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Topology Comparison of Single-diode Rectifiers: Shunt Diode vs. Series Diode

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***Abstract*—Single-diode rectifiers have been widely adopted in nowadays wireless power transfer and wireless energy harvesting due to its compact design and low cost. However, few studies are focused on comparing the two typical topologies – shunt diode and single diode. In this paper, we compare and contrast these two topologies thoroughly in terms of the RF-to-dc conversion efficiency and the circuit complexity. ADS harmonic balance solver is employed to conduct the study.**

***Keywords*—Diode, rectifier topology, WEH, WPT.**

I. Introduction

As the internet of thing (IoT) and 5G communication mature, wireless power is demanded increasingly because the wireless sensors or systems under the IoT and 5G frameworks are expected to self-stain by harvesting the ambient RF energy or access RF power wirelessly [1]. In the wireless energy harvesting (WEH) and the wireless power transfer (WPT) systems, rectifiers with high RF-to-dc conversion efficiency is of utmost significance.

Due to the nonlinear effect of diodes, rectifiers is capable of transforming ac power into its dc form [2], [3]. A typical rectifier comprises four main components [4]: a band-pass filter, a diode, a load capacitor C_L and a load resistor R_L (see Fig.1). To design a rectifier, the complex nonlinear effect as well as the topology of the circuit must be taken into consideration. Researches related to rectifiers mainly focused on the high conversion efficiency [5], the wide input power range [6], the multi-band of operating frequencies [7], the antenna beam alignment [8]–[11] as well as the rectification model [12], [13]. Few studies consider the difference between shunt-diode and series-diode rectifiers, where both of them are frequently used. It seems that a revisit of the two primitive topologies is needed

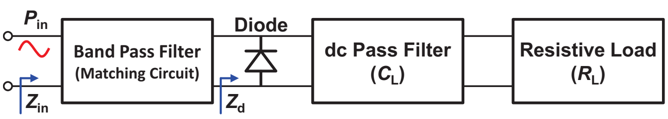

Fig. 1. The four main components of a typical rectifier circuit: a) band pass filter (matching circuit), b) diode, c) dc pass filter, d) resistive load, R_L.

In this paper, we compare and contrast thoroughly the shunt and series topology of the rectifier and try to demonstrate the advantage and disadvantage of them. Such a study can be useful to the design of rectifier according to different applications and scenarios. ADS harmonic balance (HB) solver is employed to perform the study.

II. Circuit Analysis of Rectifier Topology

We compare the shunt- and series-diode rectifier topologies using circuit analysis. Fig.2 shows the typical circuit for a shunt-diode rectifier, where a dc block is used in the front to prevent dc signal from affecting the RF source; an RF choke helps in forming the RF loop. The RF choke can be realized by an inductor or an quarter-wave transmission line [14]. When considering the RF and dc components individually, Fig. 2(b) and 2(c) show the simplified circuit for the RF and the dc loops, respectively. The diode is excited by the RF input, while generating dc output in different branches.

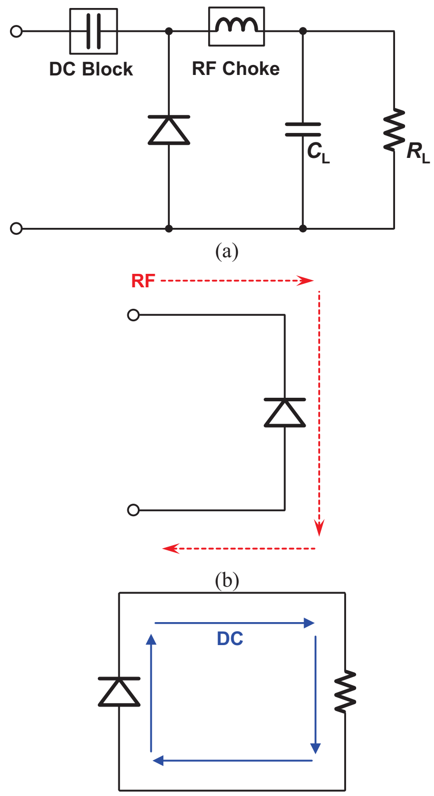

Fig. 2. (a) Shunt-diode rectifier circuit and its (b) RF and (c) dc loops.

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Fig.3 shows the typical circuit for a series-diode rectifier, where likewise a dc block prevents the dc signal from affecting the RF source; an RF choke helps in forming the RF loop. The RF choke can be realized by an inductor or a transmission line. When considering the RF and dc components individually, Fig. 3(b) and 3(c) show the simplified circuit for the RF and dc loops, respectively. The diode is excited by the RF input, while generating dc output in different branches.

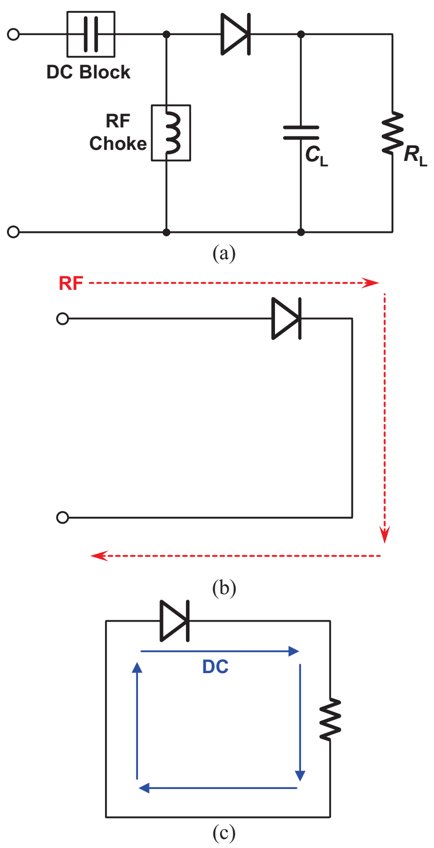

Fig. 3. (a) Series-diode rectifier circuit and its (b) RF and (c) dc loops.

From Figs. 2 and 3, it is easy to observe that both shunt-diode and series-diode have the same RF and dc loops. Therefore, assuming under the same input power, both topologies ideally have the same RF-to-dc conversion efficiency. Note that the matching circuit in Fig. 1 has been ignored in the above analysis. In actual realizations with matching circuits, the two topologies may differ in terms of efficiency and dimensions.

III. Validation by Simulation

To validate the above conclusion based on circuit analysis, we consider two cases where simulation results are obtained by ADS HB solver. The first case considers diode HSMS2860 working at 2.45 GHz. Fig. 4 shows the efficiency η and output dc voltage V_0 versus the input power P_{in}. It can be observed that the two topologies – shunt-diode and series-diode show the identical performance for the diode HSMS2860 at 2.45 GHz. The highest η = 86.62% occurs at P_{in} = 3.962 dBm, where V_0 = 3.282 V.

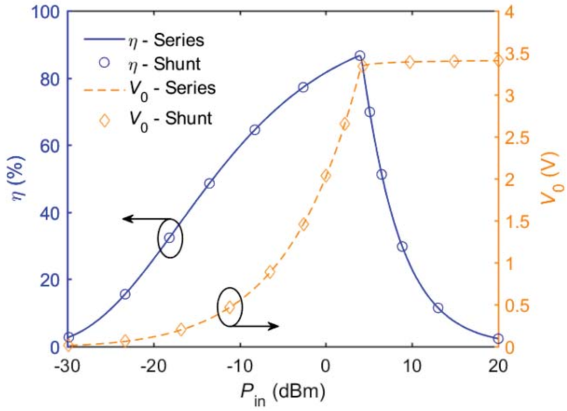

Fig. 4. Efficiency η and output dc voltage V_0 vs. the input power P_{in} of diode HSMS2860 at 2.45 GHz.

Case two consider the same diode operating at 915 MHz. Fig. 5 shows the efficiency η and output dc voltage V_0 versus the input power P_{in}. Likewise, the two topologies act identically with the highest η = 88.92% occurs at P_{in} = 3.822 dBm, where V_0 = 3.275 V.

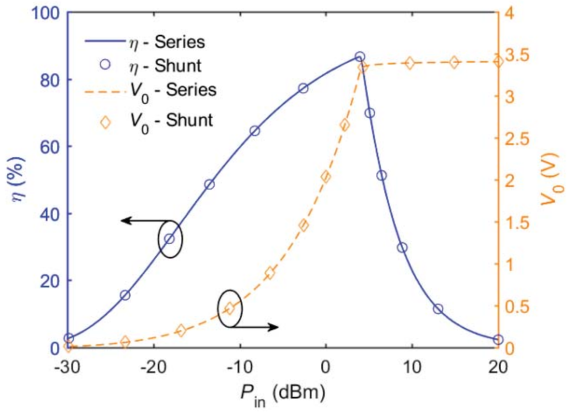

Fig. 5. Efficiency η and output dc voltage V_0 vs. the input power P_{in} of diode HSMS2860 at 915 MHz.

In both cases, R_L = 5,000 Ω, C_L = 22 uF. From the two cases, it can be concluded that 1) ideally the two topologies work identically; 2) their performances do not vary much as frequency. However, it is worth mentioning that in actual realizations, this may not be the case because of the difference caused by matching network, circuit implementation and layout.

IV. Conclusion

In this paper, we compare and contrast the two primitive topologies in single-diode rectifiers – shunt-diode and series-diode. Ideally, the two topologies have the same performance in terms of the RF-to-dc conversion efficiency. However, this may not be the case when considering the matching network, the circuit realization and the final layout.

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