna, complex impedance matching.

1. Introduction

Wireless energy harvesting is an idea of converting ambient RF energy to dc power, then supply to low-power electronic devices. A rectenna can be used to realize energy harvesting. Now many efficient single-band rectenna has been designed [1]. In order to collect as much energy as possible, dual-band rectenna [2], multiband rectenna [3] and broad-band rectenna [4] has been designed. In this paper, a broad-band rectenna is proposed. In addition, a two-branch rectifier is designed to cover a wider bandwidth.

2. Rectenna Structure

As shown in Fig. 1 (a) and (b), a rectenna has been designed. The antenna and rectifier circuit (Fig. 1 (e)) are print on the 20-mil-thick Duroid 5880 substrate ($\epsilon_r = 2.2$). The dimension of the rectenna is $230 \times 130 \times 130 \text{mm}^3$.

(1) Antenna Design

In order to receive the RF signal from various directions, a broadband dual-polarization antenna is designed. Two identical wideband exponential tapered slot antennas depicted in Fig. 1(c) and (d) are vertically inserted together to achieve dual polarization, as shown in Fig. 1(a). The microstrip feed line in Fig. 1(b) and (d) will be connected to the rectifier circuit shown in Fig. 1 (e)

(2) Single-branch Rectifier Design

A parallel voltage doubler structure is selected in both rectifier circuits in Fig. 2, Because both half of wave can be rectified by the diode and starting from only one diode threshold voltage.

A matching circuit between antenna and rectifier ensures the antenna transmits the maximum power to the rectifier

circuit. In this work, an advanced complex impedance broadband matching theory described in [5] has been used to improve the performance of the circuit. By modifying the parameters, the matching circuit can achieve a broadband matching within 1GHz frequency band. With the optimization of the software Advanced Design System (ADS), the bandwidth meets the requirement. The final design is shown in Fig. 2(a). The matching circuit consists of three microstrip line and an 11-nH chip inductor. The SMS7630 Schottky diode has been selected as its low biasing voltage requirement [6] and good conversion efficiency. The load resistance is $4\text{k}\Omega$ in order to achieve the best efficiency.

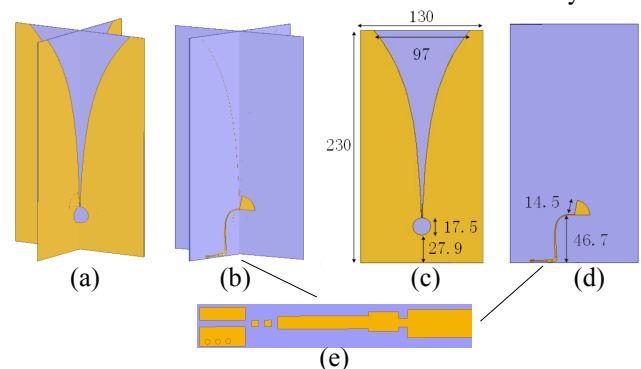


Fig. 1. The structure of rectenna. (a) 3-D model of the proposed rectenna. (b) Another side of the rectenna. (c) The front of the TSA antenna. (d) The back of the TSA antenna. (e) The magnified view of the zoom region in (b) and (d). The parameters are in unit: mm.

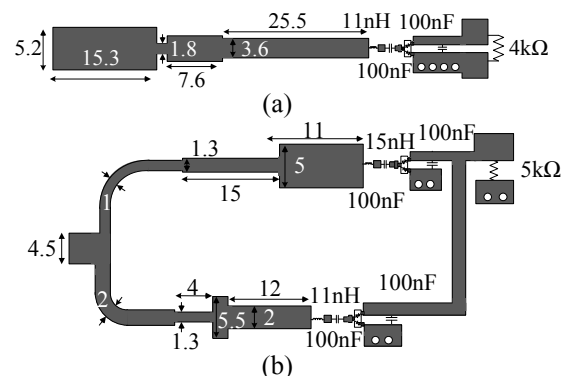


Fig. 2. The structure of rectifying circuit. (a) Single-branch (b) Two-branch. The parameters are in unit: mm.

(3) Two-branch Rectifier Design

Due to the nonlinearity of the Schottky diode, the input impedance of the rectifier varies with the input power,

frequency and load resistance. Therefore, it is difficult to reach a wider frequency band with only one matching circuit branch. In order to solve this problem, we designed a two-branch rectifier, each branch matching a part of the frequency band. The structure is shown in Fig. 2(b), a voltage doubler rectifier is selected in each branch to improve efficiency. Both matching branch consists of three microstrip and a chip inductor (15nH and 11nH respectively). The optimal resistance is selected as 5k Ω .

3. Results and Discussions

(1) Wideband Antenna

The simulated reflection coefficients (S_{11}) are shown in Fig. 3. The 10-dB return-loss bandwidths are from 0.75GHz to 2.45GHz.

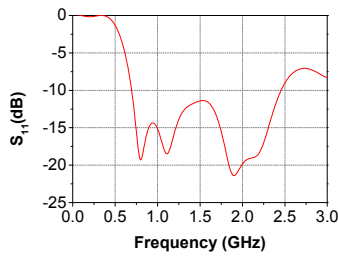


Fig. 3. The reflection coefficients of antenna.

(2) Rectifier

The RF-to-dc conversion efficiency of the rectifier can be calculated by

$$\eta_{RF-dc} = P_{dc} / V_{dc} = V_{dc}^2 / (P_{RF} \times R_L) \quad (1)$$

Where P_{dc} is the output dc power, P_{RF} is the RF power received by rectifier, V_{dc} is the output dc voltage across the resistive load and R_L is the load resistance.

As shown in Fig. 4(a) and (b), the S_{11} of the single-branch and two-branch rectifier is less than -6dB over the entire frequency band (1.75-2.5GHz of the single-branch rectifier, 0.85-0.95 and 1.7-2.45GHz of the two-branch rectifier) at -10dBm RF input power. The conversion efficiency in three input power level against frequency of the single-branch and two-branch rectifier in Fig. 5(a) and (b) is respectively greater than 40% and 45% at -10dBm input over the desired frequency band, witch demonstrates that the rectifiers are of a broad bandwidth and highly efficient. The maximum efficiency of the two rectifier is 70% and 65% respectively when the input power is 0dBm.

4. Conclusion

In this paper, a highly efficient broadband rectenna has been proposed. A broadband dual-polarization antenna has been designed to receive RF energy in arbitrary direction to

rectifier. The maximum efficiency of the rectifiers is 70% in 0dBm input and 53% in -10dBm input. The bandwidth of the single-branch rectifier is 1.75-2.5GHz, and the bandwidth of the two-branch rectifier is 0.85-0.95, 1.7-2.45GHz.

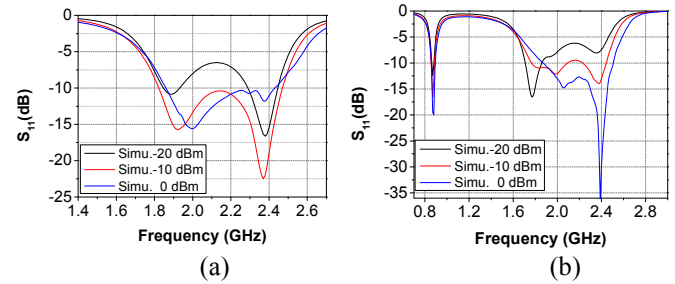


Fig. 4. Simulated reflection coefficients of rectifier. (a) Single-branch (b) Two-branch.

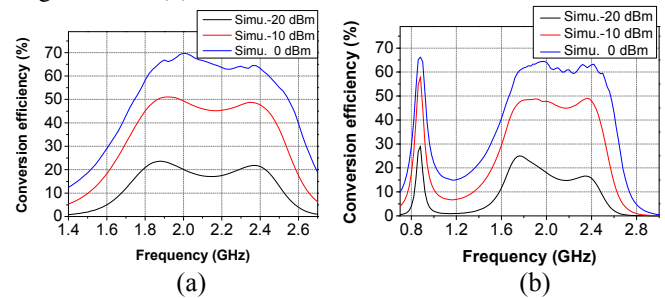


Fig. 5. Simulated RF-to-dc conversion efficiency of rectifier versus frequency at different input power levels. (a) Single-branch (b) Two-branch.

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