An AC-DC Rectifier Design at 2.45 GHz for Wireless Power Transfer

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***Abstract*— In this paper, a microwave doubler rectifier design at 2.45 GHz is presented. This rectifier consists of a short-circuited matching network, DC block interdigital capacitor and output radial filter. Two fast switching Schottky diodes of HSMS 286B are used for rectification process. The proposed rectifier is fabricated on a low-cost FR-4 substrate with relative permittivity of 4.4. From experimental results, the proposed rectifier can achieve an output greater than 7 V at an input power of 20 dBm. This rectifier has the capability of providing a high output voltage at low cost, which makes it suitable for wireless power transfer (WPT) applications.**

***Index Terms*— High output DC voltage Rectifier; Schottky diode; Wireless power transfer (WPT).**

I. INTRODUCTION

Recently, wireless power transmission (WPT) has taken a considerable interest as it can be used in many modern applications such as RF energy harvesting [1]-[2]. A WPT system consists of a transmitting antenna, a receiving antenna, and AC-DC rectifier. In order to improve the system performance, the output DC voltage of the rectifier is very important to be as high as possible. There are two types of rectifiers which are DC-DC rectifier and AC-DC rectifier. This paper focuses on the latter rectifier. A rectifier consists of an input matching circuit, Schottky diodes, and output DC filter to blocks the high order harmonic frequencies generated due to the nonlinear behaviour of the diodes. There have been many types of research about rectifier design that aimed to increase its output DC voltage. Some researchers use a DC Low pass filter to reject harmonics generated during rectification process of the diodes [3-6]. This technique is able to block high order harmonics. However, the output DC voltage is quite low. In [7], an efficient rectifier is designed using class F- rectifier. However, the total size of the rectifier is quite large which limit the rectifier applications. In [8], a rectifier design with stubs to block high order harmonics is designed. Although this rectifier can achieve high output DC voltage, the rectifier design is complex.

The rectifier rectification capability is determined by the diode loss, the impedance mismatch loss, and the substrate and conductor loss in the printed circuit board (PCB), where the diode loss dominates among all the losses. For a well-matched rectifier fabricated on a low-loss PCB, the rectifier efficiency is approximately equal to its diode efficiency. Therefore, the diode used in this design is HSMS286B which has the advantage of fast switching, low breakdown voltage, and small junction resistance. The equivalent circuit of HSMS286B diode is shown in figure 1. R_S is the series resistance, C_j is junction capacitance, and R_j is junction resistance. The lower is the series resistance, the higher is the forward bias current. The junction capacitance is minimized to achieve higher output voltage. The junction resistance, R_j depends on temperature and the saturation current of the diode.

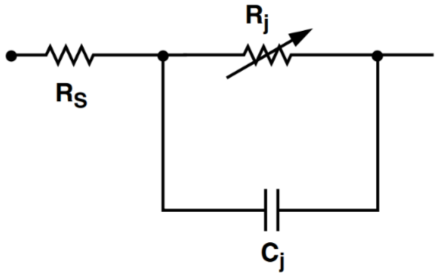
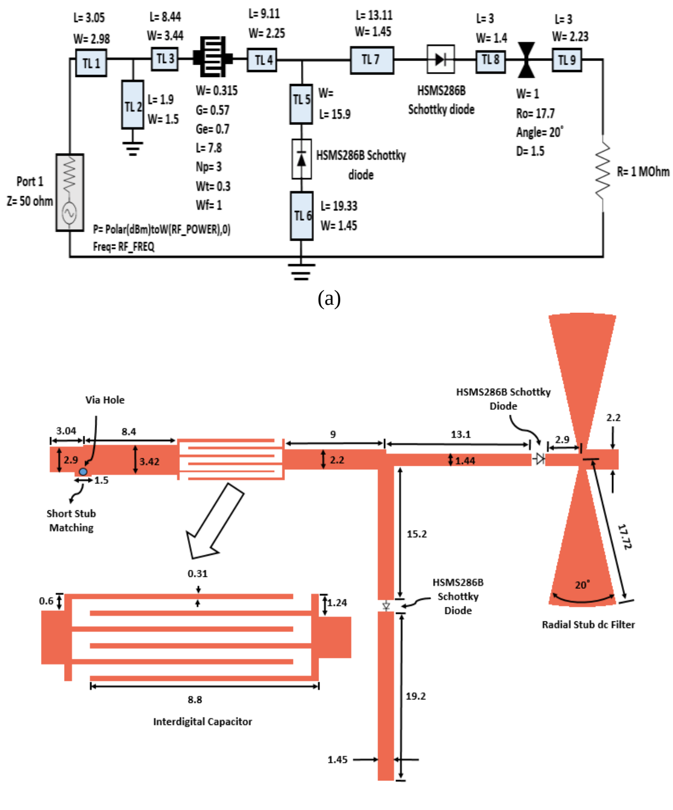


Figure 1: The equivalent circuit of HSMS286B dide

II. GEOMETRY DESIGN PROPOSED RECTIFIER



(a)

(b)

Figure 2: Geometry design of the proposed rectifier, (a) Schematic circuit of the voltage doubler rectifier with short- circuited stub (b) Layout of the voltage doubler rectifier with short- circuited stub

The geometry design of the proposed rectifier consists of input interdigital capacitor, which works as a DC block, short-circuited matching network, two Schottky rectifying diodes and output radial filter. The function of the radial filter is to block leakage from the load and eliminates ripples. The proposed doubler rectifier is shown in figure 2. Figure 2(a) shows the schematic circuit of the voltage doubler rectifier with a short-circuited stub. The layout of the voltage doubler rectifier is shown in figure 2(b).

III. RESULTS AND DISCUSSION

This section presents the results and analysis of the doubler rectifier in terms of S-parameters of the short-circuited matching network, simulated and measured return loss of the doubler rectifier and simulated and measured output DC voltage.

A. *Rectifier Matching Network*

The input impedance of the rectifier is small, and it is in terms of real and imaginary parts. Therefore, a matching network is required to match the input impedance to the same impedance of the coaxial cable. A short-circuited matching network is first simulated at 2.45 GHz. The matching network can match the input impedance of the rectifier to 50Ω impedance. The simulated S-parameters of the short-circuited matching network for the double diode rectifier is shown in figure 3. The return loss (S11) refers to how much power reflected to the source. The lower is the return loss (S11), the better is the matching between the source and load. S12 represents the isolation between the two ports. High isolation means low power being low. In this design, the return loss (S11) of the matching network is less than -21 dB and the (S12) isolation is greater than -7 dB.

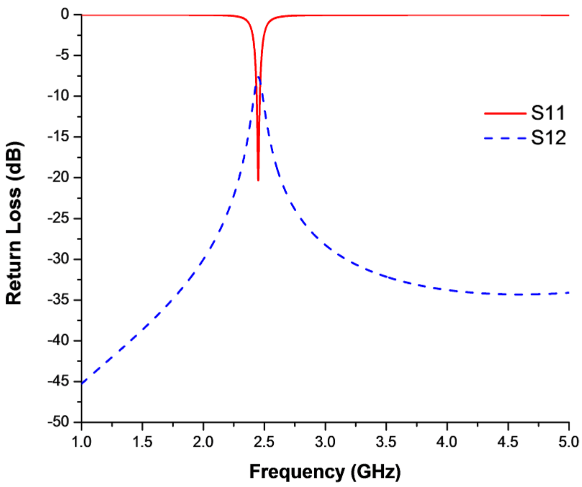


Figure 3: Simulated S-parameters of the short-circuited matching network for the double diode rectifier

B. *Return Loss of The Rectifier*

The simulated and measured return loss of the double diode rectifier with short-circuited stub matching network is shown in figure 4. The simulated return loss is less than -16 dB at 2.45 GHz. The measured return loss is less than -20 dB. The measured return loss is better than simulated return loss. However, the measured return loss is at 2.48 GHz. There is a slight shift in the frequency from 2.45 GHz to 2.48 GHz, which is due to the permittivity variation of the FR-4 substrate. The measurement result of the return loss has a better return loss compared to the simulated one, which due to fabrication process effect on the short-circuited matching network. Study of the fabrication effects and optimization of the matching network can be conducted. Thus, the short-circuited matching network would have a better performance.

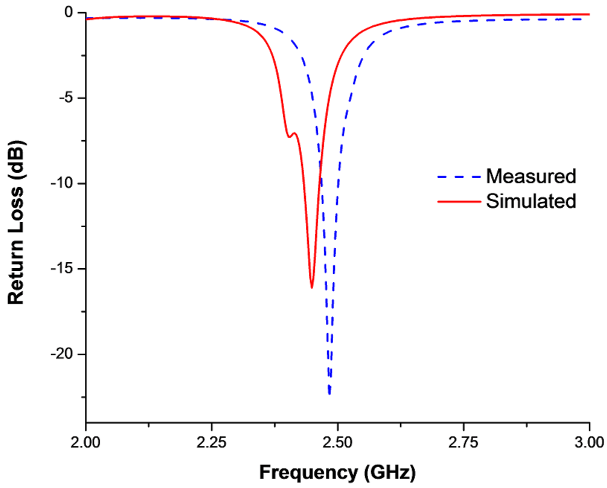


Figure 4: Simulated and measured return loss of the double rectifier with short stub matching circuit

C. *Output DC Voltage*

The experimental setup of the proposed rectifier was carried by connecting the input port of the proposed rectifier into an AC function generator. The output DC voltage was measured by using Voltmeter. The output DC connectors of the rectifier were connected to different load resistance in order to study the effect of the load resistance on the output DC voltage and the conversion efficiency. The experimental setup of the proposed rectifier is shown in figure 5.

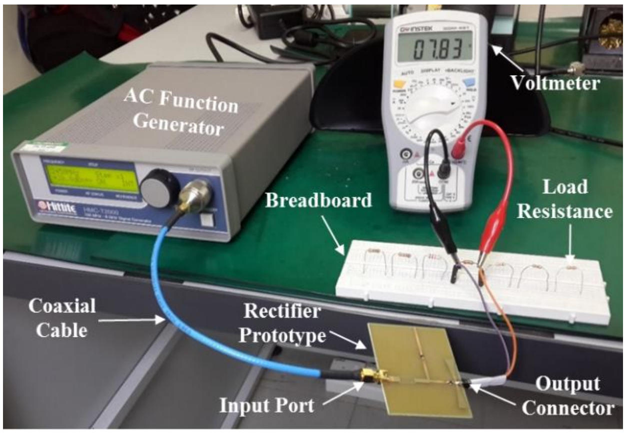


Figure 5: Experimental measurement of the doubler rectifier

The output DC voltage of the doubler rectifier with short stub matching is simulated and measured at different input power from -20 dBm to 20 dBm. Figure 6 shows the simulated and measured output DC voltage. The output DC voltage obtained from the doubler rectifier with short-circuited stub matching can achieve an output DC voltage of 7 V at an input power of 20 dBm. Short-circuited stub has the advantage of less power dissipated.

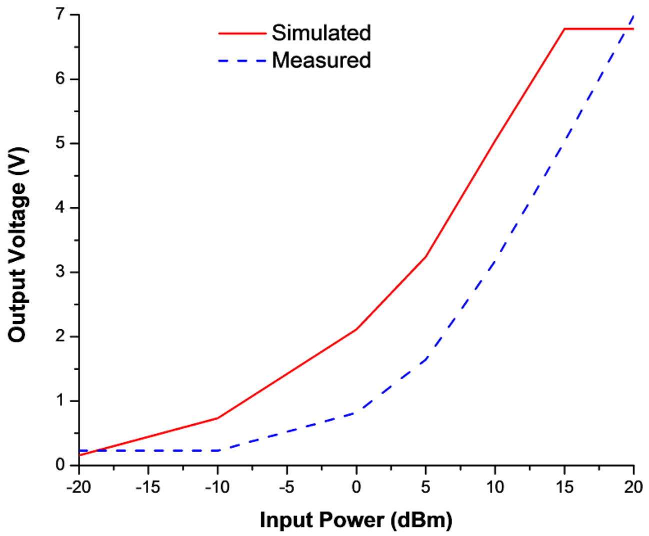


Figure 6: Simulated and measured output DC voltage of the doubler rectifier with short stub matching circuit

IV. CONCLUSION

This paper has presented an AC-DC rectifier design at 2.45 GHz. The proposed rectifier can achieve an output greater than 7 V at an input power of 20 dBm. The total cost of the proposed rectifier design is low due to the use of FR-4 substrate. These advantages make it a suitable candidate wireless power transfer (WPT) and RF Energy harvesting applications.

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