# Rectenna Design of GSM Band Signal for Energy Harvesting

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## Abstract

In the recent days, the usage of wireless communication plays vital role in this electronic world. The utilization of RF signals from sources is more. These RF signals can be utilized and converted as usable DC power by using rectenna. This paper presents design of rectenna for 900MHz (GSM band) frequency. The received signal is matched with voltage multiplier circuit for RF to DC conversion and high voltage output. Villard voltage multiplier circuit is used. The designed antenna radiates 3.576dB power at 900MHz.The rectification has single stage voltage multiplier gives 2.688V with the maximum input value of 181mV and minimum input value of 1.456mV. By using single stage voltage multiplier, the output voltage is 4.139V with maximum input value of 181mV, minimum input value of 7.99mV Advanced Design System (ADS 2008) is used for simulation.
**Keywords: Antenna, Matching circuit, RF Energy harvesting, Rectenna, Voltage multiplier**

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## I. INTRODUCTION

In the inter-connected world, the numbers of mobile users are increasing day-by-day. Also the use of Wi-Fi connections in colleges, industries, software companies makes the availability of RF sources in a large manner. Wireless power transfer is one of the emerging technologies. Energy harvesting is used for charging of mobile devices. Wireless communication would be the transmission in the energy spanning a distance without the usage of wires or cables, where distance can be short or long. Wireless operations permits services, for example long-range communications, which are merely unfeasible using wires.

In this paper, we presented the design of single band antenna for RF energy harvesting system. The designed antenna has resonant frequency at 900MHz with the gain of 3.576dB. The efficiency of this patch antenna is considerably high. The rectifier circuit is also designed which can operate at desired frequency bands. The matching circuit is connected with voltage multiplier circuit and the output voltage is 2.688V with input voltage of 181.4mV.The microstrip patch antenna and the rectifier circuit in this paper are designed and simulated separately.

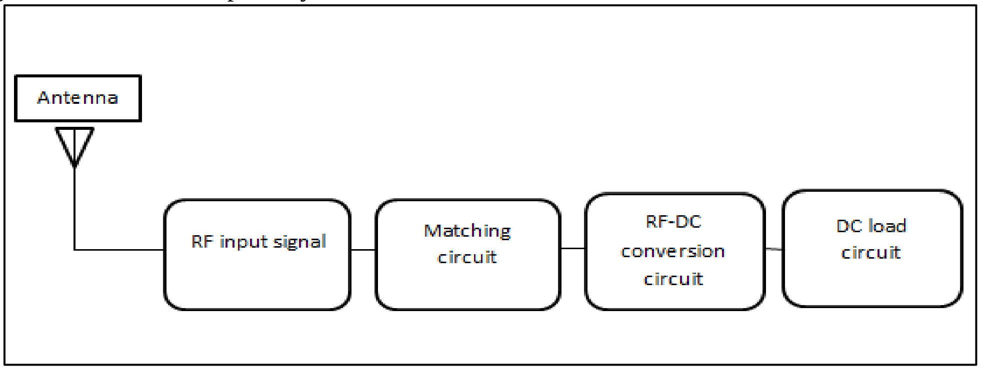


Fig. 1: Block diagram of rectenna

The block diagram represents the circuits that comprise the rectenna. The antenna which used here is microstrip patch antenna and it is used to receive signals. The received signal is matched with the circuit using voltage multiplier circuit. Then the voltage multiplier circuit is used for high output voltage. The Schottky diode is used in the voltage multiplier circuit.

 

## II. ANTENNA

The first step of the rectenna design is antenna design. Microstrip patch antenna is used to operate at 900MHz. The antenna uses FR4 substrate with dielectric constant Cr=4.4 and the thickness of the substrate is 1.6mm, loss tangent is 0.02.The dimension calculated for the microstrip patch antenna includes length and width of the patch, width of the patch is W=117mm, extended length of the patch is L=91mm.The designed antenna resonates at 900MHz.Inset feed method is used. The following figure shows the layout of the antenna.

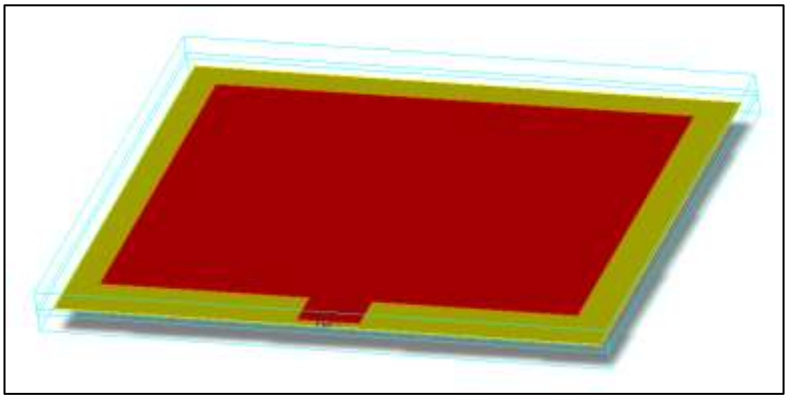

Fig. 2: Antenna layout

## III. RECTIFICATION CIRCUIT

Rectifier circuits convert the input AC voltage into DC voltage. This rectification process is mainly done by Schottky diode in the voltage multiplier circuit. Schottky diode of HSMS-285b is used here. It has low turn on voltage of 0.2 to 0.3 Volts compared with silicon diode. It has fast recovery time. Voltage multiplier can be called also charge pump and the basic circuit of a Villard voltage multiplier is called Cockcroft-Walton voltage multiplier.

### *A. Matching Network*

Matching network is mainly used to match the frequency received from the antenna with the rectification circuit.LC matching circuit is used for low frequency application. It is used to decrease the value of the reflected power and to increase the efficiency of the rectifier, to ensure the maximum power transfer. The value of the matching network will calculated using smith tool from ADS to match the circuit at frequency of 900MHz.

### *B. Voltage Multiplier Circuit*

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.

A single stage voltage multiplier circuit consists of 2 diodes HSMS-285b, 2 capacitors 70 pF and load resistor with value of 100 KΩ. The circuit consists of two sections such as a diode and a capacitor for rectification. The RF input signal is rectified in the positive half of the input cycle, followed by the negative 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.

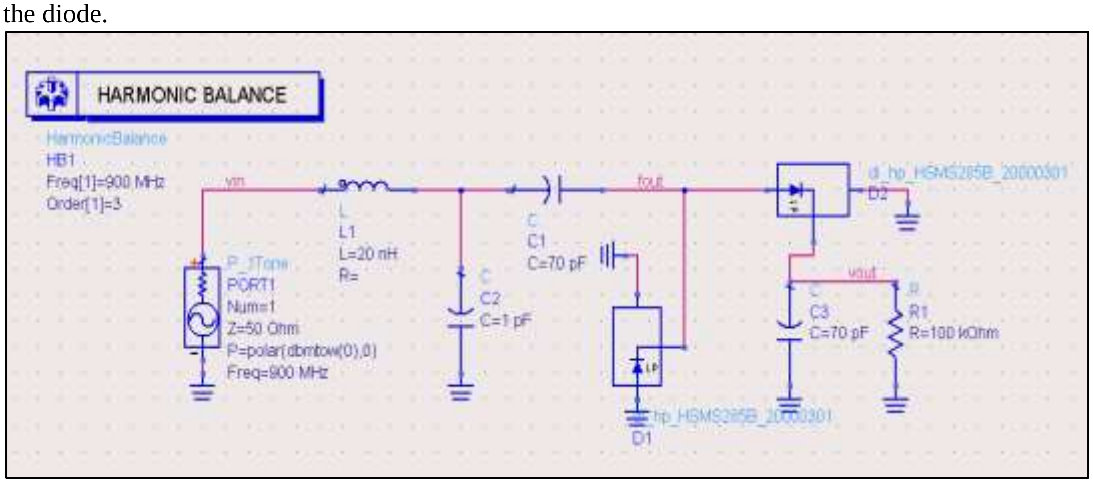


Fig. 3.1: single stage voltage multiplier

The figure 3.1 picture shows the design the 2-stage voltage multiplier using diode HSMS-2850. The output voltage across the load decreases during the negative half cycle of the AC input signal. The voltage decrease is inversely proportional to the product of resistance and capacitance across the load. Without the load resistor in the circuit, the voltage would be hold indefinitely in the capacitor and look like a DC signal, assuming ideal components. The capacitors are charged to the peak value of the input RF signal and discharge to the series resistance (R1) of the diode. Thus the output voltage across the capacitor of the first stage is approximately twice that of the input signal. As the signal swings from one stage to another, there is an additive resistance in the discharge path of the diode and increase of capacitance due to the stage capacitors. By using single stage voltage multiplier circuit, the output voltage obtained is 2.668V with the input of 1.456mV and the using double stage voltage multiplier the output voltage is 4.139V with input of 7.99mV. The measure of magnitude of input and output voltages can be done using Harmonic Balance (HB) Simulation

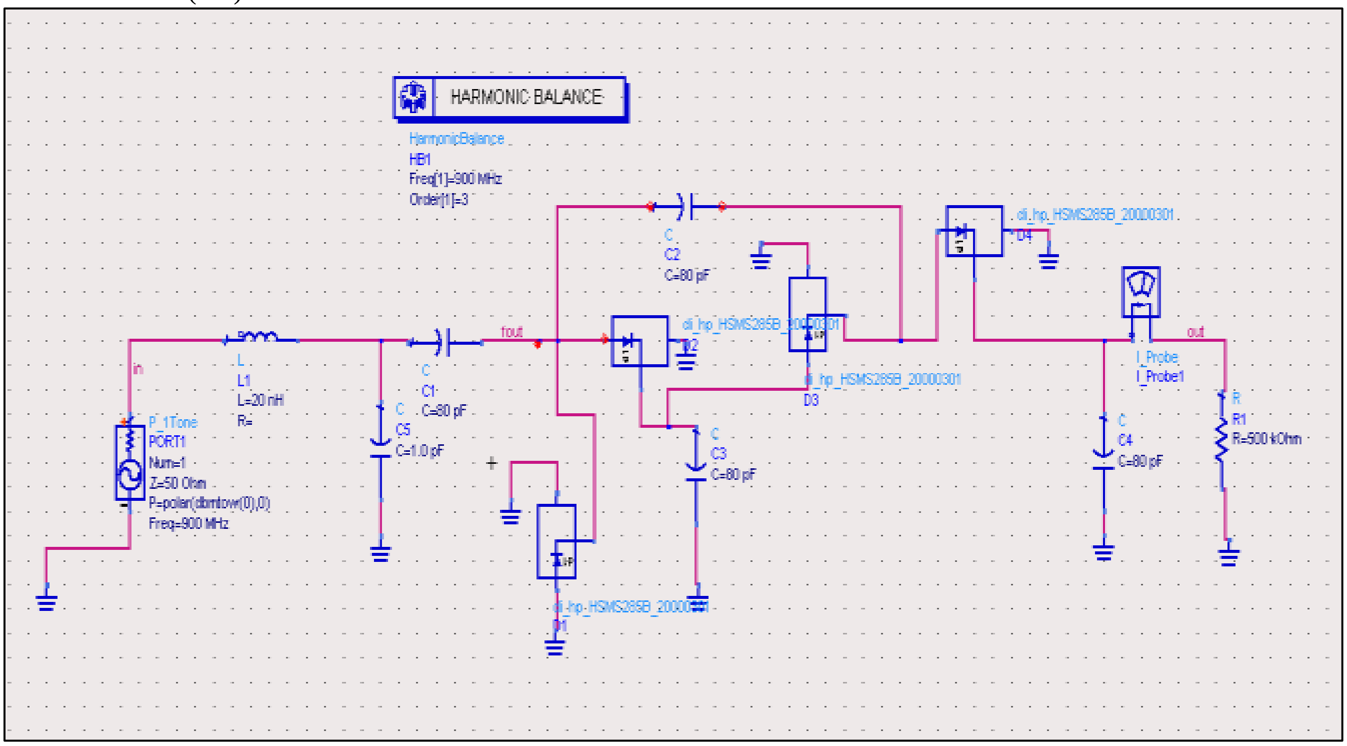

Fig. 3.2: Two stage voltage multiplier

The obtained voltage is the harvested energy from the rectenna. This harvested energy is in the DC form.

## IV. EXISTING SYSTEM

The existing antenna has the radiated power of 0.00209 Watts, directivity of 6.18105 dB and gain of 5.88572 dB for the corresponding frequency band of l.8 GHz and it has the radiated power of 0.00308 Watts, directivity of 5.55555 dB and gain of 5.0256 dB for the corresponding frequency band of 2.4 GHz. S11 parameter denotes return loss. If the S-Parameter value is 0dB, then all the power is reflected from the antenna and nothing is radiated. The return loss should be less for the antenna. Here the design has achieved the return loss of about -25.339 dB at around 1.8 GHz and -21.273 dB at 2.4 GHz.

## V. SIMULATION OUTPUT

### A. *Antenna*

*1) S-Parameter output*

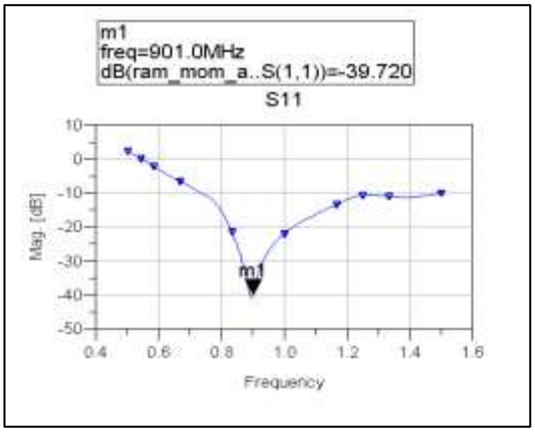


Fig. 4.1: Proposed system output

The existing output shows that the Magnitude gain of the antenna is low. So the signal received by the antenna has more attenuation. Proposed output shows that the designed antenna radiates maximum at 900MHz with the magnitude gain of 3.576dB. The return loss is -39.720dB. The directivity and gain are opposite in phase with equal magnitude.

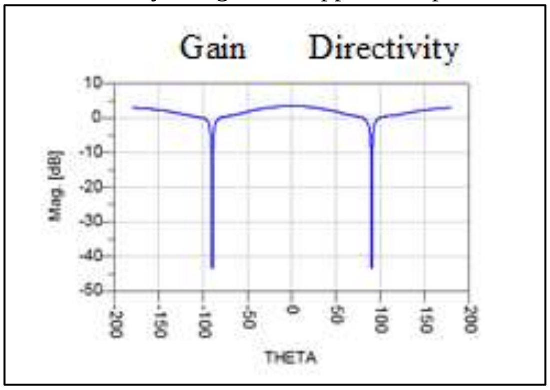


Fig. 4.2: Gain and Directivity

The radiation or antenna pattern describes the relative strength of the radiated field in various directions from the antenna, at a constant distance. The radiation pattern is a reception pattern as well, since it also describes the receiving properties of the antenna. The radiation pattern is three-dimensional, but usually the measured radiation patterns are a two-dimensional slice of the three-dimensional pattern, in the horizontal or vertical planes. These pattern measurements are presented in either a rectangular or a polar format. The effective angle of the antenna is 316.02degrees and the maximum intensity 0.004516(watts/radian).The below mentioned figure shows the radiation pattern of the designed antenna.

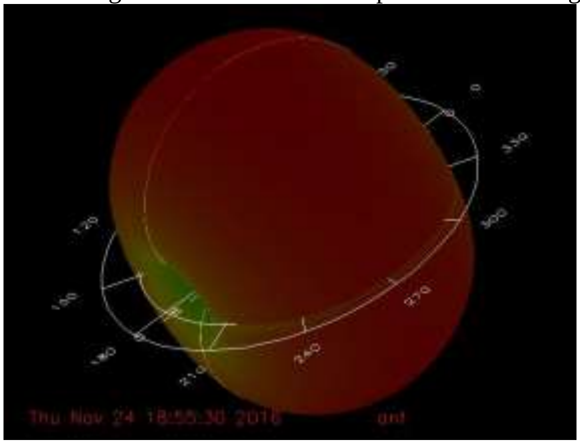

Fig. 4.3: Radiation pattern

### *B. Rectifier Output*

The rectified output shows that signal is rectified and it is multiplied using voltage multiplier output. The output voltage for single stage voltage multiplier is 2.669V with the input voltage of 1.66mV. To increase the value of the DC output, matching circuit is added between the source of generator and the rectifier circuit to decrease the value of the reflected power and to increase the efficiency of the rectifier, to ensure the maximum power transfer, matching circuit will added between the source and the rectifier. By using the two stage voltage multiplier circuit the output voltage obtained is twice than that of the single stage voltage multiplier. Because of the multiple stage of diode capacitance combination, the output voltage is 4.140V for the input voltage of 7.88mV.

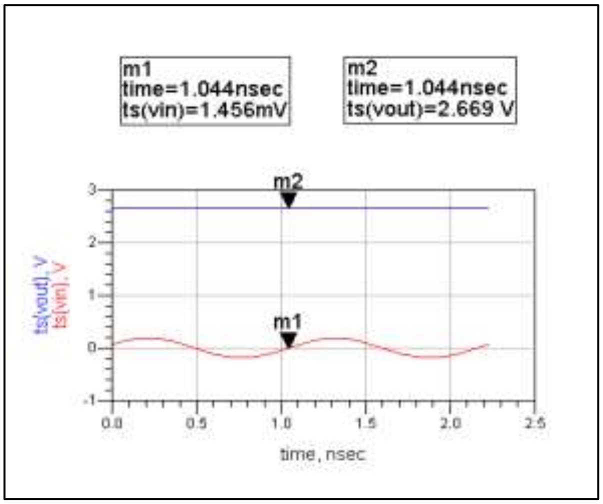


Fig. 4.3: Single stage voltage multiplier output.

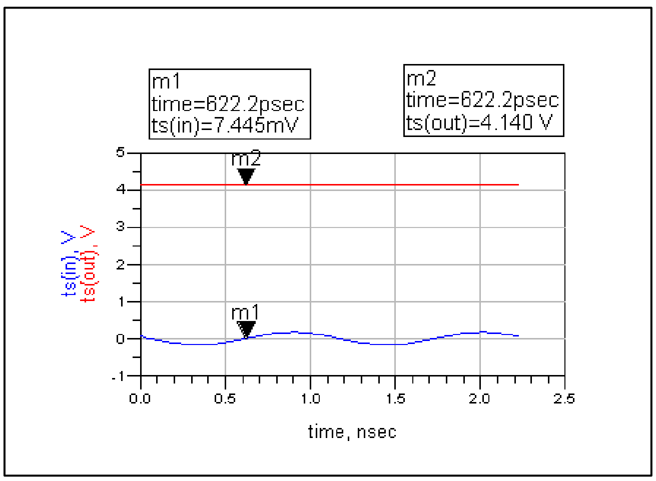


Fig.4.4: Two stage voltage multiplier output

## VI. CONCLUSION

| *FREQUENCY (GHz)* | *1.8* | *2.4* | *0.9* |
|---|---|---|---|
| *OUTPUT VOLTAGE(V)* | *0.459* | *0.768* | *2.668* |

In rectenna design, an antenna which is designed can radiate with gain of 3.4912dB and directivity of 3.053dB at 900MHz (GSM Band). And thus the microstrip patch antenna has been designed and simulated in ADS 2008.The designed rectenna harvest more output voltage 2.668V than the existing system. In wireless sensor networks, the sensor nodes can either directly powered using rectenna or the harvested voltage can be stored using some storage devices. Since the voltages obtained at these frequencies are not sufficient to directly power the sensor nodes, it can store using a super capacitor or micro batteries for further use. In order to increase the amount of harvested voltage, this work can be extended by including the more stages in the voltage multiplier circuit.

## VII. FUTURE SCOPE

The rectenna can be implemented with other types of antenna and the power conversion efficiency can be improved by including more stages in the voltage multiplier.It can be designed for multiband frequency.

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