ISSN 2348 – 9928
IJAICT Volume 4, Issue 11, March 2018 Doi:01.0401/ijaict.2018.03.18 Published on 05 (04) 2018

COUPLING ANALYSIS OF ELECTROMAGNETIC AND CIRCUIT SIMULATION FOR 2.45GHz VOLTAGE DOUBLER RECTENNA

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Abstract— ***The voltage doubler (VD) behavior of a 2.45-GHz VD-type Rectennas is proposed. An important feature of the developed VD-type Rectennas is the absence of the charge pump capacitor that is present in conventional VDs. Based on the course simulation and measurement consequences, the urbanized VD-type Rectennas demonstrate drastic improvement to the radio frequency-to-direct current (RF–dc) conversion efficiency in comparison with a half-wave rectifier (HWR)-type Rectennas at production loads exceeding 100 _. From the simulation, both the VD- and HWR-type Rectennas show VD behavior, even without the charge pump capacitor. This behavior was found to be attributable to the electric charge stored in the junction and package capacitances of the Schottky barrier diode in the Rectennas. Additionally, it was found that the improvement of the RF–dc conversion efficiency is caused by the voltage conservation in the series diode. This improvement is dependent on the microwave period and the electric discharge time constant. When the microwave period is comparable with the electric discharge time constant, the VD-type Rectennas conserves a dc voltage even when the input microwave voltage is negative. These phenomena were observed by analyzing the voltage and current waveforms of the Rectennas equivalent circuit obtained via circuit simulation.***

Keywords **— Capacitance, Circuit Simulation, Equivalent Circuits, Microwave Measurement, Rectennas**

I. INTRODUCTION

Voltage Doubler is an energy multiplier direction which has a voltage enlargement cause of two. The method consists of only two diodes, two capacitors and an oscillating AC input voltage. This easy diode-capacitor pump circuit gives a DC output voltage equal to the peak-to-peak value of the sinusoidal input. In other language, double the peak voltage value since the diodes and the capacitors work jointly to effectively double the voltage.

During the negative half cycle of the sinusoidal input waveform, diode D1 is forward biased and conducts charging up the pump capacitor, C1 to the peak value of the Because there is no return path for capacitor C1 to discharge into, it remains fully charged acting as a storage device in series with the voltage supply. At the identical occasion, diode D2 conducts via D1 charge up capacitor, C2.

During the positive half cycle, diode D1 is reverse biased blocking the discharging of C1while diode D2 is forward biased charging up capacitor C2. But since there is a voltage across capacitor C1 already equivalent to the crest input voltage, capacitor C2 charges to twice the peak voltage worth of the contribution signal.

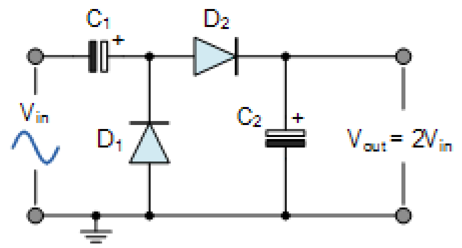

Fig 1 : Inputvoltage,(Vp).

In other words, V(positive peak) + V(negative peak), so on the negative half-cycle, D1charges C1 to Vp and on the positive half-cycle D2 adds the AC peak voltage to Vp onC1and transfers it all to C2. The voltage across capacitor, C2 discharges during the weight prepared for the subsequently half cycle.

II. DESCRIPTION ABOUT ANTENNA

2.1 Over view of Voltage Multiplier

Voltage multiplier circuit multiply the input voltage .Villard voltage multiplier is circuit is used. To improve the efficiency of the voltage multiplier, single stage, double stage and multi stage voltage can be used. The RF input indication is rectified in the positive half of the input cycle; follow by the unhelpful half of the input cycle. Then the voltage is stored in the capacitor. The voltage stored in the input capacitor during one half cycles is transferred to the output capacitor during the next half cycle of the input signal. Thus, the voltage in the output capacitor is roughly two times the peak voltage of the RF source minus the turn on voltage of the diode.

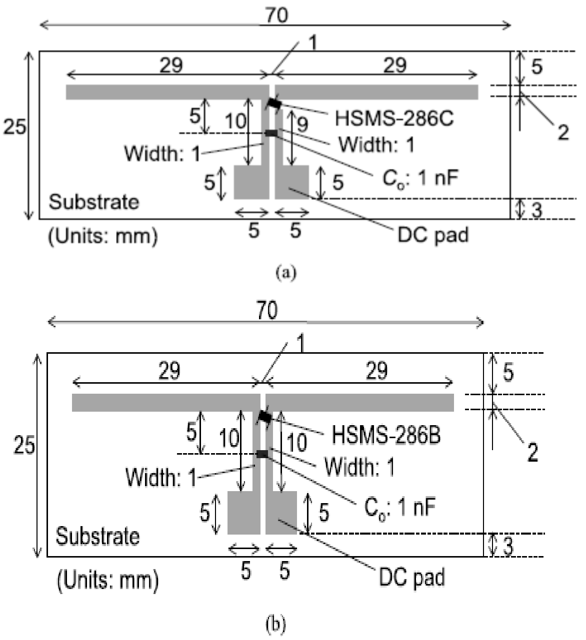

Fig 2 : Layouts of the developed rectennnas.
(a)VD-type rectenna (b)HWR-type rectenna.

2.2 Layouts

Two Schottky barrier diodes (SBDs) *D*1 and *D*2 are mounted in series and in shunt. A smoothing capacitor with a capacitance of *Co* is located between the transmission lines, which have characteristic impedances and lengths of *ZL* and *d*, respectively. The dc voltage is output at the load *RL*. The Rectennas substrate is a liquid crystal substrate (R-F705T, Panasonic) with a thickness of 50 μm. At 2 GHz, the relative permittivity and loss tangent of the substrate are 3 and 0.0008, respectively.

The antennas and the transmission lines are made of copper with a thickness of 12 μm on one side. The Rectennas has the dimensions of 70 mm × 25 mm and weighs less than 1 g. The half-wave dipole antenna branch is 29 mm in length. A 1-nF ceramic capacitor (GRM188B11H102KA01D, Murata) was used as the smoothing capacitor. Transmission lines of 5 mm in length were inserted in two sections: between the SBD and the smoothing capacitor and between the smoothing capacitor and the dc pad, which was connected to the load during measurement.

The equivalent circuit of the HWR-type rectenna can be expressed by replacing the SBD *D*2 with a short.The half-wave dipole antenna is expressed as a resonant circuit of *L A* and *CA.*

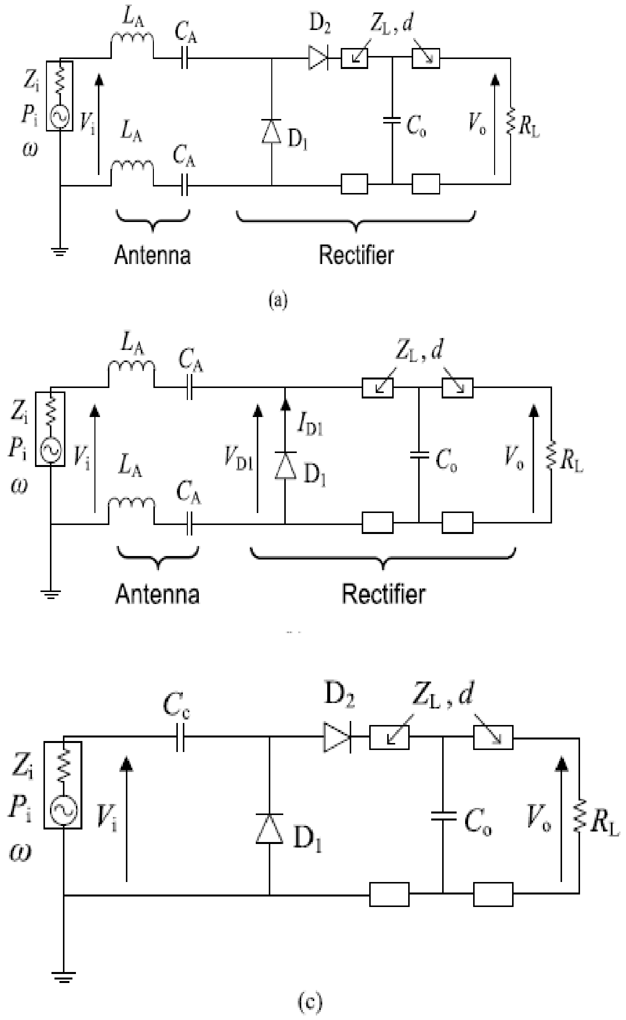

Fig 4 : Equivalent circuits of (a) VD-type rectenna [11], (b) HWR-type rectenna, and (c) conventional DCP VD.

III. RECTENNA EVALUATION METHODS

3.1 Circuit Simulation

Equivalent circuits of the VD-type rectenna [11], HWRtype rectenna, and conventional Dickson charge pump (DCP) VD are shown in Fig. 4(a)–(c), respectively. SBD models HSMS-286C and HSMS-286B were used in the VD and HWR-type rectennas,respectively. In a previous study measurement results demonstrated that the VD-type Rectennas behaves as a VD even in the absence of a charge pump capacitor. In this paper, the VD behavior in the developed VD-type Rectennas was analyzed via circuit simulations. Fig. 3(a) and (b) shows enlarged views of the layouts of the VD- and HWR-type rectennas,respectively.

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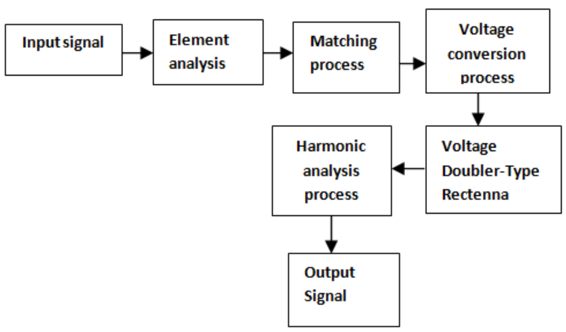
3.2 Rectanna Design

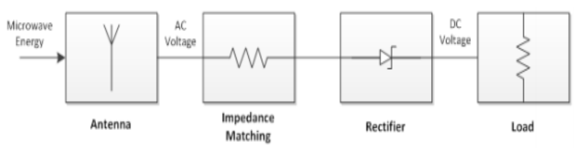
The Rectennas is on average denoted as rectifying antenna at microwave power transmission organization essentially combines the functions of an antenna and high efficient rectifier circuits. In its simplest form, Rectennas consists of a collection of receiving antenna elements that feeds a low pass filter circuit terminated in some rectifying diodes. Rectenna has many desirable characteristics, including followings: 1. In its pure form, the aperture collection efficiency is independent of the illumination density distribution across the aperture regardless of the size of the aperture. 2. An overall conversion efficiency from incident microwave power to DC power output could be achieved over 85%. 3. Rectenna can be calculated for any beloved frequency to harvest RF power which is incredibly cost effectual and simple to intend.

3.3 Block Diagram for measurement setup



3.4 Rectifier Antenna Theory

The microwave oblige is transformed interested in AC voltage by the antenna and then official during an impedance matching circuit to the rectifier, which, in turn, converts it into DC voltage for the load. The impedance matching circuit ensures maximum power transfer by matching the input impedance of the rectifier to that of the antenna. In some designs, however, the matching circuit is rendered useless by creating an antenna that matches perfectly the rectifier input impedance. In our research regarding wireless energy transmission, we studied its applicability on a family of antennas called micro strip patch antennas. The motive for this alternative are the minute scope of the antenna and its short manufacturing cost, which would make it an ideal alternative for wireless sensor networks.



A patch antenna is a flat, low-profile type of radio antenna which is easily mountable on any even surface. It is typically built out of two parallel sheets of conductive metal, one of which serves as an active element and the other, usually larger, one serves as a ground plane. A dielectric usually lies between the two sheets. The ensemble forms a resonant segment of micro strip transmission line which needs to have the length of approximately half of the wavelength of the radio waves it is tuned to. Over conventional microwave antennas, patch antennas have the advantage of being able to be constructed on the same materials and using the same techniques as those used in the printed circuit board industry

Equations

1) $Pi=(\lambda^2/4\Pi)GrWr$
2) $2)w=1\div\sqrt{LaCa}$

3.5 Matching Network

Matching network is mostly worn to competition the occurrence received from the antenna with the rectification route.LC matching circuit is used for low frequency application. It is used to decrease the value of the reflected power and to augment the efficiency of the rectifier, to create convinced the maximum power transfer. The worth of the matching network will designed using smith tool from ADS to match the route at frequency of 900MHz.

3.6 Harmonic Rejection process

During process of rectification, harmonics are generated. These harmonics are radiated back through antenna. Thus significant energy is lost. To suppress re-radiation and to maximize the power conversion, a harmonic rejection LPF is placed between antenna and rectifier setup. The cut-off frequency for LPF has been selected such that second harmonic signals are rejected. As shown simulated harmonic rejection low pass filter has insertion loss less than 0.6 dB and harmonic rejections greater than 10 dB with a compact die size of 1.6 mm2 .

IV. RESULTS

4.1 RF–DC Conversion Efficiency and Output Voltage

Figs. 6 and 7 show the simulation and measurement results of the RF–dc conversion efficiency η and output dc voltage *Vo*, respectively, of the VD- and HWR-type rectennas and the conventional DCP VD at various loads *RL* . With respect to the conventional DCP VD, only the simulation results were obtained. The optimal η of the VD-type rectenna was 56.9% at RL=469 in the simulation and 47.4% at RL=1.5k in the measurement. The optimal η of the HWR-type rectenna was 21.8% at RL=101 in the simulation and 23%% at

RL=70.3 in the measurement

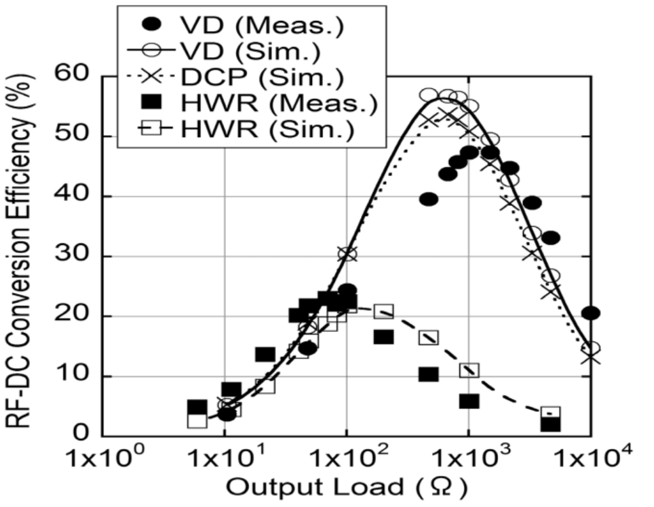


Fig. 6. Simulation (Sim,) and measurement (Meas.) results for the RF–dc conversion efficiency of the VD-type rectenna, the DCP VD, and the HWR-type rectenna.

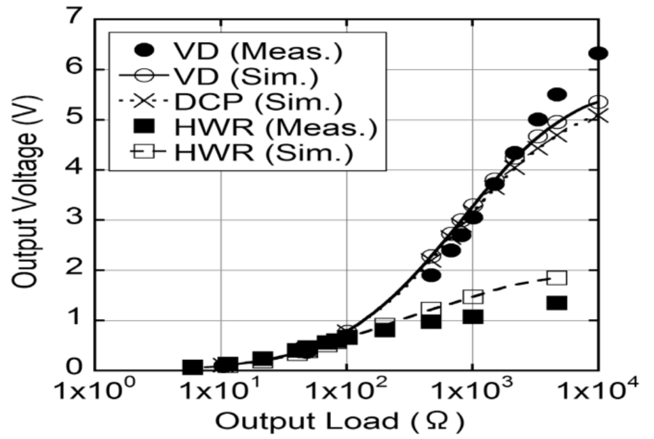


Fig. 7. Simulation (Sim.) and measurement (Meas.) results for the output dc voltage of the VD-type rectenna, the DCP

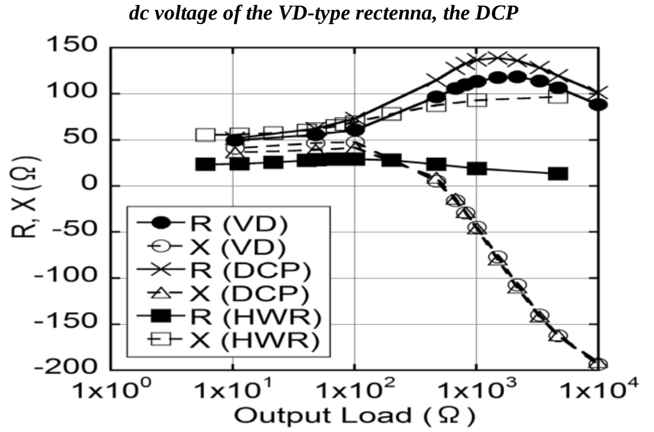


Fig. 8. Simulation results for the input impedance of the VD-type rectenna, the DCP VD, and the HWR-type rectenna.

4.2 Wave forms

Figs. 8 and 9 show the simulation results of the input impedance *R* + *j X* and reflection coefficient |*S*11| at the fundamental frequency 2.45 GHz, respectively, of the VD- and HWR-type rectennas and the conventional DCP VD at various loads *RL* . From these results, the input impedance of the VD-type rectenna shows a similar trend as the conventional DCP VD. Increasing the output load, the resistance had the peak around *RL* = 1.5 k_, and the reactance went from positive to negative.

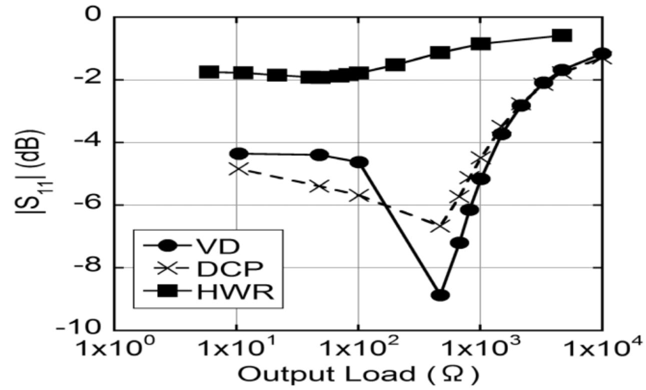


Fig. 9. Simulation results for the reflection coefficient of the VD-type rectenna, the DCP VD, and the HWR-type rectenna.

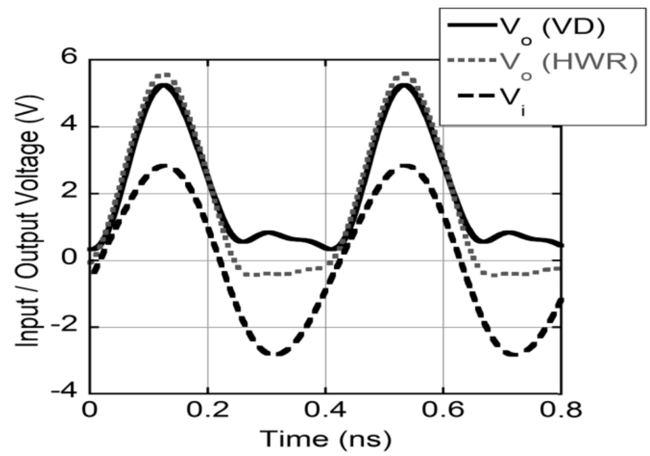


Fig. 10. Waveforms of the input voltage Vi and the output voltages Vo of the VD-type rectenna and the HWR-type rectenna at an output load RL of 1 k.

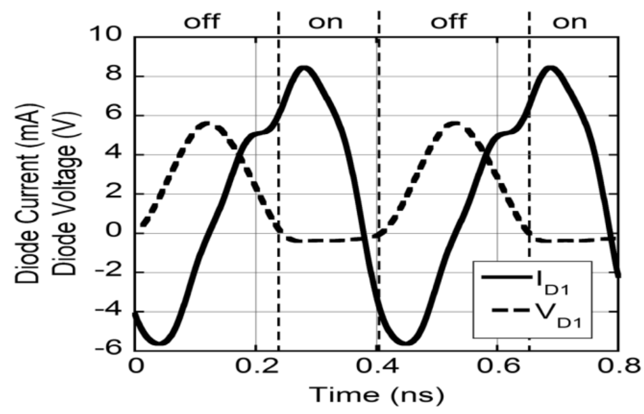


Fig. 11. Waveforms of the diode voltage VD1 and the diode current ID1 of the shunt diode D1 in the HWR-type rectenna at an output load RL of 1 k.

The labels "ON" and "OFF" in the figure indicate when the diode was forward and reverse biased, respectively.

V. CONCLUSION

The VD behavior of the VD-type Rectennas was analyzed through simulation and measurement and comparison with the behavior of the HWR-type Rectennas. Both the developed VD- and HWR-type Rectennas showed VD characteristics, even without the charge pump capacitor, because of the electric charge in the SBD. Moreover, the VD-type Rectennas showed better RF–dc conversion efficiency than the HWR-type Rectennas for output loads exceeding 100 _ because of the voltage conservation in the series diode as well as impedance matching between the input impedance of rectifying circuit and the dipole antenna. The VD behavior of the developed VD-type Rectennas is dependent on the microwave period and the electrical discharge time constant calculated from the output load and the combined junction and package capacitances of the diode. When the microwave period is comparable with the electrical discharge time constant, the VD-type Rectennas conserves a dc voltage even when the input microwave voltage is negative. When the former is much longer than the latter, the Rectennas behaves similar to the HWR-type Rectennas. As shown in the simulation and measurement results, the developed VD-type Rectennas strongly depended on the output load. For improving the efficiency over a wide output load range, insertion of a dc–dc converter will be effective. As a future work, a more precise diode model and a coupling analysis between the electromagnetic simulation and circuit simulation will be necessary to bridge the difference between simulation and measurement results, because the developed Rectennas can reradiate the fundamental and harmonics through the dipole antenna.

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