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Application of Advanced Rectenna System with the help of Modified Rectifier Design

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ABSTRACT

This paper presents a better efficiency 2.56-GHz rectifier that can generated very low input RF power efficiently. A new rectifier has been proposed here for the application of advanced rectenna system application. The proposed paper inform us about single-band rectifier has been implemented with simulation. With an efficient input matching network, the measurement results for an input power level of 20 dBm show peak RF-to-DC efficiencies of 76% and output dc voltage of 3.27 V at frequency 2.44 GHz.

Keywords—Rectifier; RF energy harvesting; wireless power transmission (WPT); rectenna.

1 INTRODUCTION

As a key component of rectenna, microwave rectifier has been widely used in wireless power transmission with a heavy power and kilometer-range transfer [1]. The single frequency operated at 2.45 GHz, 5.8 GHz, 10 GHz and 35 GHz have been reported in [2]-[4]. The high power microwave rectifier has also been demonstrated in [5]. However, those works all focused on the high-power and long distance transmission such as the application of solar-power satellites. Recently the development of wireless charging and energy harvesting draws the interest of research to rectifier for short distance and low incident power densities. Additionally, due to the requirement of energy harvesting applications, distinct operating frequency points are not enough to harvest the RF powers and moreresearch is needed to find out the potential power sources frequency spectrum [6].

The investigation for the rectifier below 1W with single frequency operation is emerging in the application of microwave rectifier in [7], [8]. The low incident power level with different frequencies rectifiers are proposed for energy harvesting from RF power sources such as intentional GSM 1800 MHz, GSM 2100 MHz, WLAN and WiFi [9]. Therefore, study of rectification circuit is of interest which can cover the potential frequencies where high power density sources are available.

In this paper, a simplified rectifying structure operated efficiently at low incident power levels of 20 dBm, with good input impedance matching is presented for wireless energytransfer.

RECTIFIER DESIGN

The key to improve transmission RF-DC conversion efficiency is the rectifying circuit. The main element of the proposed rectifying circuit is shown in Fig.1. This input rectifier will receive RF power at 2.44 GHz and converts it to the dc-power through a schottky diode. The capacitor acts as a dc-pass filter to prevent microwave power from reaching the load and reflects it back to the diode to be convert again. A resistive load is placed at the end to extract the dc power.

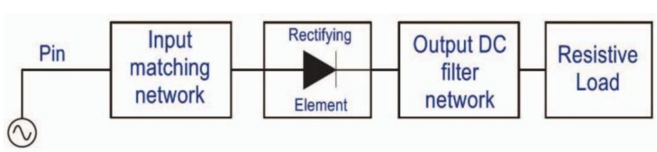


Fig. 1. Block diagram of rectifier.

The rectifier is fabricated on a 1.58mm-thick Taconic TLY-5-0600-C1/C1 substrate with a dielectric constant of 2.2 and loss tangent of 0.0009, which will be operated at frequency 2.44 GHz. This structure consists of a schottky diode, a dc-pass filter, and a resistive load as shown in Fig.2. The Schottky HSMS-2820 diode was choosen because it has a low built-in voltage with fast switching response, low series resistance, and good RF characteristics. It is placed across two sides of the line without drilling holes on the dielectric layer. To reduce the size of the rectifier, a capacitor has been simply connected in parallel to act as a dc-pass filter. A quarter wavelength transformer is designed in front of the rectifying diode. Then, a capacitor and resistive load have been simply connected parallel which placed at the end after rectifying diode to extract the dc power.

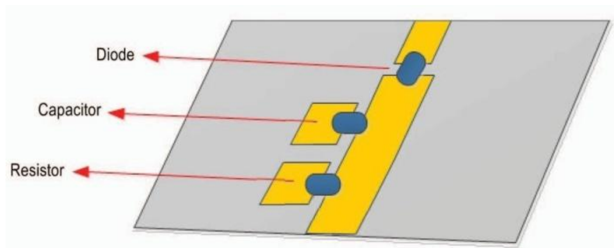


Fig. 2. Configuration of the proposed rectifier.

Because of the nonlinear characteristics of the diode, it can generate some high-order harmonics that may be radiated by the antenna. To block these harmonics and increase the efficiency of this rectifier, a filter is commonly inserted between the antenna and the rectifier. In this design, the rectifier is designed to match filter at 2.44 GHz so that the high-order harmonics can be obstructed. A quarter wave transformer is used to match the 50 impedance on the input impedance of the rectifier circuit. The total circuit size, excluding connectors, is 32.57 x 100 mm.

RESULTS

In this section, the simulation and measurements of the rectifier design are presented. Fig. 3, simulation has been performed using the diode model available in the Agilent ADS component library. The values and positions of the capacitor and resistor were adjusted to optimize the matching performance and the conversion efficiency. Commonly, the input impedances of the RF is 50Ω. Thus, the optimization goal of the rectifier in ADS was set to be matched to the first input impedance. The simulated output DC voltage, V_{out}, efficiency η for the frequency 2.44 GHz are plotted in Fig. 4 and Fig. 5, for an input power range from 0 dBm to 20 dBm. The simulated maximum efficiency at 2.44 GHz is 89% when the rectifier receives RF power of 20 dBm, and 3.82 V output DC voltage is obtained. In this paper, a 2 KΩ load resistance and a 47 pF block capacitor are selected for maximum power efficiency at a given input power level.

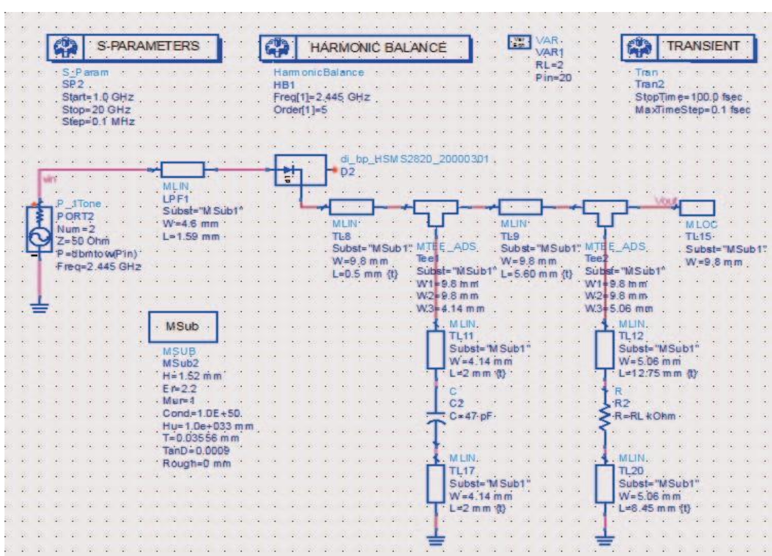


Fig. 3. Layout design of rectifier using ADS Agilent software.

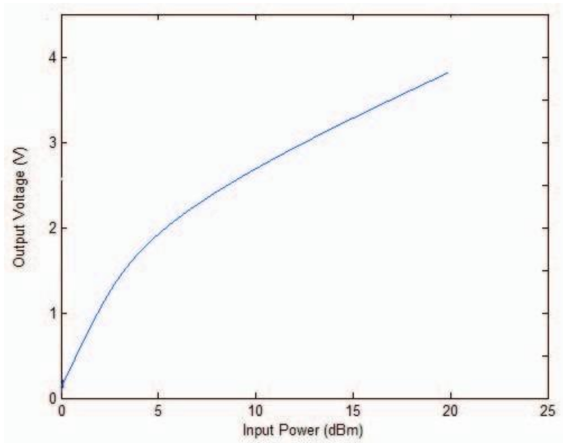


Fig. 4. Input power versus output voltage.

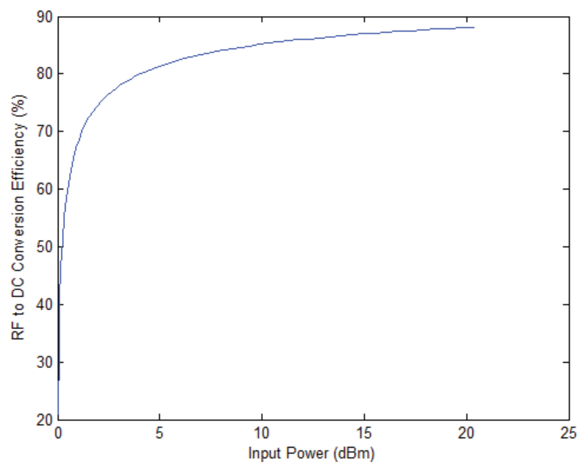
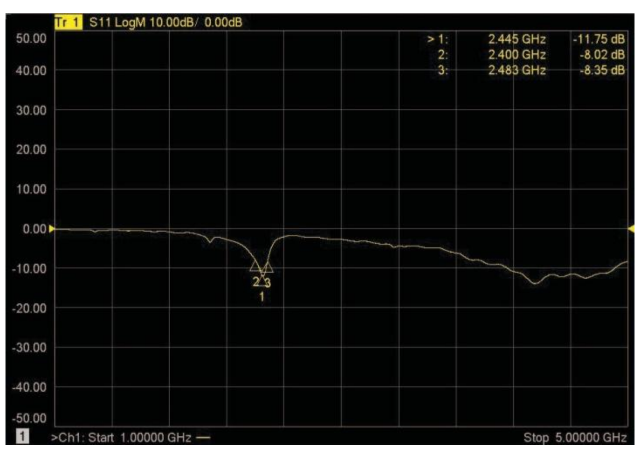
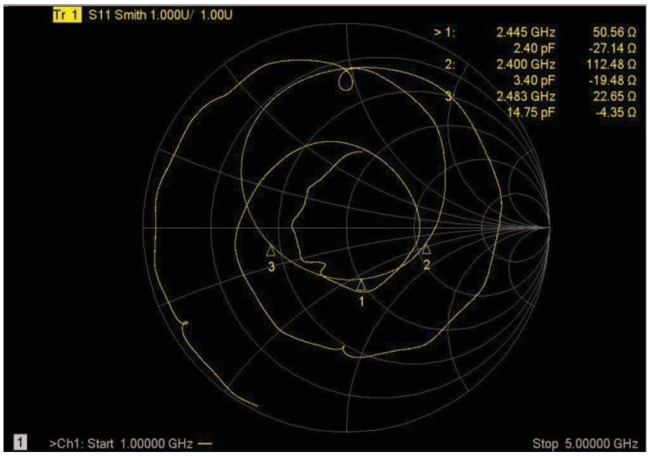


Fig. 5. Input power versus RF-DC efficiency.

Finally, in Fig. 8 and Fig. 9 shows the frequency response measurement results of the rectifier. It shows that the elements can operate with a resonant frequency at 2.44 GHz. The rectifier parameter S_{11} is -11.75 dB and the output line of this structure has impedance around 50.56-j27.14▲ at 2.44 GHz.



(a)



(b)

Fig. 6. (a) S11 and (b) Input impedance of rectifier

In Figure 7, the rectenna was tested using RF signal generator *Agilent N9310A* and mixed signal oscilloscope *LeCroy MSO 64MXs-B*. The RF signal generator given PRF = 20 dBm was used for transmitting power at 2.44 GHz to the input rectifier. Then, the oscilloscope was used for measure the DC output voltage which produced by rectifier.

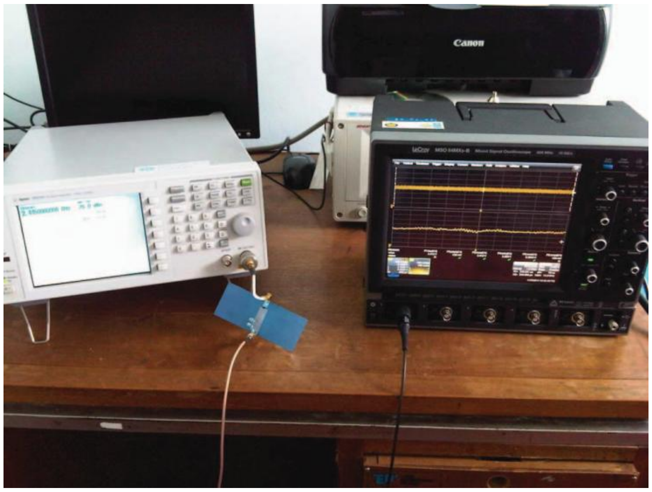


Fig. 7. Complete rectifier measurement setup.

The overall efficiency ( ) has been calculated according to

$$\eta = \frac{P_{DC}}{P_{RF}}\ x\ 100\% \qquad (1)$$

where PRF is input RF-power to the rectifier, and PDC is output DC power which was obtained by a rectifier. The measured output DC voltage and conversion efficiency of rectifier are shown in Table 1. The optimal value of efficiency is obtained around 2 K▲ load resistance. Then, the rectifier measurement exhibits an output dc voltage of 3.27V and maximum measured overall efficiency of 76% at frequency 2.44 GHz.

TABLE I RECTIFIER PERFORMANCE

Results	Pin [dBm]	VDC [Volt]	PDC [W]	Efficiency
Simulation	20	3.82	0.0881	89 %
Measurement	20	3.27	0.0752	76 %

CONCLUSION

In order to realize a RF energy harvesting at microwave frequencies, a rectifier element is presented in this paper. Experimental validation of the proposed topology is demonstrated through the fabrication and prototyping of a rectifier module for 2.44 GHz. The optimal input impedance for matching the rectifier has been investigated by use of the method of simulation. Based on the measurement of the rectifier, the manufactured rectifier circuit achieved 3.27 V of output voltage and 76 % conversion efficiency at the 20 dBm input power.

REFERENCES

[1] W.C. Brown, "The history of power transmission by radio waves," *IEEE Trans.Microw.Theory Tech.*,vol.32,no.9,pp.1230-1242, 1984.

[2] 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, 2002.

[3] J. McSpadden, L. Fan, and K. Chang, "Design and experiments of a high- conversion-efficiency 5.8-GHz rectenna," *IEEE Trans. Microw. Theory Tech.*,vol.46,no.12,pp.2053-2060, 1998.

[4] T.-W. Yoo and K. Chang, "Theoretical and experimental development of 10 and 35 GHz rectennas," *IEEE Trans. Microw. Theory Tech.*,vol.40,no.6,pp.1259-1266, 1992.

[5] C.-Y.Liou, M.-L. Lee, S.-S. Huang, and S.-G. Mao, "High-power and high-efficiency RF rectifiers using series and parallel power-dividing networks and their applications to wirelessly powered devices," *IEEE Trans. Microw. Theory Tech.*,vol.61,no.1,pp.616-624, 2013.

[6] L. Li, "Wireless power transmission: State-of-the-arts in technologies and potential applications (invited paper)," in 2011 Asia-Pacific Microwave Conference Proceedings (APMC), 2011, pp. 86-89.

[7] N. Zhu, K. Chang, M. Tuo, P. Jin, H. Xin, and R. Ziolkowski, "Design of a high-efficiency rectenna for 1.575 GHz wireless low power transmission," in *IEEE Radio Wireless Symp. (RWS)*, 2011, pp. 90-93.

[8] Y.-J. Ren and K. Chang. "5.8-GHz circularly polarized dual-diode rectenna and rectenna array for microwave power transmission," *IEEE Trans. Microw. Theory Tech.*,vol.54,no.4,pp.1495-1502, 2006.

[9] M. Pinuela, P. Mitcheson, and S. Lucyszyn, "Ambient RF energy harvesting in urban and semi-urban environments," *IEEE Trans. Microw. Theory Tech.*,vol.61,no.7,pp.2715-2726, 2013.