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Design and Simulation of a 900 MHz Rectifier for Rectenna Application

K.Kaviarasu and V.Ganesh

Abstract— **Wireless Power Transmission (WPT) plays an important role of delivering power from a source to end device without wires or contacts. This is achieved by using a Rectenna which is a combination of an antenna and the rectifier. The antenna is used to receive the RF signal and rectifier is used for converting the Received RF/Microwave signal into DC signal. The impedance of the antenna and the rectifier is matched by using the impedance matching circuit. In this work, the design and simulation of Rectifier and matching circuit are carried out at 900 MHz GSM signal using Advanced Design System Software. The lumped constants of the rectifier are optimized using ADS software. The Agilent HSMS 2862 Schottky diode is used for rectification. From the simulation results, DC output power, voltage, current and efficiency are plotted with respect to the input power. A matching circuit is designed using an ideal transmission line model for matching the impedances of the source and the rectifier. This Rectifier is used for Rectenna applications.**

Index Terms— **RF waves, Rectifier, DC power.**

I. INTRODUCTION

IN the fast moving digital universe, WPT plays an important role of delivering power from a source to end device without wires or contacts. The recent growth in wireless data applications and the surge in the use of portable electronic devices have dramatically increased the market potential for wireless energy transfer technologies. A 35 GHz rectenna has been developed for millimeter wave energy harvesting using 4×4 microstrip patch antenna array and a GaAs Schottky [1].For wireless sensor networks, a 2.45 GHz rectenna has been implemented using a modified Vivaldi antenna and voltage multiplier [2]. A novel planar rectenna has been presented for wireless power transmission applications using a slot antenna and a microstrip rectifying circuit. The RF to DC conversion efficiency of 21% has been achieved [3].A wearable rectenna at ultra-high frequency band has been developed using textile material. A compact patch antenna and a full wave bridge rectifier have been used to achieve a maximum efficiency of 50% over the frequency [4]. An energy harvester has been designed using a one – sided directional flexible antenna with an impedance matching circuit, a resonant circuit and a booster circuit. Power efficiency of 58.7% has been achieved for 10 M Ω [5]. Ambient RF energy harvesting has been implemented using a dual band rectenna at 1800 MHz and UMTS 2100 MHz bands. Broad band quarter wavelength quasi-yagi antenna array has been designed to achieve the gain of 10.9 and 13.3 dBi at 1.85 and 2.15 GHz frequency respectively. A dual band rectifier also has been designed to enhance the RF to DC power conversion efficiency at ambient RF power level [6]. A highly efficient compact rectenna has been designed for wireless energy harvesting application at 900 MHz signal. This consists of a compact and light weight folded dipole antenna and a rectifier circuit using HSMS 2862 Schottky diode. Efficiency of 73 % has been achieved [7]. The different types of rectennas are presented for Wireless Power Transmission and Energy Harvesting applications [8-14].In this proposed work a rectifier is designed for Rectenna applications at 900 MHz signal. This paper is sectioned as follows. Section II describes the design of rectifier and matching circuit. Section III discusses the simulated results of the rectifier and conclusions are presented in section IV.

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II. RECTIFIER AND MATCHING CIRCUIT

The Rectenna termed as rectifying antenna which is the combination of the antenna and a non-linear rectifying element. The two elements are integrated into a single circuit, such a system is capable to receive RF power and to converts the RF power into dc power. Schottky diode is used for rectification.The three main components of rectenna are antenna, matching circuit and rectifier. Fig. 1 shows the block diagram of rectenna.

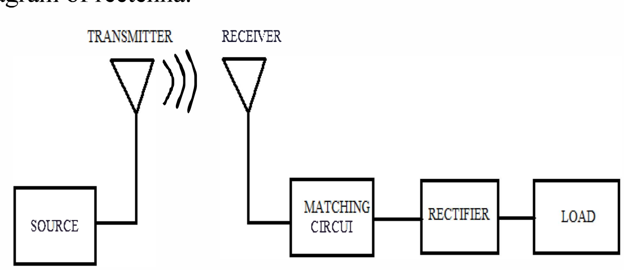

Fig. 1. Block Diagram of a Rectenna

The antenna is used to collect RF power and transfer the energy to the Matching Circuit. The rectifier is perhaps the most important component within the rectenna, converting incoming RF power into DC power. It usually consists of a diode with a high switching speed. Matching circuit is used to match the impedance of the antenna and the rectifier. Choosing a proper diode is one of the important factor since the diode is the main source of loss and its performance determines the overall performance of the circuit.Avago HSMS-8202 and HSMS-286x Series are specified for low turn on threshold voltage or forward voltage drop around 100 mV. The diodes get turned on during each cycle for less than 100mV.

The objective of this work is to design a rectifier circuit with high RF to DC conversion efficiency. The power conversion efficiency of a rectifier is mainly determined by three parameters of a diode. Series Resistance (R_s) which limits the efficiency, zero bias junction capacitor (C_{jo}) which affects low harmonic currents oscillates through diode, breakdown voltage (V_{br}) which limits the power handling capability of the rectifier circuit. It is necessary to select a diode having high speed switching characteristics in order to follow a high frequency input signal and have a low cut off voltage to operate at a low RF input power. The selection of the microwave substrate is done in such a way that the power losses to be minimized. Usually very thin substrates exhibit more losses than thicker ones when the dielectric constant remains the same. Optimization at layout level is done for achieving the best possible result. Fig. 2 shows the designed rectifier circuit at 900 MHz. A self-generated source of 0 to 9 mW Power with 50 ohm impedance is used instead of the antenna. The second section is filter to remove the harmonics and the last section is Rectifier with load of 1000 ohm. HSMS 2862 diode is used for rectification.

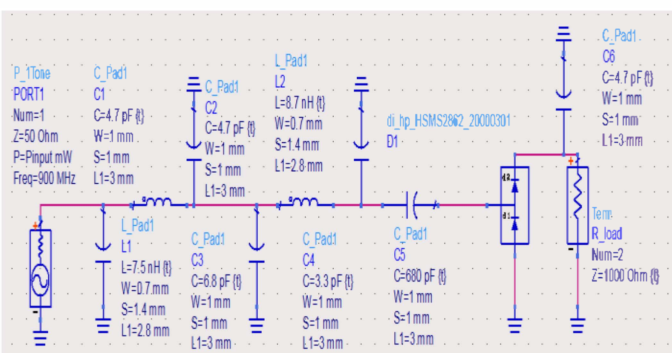

Fig. 2. Rectifier Circuit of GSM-900 signal

A proper matching circuit is needed to transfer maximum signal from source to diode. This matching circuit is designed using Lumped Components. Ideal Transmission Lines tool is used for impedance matching. Fig. 3 shows the impedance matching circuit which matches the source and load impedance.

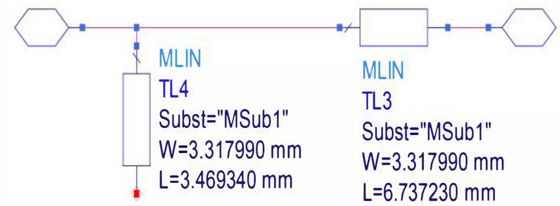

Fig. 3. Matching circuit

III. RESULTS AND DISCUSSIONS

The simulation of rectifier for the GSM 900MHz signal is performed using Harmonic balance analyzer in ADS software. The rectifier Output Voltage and Current are plotted with respect to the input RF Power. The Output Power is plotted with respect to input Power. The calculated conversion efficiency of the rectifier is also plotted with respect to the input power. The GSM Rectifier is designed for the frequency of 900MHz. All the results of the rectifier are obtained at a load resistance of 1000Ω. Fig. 4 and Fig. 5 show the simulated results of the obtained Output Voltage and Output Current with respect to the input RF Power of 0 to 9 mW. The maximum DC output voltage and current of 2.3 V and 2.3 mA are obtained at 9 mW RF input power. From the graphs, the DC output voltage and current are also increased when the input RF power is increased.

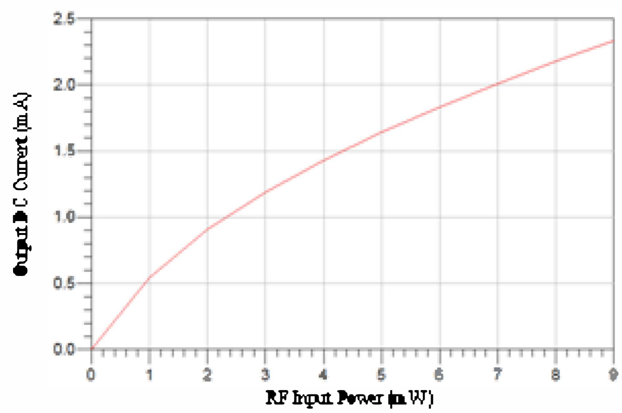

Fig. 4. Output current of GSM-900 MHz rectifier Circuit

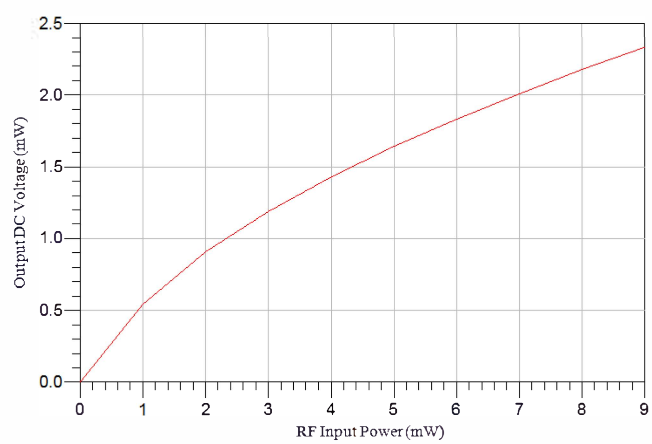

Fig. 5. Output voltage of GSM-900 MHz rectifier Circuit

Shabnam Ladan et.al. [7] have been obtained a maximum DC output voltage of 2.6 V at 9 mW input power. Fig.6 shows the graph of input power versus output power. From the graphs, the maximum DC output power of 5.4 mW is obtained at the RF input power of 9mW.Shabnam Ladan et.al. [7] have been obtained a maximum DC power of 6.5 mW at 9 mW input power.

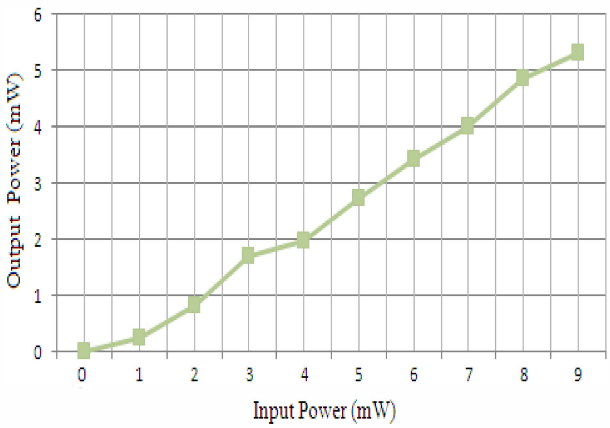

Fig. 6. Output Power versus Input Power of GSM Rectifier

The RF to DC conversion efficiency of the rectifier is defined as

$$\eta = P_{dc} / P_{in} \tag{1}$$

$$P_{dc} = V_d^{\,2} / R_L \tag{1}$$

Where P_{in} is the Incident RF Power and V_D is the DC voltage on the load and R_L is the load Resistance. Fig. 7 shows the plot of conversion efficiency versus input power. The maximum efficiency of 60 % is obtained at 9 mW input power. Shabnam Ladan et.al. [7] have been achieved a maximum conversion efficiency of 73 % at 9 mW input power.

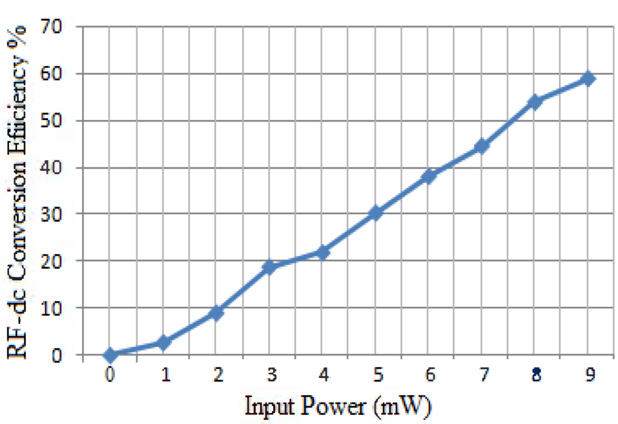

Fig. 7. RF-DC Conversion Efficiency versus Input Power

IV. Conclusion

WPT holds a promise able future for generating a small amount of electrical power to drive partial circuits in wirelessly communicating electronics. In this work a rectifier has been designed and simulated for 900 MHz GSM Band signal. The design of the rectifier and matching circuits has been optimized using Advanced Design System (ADS) software. From the simulation results the maximum efficiencies of 60 % has been obtained respectively at 9 mW input power. Further the DC output voltage, current, power and efficiency have been plotted with respect to the input power of 0 to 9 mW. Source and rectifier impedances have been matched using matching circuits. This rectifier may suitable for Rectenna applications.

References

[1] Ali Mavaddat, Seyyed Hossein Mohseni Armaki, Ali Reza Erfanian, "Millimeter Wave Energy Harvesting Using 4×4 Microstrip Patch Antenna Array", *IEEE Antennas and wireless propagation letters*, Vol. No. 10, 2015, pp. 1536-1225.

[2] FabizioCongedo, "A 2.45-GHz Vilvadi Rectenna for the Remote Activation of an End Device Radio Node", *IEEE Sensor Journal*, Vol. No. 13, 2013, pp. 1530-4371.

[3] GiuseppinaMonti, LucianoTarricone and Michele Spartano , "X-Band Planar Rectenna," *IEEE Antennas and wireless propagation letters ,Vol 10*, 4,2011, pp.1116-1119.

[4] GiuseppinaMonti, LucianoTarricone and Michele Spartano "UWB Wearable Rectanna on Textile Materials," *IEEE Antennas and wireless propagation letters, Vol 10, 4*, 2011, pp.1116-1119.

[5] HaruichiKanaya, "Energy Harvesting circuit on a One-Sided Directional Flexible Antenna", *IEEE Microwave and wireless Component letters, Vol 23*, No.3. 2013,pp.1351-1309

[6] Hucheng Sun, Yong-xinGuo, Miao He, and ZhengZhong , "A Dual-Band Rectenna Using Broadband YagiAntenna Array for Ambient RF Power Harvesting," IEEE *Antennas and Wireless Propagation Letters, Vol. 12*, 2013, 2013,pp.918-921.

[7] Hucheng Sun, Yong-xinGuo, Miao He, and ZhengZhong , "Design of a High-Efficiency 2.45-GHz Rectenna for Low-Input-Power Energy Harvesting," IEEE Antennas And Wireless Propagation Letters, Vol. 11, 2012,*2013,* pp.929-952.

[8] James O. McSpadden, Lu Fan and Kai Chang. "Design and Experiments of a High-Conversion-Efficiency 5.8-GHz Rectenna," *IEEE Transactions on Microwave Theory and Techniques, VOL. 46, NO. 12, 1998,* pp.2053-2060.

[9] JiapinGuo, Member, Hongxian Zhang and Xinen Zhu," Theoretical Analysis of RF-DC Conversion Efficiency for Class-F Rectifiers,*" IEEE Transactions on Microwave Theory and Techniques, Vol. 62, No. 4*, 2014.

[10] Naoki Shinohara, TomohikoMitani and Yong Huang "A Constant Efficiency of Rectifying Circuit in an Extremely Wide Load Range" *IEEE Transactions On Microwave Theory And Techniques, Vol. 62*, No.4, 2014.

[11] ShabnamLadan, Nasser Ghassemi, "Highly Efficient Compact Rectenna for Wireless Energy Harvesting Application," *IEEE Microwave Magazine, Vol 10, No 4*, 2013, pp.1527-3342.

[12] Simon Hemour, Yanpin Zhao "Towards Low-Power High efficiency RF & Microwave energy harvesting," *IEEE Transactions on Microwave Theory And Techniques, Vol. 62,* No. 4,2014.

[13] Zied Harouni, Laurent Cirio, Lotfi Osman, "A Dual Circularly Polarized 2.45-GHz Rectenna for Wireless Power Transmission ," *IEEE Antennas and wireless propagation letters*, Vol. 10, No. 4,2011,pp-306-309.

[14] Mohammod Ali et al.,"A Dual Circularly Polarized 2.45-GHz Rectenna for Wireless Power Transmission ," *IEEE Antennas and wireless propagation letters*, Vol. 10, No. 4,2005,pp-205-208.