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Effect of Load Resistance and Power variation on RF Energy Harvester Circuit

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ABSTRACT

In this research paper author proposed 4 different circuit networks for RF energy harvesting. Three circuits were compared based on variation in the load resistance, and all these variable load circuits were compared with the variation of power and comparison of the same is presented. Three circuits with single, double and triple stages of the rectifier is presented and compared. It has found that at the value of 85KΩ of the load resistance, all three circuits showed good efficiency and high output voltage. And when power was varied then at -6dBm of power better efficiency and output voltage has been achieved.
Keywords : Energy harvester, stage rectifier RF to DCpower conversion.

I. INTRODUCTION

There is an active research area investigating a quantity of alternative ways to extract energy from the environment and convert it into electrical energy for energizing lowest power electronic circuits directly or store it for afterward exploit. One such energy is from radio frequency. RF Energy harvest in form ambient source of available energy in the form of GSM frequency can be changed into electrical signal with the help of the antenna and then it can be rectified into DC signal with the help of the rectifier circuit. This work is being carried out thru many researchers for the following reasons:

i. The energy is independently accessible in space.
ii. Complementing the lowest power sources exploited for energizing the lowest power electronic devices, as an usage to green technology.

RF energy harvesting (EH) from ambient sender have vast potential to impaction the moveable electronic and cellular phones a devices. This thought requirements an efficient antenna along with a circuit capable of change RF signals into DC voltage, so as to replace the need for batteries.

The Authors Y. S. Song et. al. in 2010 [1] designed a CMOS based Villard voltage multiplier that captured RF energy by placing it adjacent to an RF source with power ranging from -10dBm to 5 dBm. In 2012 M. S. Bhaghini et. al. [2] designed an RF EH system with a 50Ω gap coupled microstrip antenna at 5.8GHz and 2.67GHz achieve a increase of 8.6 dB and 9dB, a bandwidth of 100MHz and 690MHz exploited a CMOS 5-stage rectifier circuit achieve an o/p voltage of 1.04V into 1MΩ load at 2.67 GHz. The writer in G. Kumar et. al. in 2011 [3] designed a square microstrip antenna with 50impedance and exploited a 6-stage Schottky diode voltage doublerto form an RF EH system at 900MHz band. This work reach an o/p voltage of 0.87V and 2.78V at a distance of 50m and 10m step by step for a accept power step of 4dBmand 5dBm from a 900MHz cell tower. In 2009 [4] the writer designed a broadband log periodic antenna at 674{680MHz and exploited a 4-stageRF DC conversion circuit. They attain an o/p voltage of 1.5V at25μA that was exploited to power a thermometer at 4.1km.

distance from a transmitter which broadcasts 960kW of power. In [2010] the market, power harvester modules are generating at 915MHz from a 4W intentional RF energy source [5]. The authors L. C. Ong in 2009 [6] designed patch antenna and antenna array at 5.8 GHz for WLAN application achieved DC voltage of 72.5mV and 428.3mV using Schottky diode and LTC5535(RF power detector) for RF-DC conversion from 16dBm power sourceat a distance of 15 cm. Microstrip patch antenna has been structural to operate at 2.4 GHz ISM band to capture straight RF vigor and charged a super capacitor to power a sensor node to 3.6V in 27s by G. Park et. al. in 2009 [7].

In this paper three harvester circuits with dissimilar phase of rectifier is presented, all the three circuits were simulated with the variable load resistance and compare of the same is presented here in this article.

The major benefit of these new proposed circuits is that they have rectifire circuits which is having only a single (double diode) schottky diode instead of two separate schottky diode (HSMS2852).

Then circuit has matching network which provide a lossless connection between transducer and rectifier. Rectifier network circuits have also a main role in energy harvesting. In which matching network circuits are used for matching the impedances of antenna with the impedance of rectifier. Matching is accomplished when greatest power is achieved proper matching is done between impedances of antenna and rectifier.

Some parameters have to be understood before making an RF energy rectifier circuit. They are,

1. Distance amid receiver and transmitter antenna.
2. Different kind of antennas and its working frequency.
3. Different kind of matching networks.
4. How many no. of multiplier phase can be exploited in rectifier circuit

Working of RF energy harvester circuit can be analyzed by many ways, like output voltage and efficiency of RF to DC conversion. Basically surrounding environment and temperature conditions affect these factors and signal power of frequency band specially underlet this conditions. Its power changes with time, since clogs or eclipse due to high obstacles. Distance amid receiver and transmitter is another parameter which highly affect the received power (Pr). Which can be represented by Friis transmission Equation?

$$P_r = \frac{[P_t G_t G_r]^2}{[4 P_i R]^2}$$

Here Pr is for received power, Pt is for transmitted power, Gr is for receiver antenna gain, Gt is for transmitter antenna gain and R is for distance between receiver and transmitter. It can be easily understood by this equation that received power is inverse proportional to square of distance or remoteness amid receiver and transmitter.

II. METHODS AND MATERIAL

Circuit Design

In this paper author define compare of three dissimilar RF vigor harvesting circuits. Power source is followed with the matching n/w that diminishes the losses and provides a perfect matching atmosphere for the antenna and the rectifier section. That rectifier has sole phase voltage doublers and rectifies the received signal and provides a constant C output to the load circuit. Following is the first harvester circuit (Single Stage),

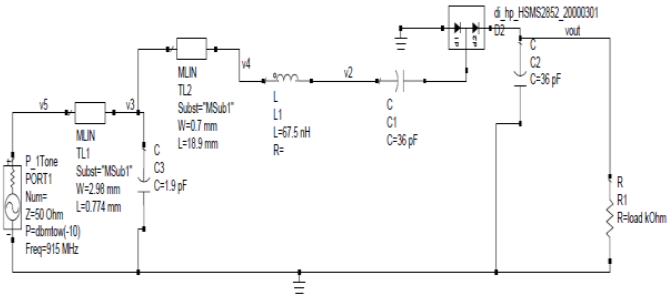

Figure 1. Single stage harvester circuit.

Second harvesting circuit comprises of 2 stages rectifier circuit that is the modified circuit of harvester presented in fig.1. that 2 stage harvester circuit is seem in figure below in fig.2,

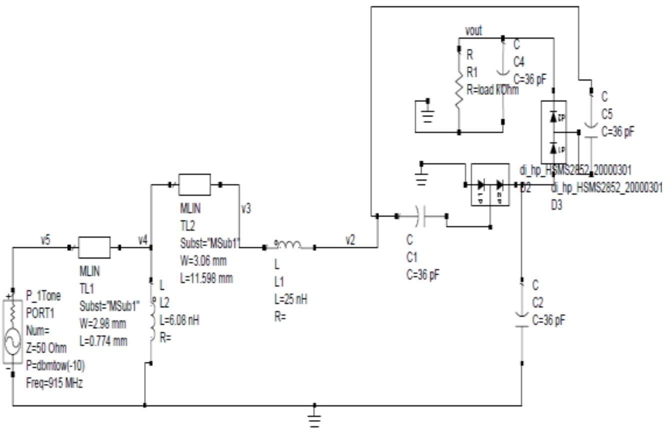

Figure 2. Two stage rectifier circuit

Third circuit that was proposed by the author in this paper is 3 stage rectifier circuits, this circuit provide better efficiency and good output voltage as well.

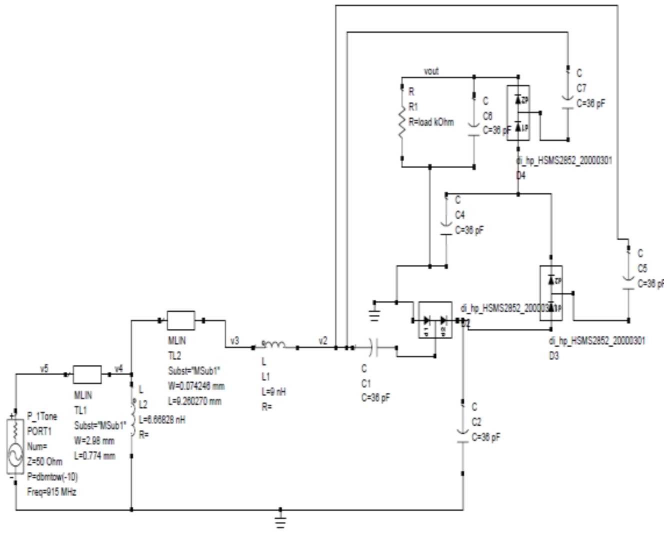

Figure 3. Three stage rectifier circuit.

For L matching network consisting of series inductor and shunt capacitor, the element value may be determined by using design equations [1]:

$$B_L = \pm\sqrt{R_L(Z_o - R_L)} - X_L \tag{1}$$

$$B_C = \pm\frac{\sqrt{(Z_o - R_L)/R_L}}{Z_o} \tag{2}$$

For all these three different circuits presented above in fig.1, 2 and 3, three dissimilar matching n/w were structural and values of capacitor and inductor were calculated by above formulas.

III. RESULTS AND DISCUSSION

Simulated results of the design in figure 1, 2 and 3 were analyzed and compared, the comparison graphs of all the three circuits are shown below. Efficiency of all the three harvesting circuits and o/p voltage of all the three harvesting circuits were compared by varying the values of load resistance. In the subsequent figure 4, it is clearly visible that at the value of load resistance of 85KΩ the efficiency is highest in all the three harvesting circuits whether they are of any kind of stage rectifier. In first stage circuit efficiency was found 65% and second and third stage rectifier circuits it has been found above 90%.

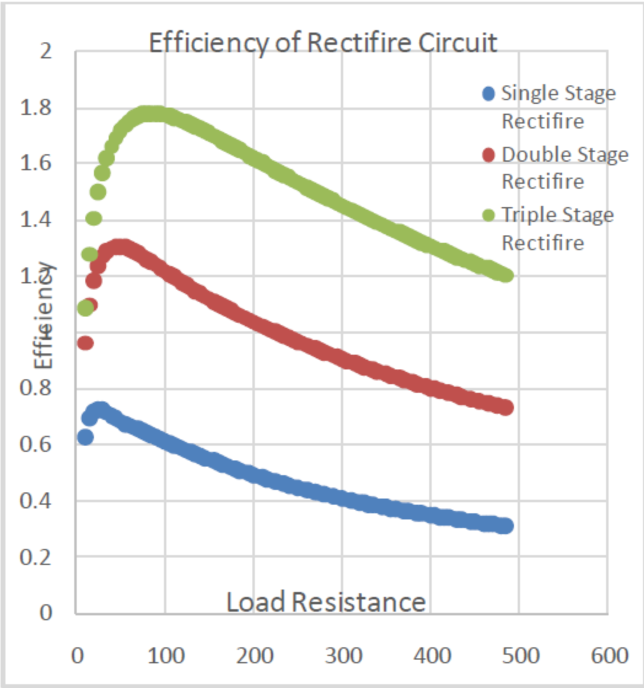

Figure 4. Efficiency of all the three circuits with variable load

The output of all the three different harvester circuits is shown below in figure no. 5.

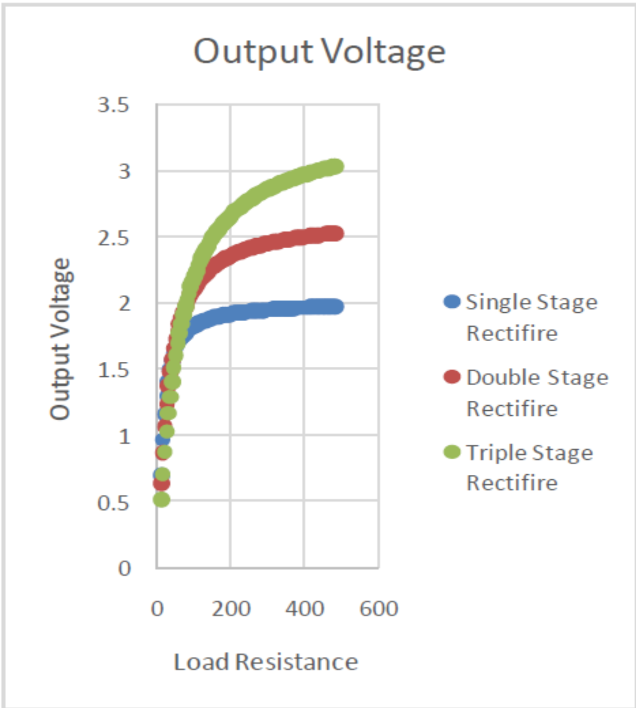

Figure 5. o/p voltage of all the three circuits with variable load.

This comparative graph shown in above figure 5, represent the o/p voltage at a certain value has reached above 2 volts at the load resistance value of 85KΩ. That is a significant achievement of having the efficiency above 90% and voltage above 2 Volts at the same value of load resistance.

Along with the variable load when this circuit is simulated with variable i/p power then significant outcome were achieve. Following is the single stage harvester circuit which was simulated with the variable power instead of variable load.

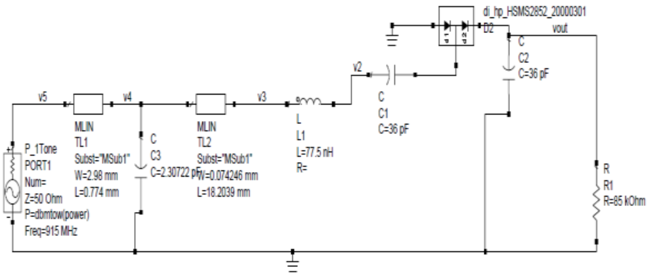

Figure 6. Single stage harvester circuit which was simulated with variable power instead of variables load resistances.

Result of the circuit shown in fig.6 according to variable power.

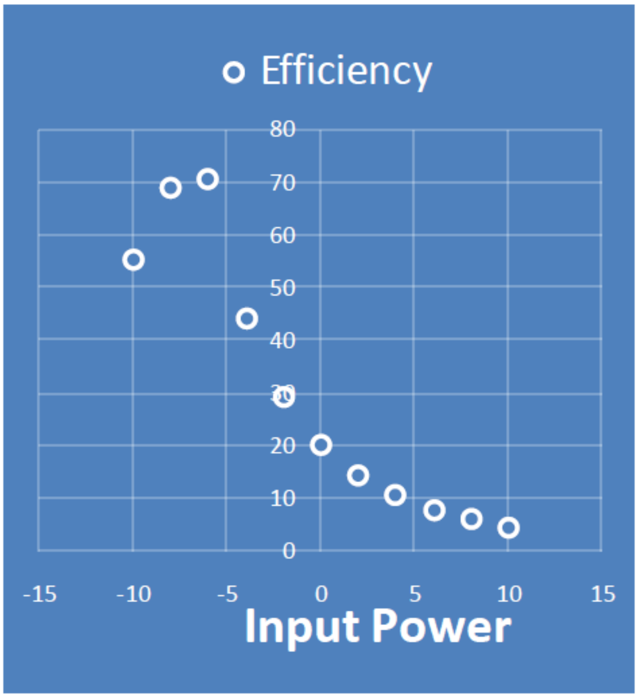

Figure 7. Simulate outcome/result of efficiency for circuit in fig.6 with variable power.

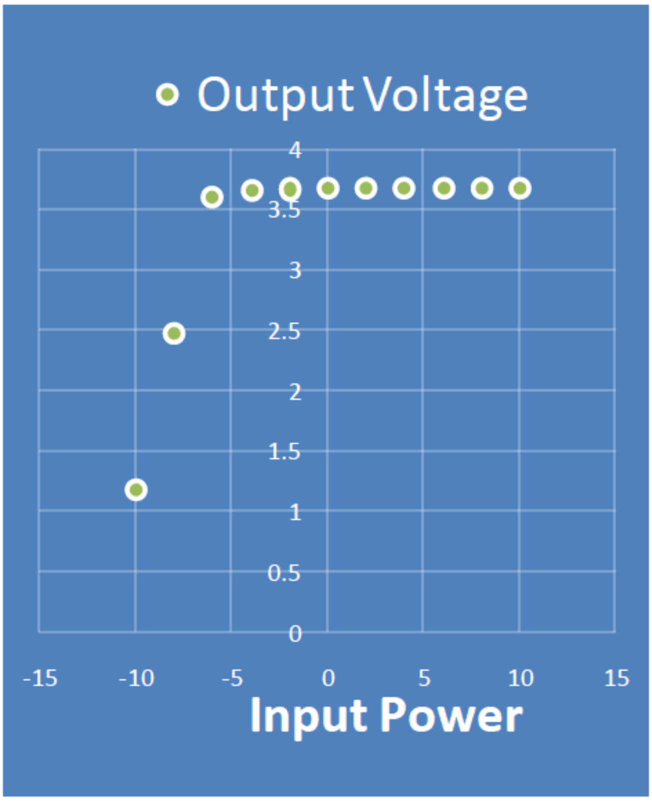

Figure 8. Simulate outcome of o/p voltage for circuit in fig.6 with variable power.

IV. CONCLUSION

In this paper the effect of variable load resistance and variable power has been presented and compared with the dissimilar stages of the rectifier as well. When there were significant results was achieved with variable load resistance of 85KΩ. when power was varied, greatest value of efficiency and output voltage was achieved at -6dBm of the input power.

Further improvement can be done in this circuit if number of stages and power will also varied accordingly along with the variable load.

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