

# RF Energy Harvesting from Cell Phone in GSM900 Band

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Abstract - *In this paper an experimental RF energy harvesting system using rectifying antenna (rectenna) to harvest ambient energy from cell phones operating at 900 MHz GSM band is presented. The proposed circuit is a combination of RMPA and rectifying circuit using Schottky diode for microwave (RF) to DC conversion. The performance of the rectenna is simulated by electromagnetic simulator Computer Simulation Technology (CST) Microwave Studio. Rectenna offers maximum radiation efficiency of around 55.61%, gain of 3.4 dBi and directivity of 5.972 dBi. The proposed rectenna design can prove to be a low cost device for wireless power transmission and RF energy harvesting. GSM 900 band is used as this is the most commonly used band for mobile communications. This rectenna offers return loss of 17 dB at frequency of around 900 MHz.*

**Key Words:** Rectangular Microstrip Patch Antenna (RMPA), Rectenna, Radio Frequency (RF), Computer simulation Technology (CST-MW), Global System for Mobile Communication (GSM).

## 1. INTRODUCTION

Recent years have seen increasing use of wireless devices in many applications like cell phones, sensor networks and other low power devices. RF energy is continuously radiated from several sources which include Mobile phones (869-890 MHz in CDMA, 935-960 MHz in GSM 900 band and 1810-1880 MHz in GSM 1800 bands), FM radio system ( 88-108 MHz ), Cell Tower Transmission (10-20 W per carrier ), Wi-Fi (2.45 GHz, 5.8 GHz), TV transmission (180-220 MHz ), AM Transmission ( 540-1600 KHz ) etc [1].

This ambient energy present around us can be harvested using a rectifying antenna, popularly known as rectenna. A rectenna comprises of antenna along with the rectifying circuit. The antenna receives the RF energy and the rectifying circuit converts it to DC electrical power [2].

Rectenna is needed for efficient utilization of wireless power. This RF power is basically “free” source of energy. The number of radio transmitters, specifically base stations, and cell phones are continuously increasing. Wi-Fi routers, laptops are also source of radio energy. Consider the case, for example, inside a single room, it is possible to collect a small measure of vitality from an average Wi-fi switch transmitting at a force level of 50 to 100 mw [3]. Basic feature of portable devices are small dimensions, so the rectenna should be as small as possible [4]. Received power is low for small sized rectenna. Thus wireless power transfer is most suitable for low-power applications for instance a low-power wireless sensor.

For testing the designed rectenna, total efficiency and conversion efficiency are given by equation (1) and (2), [5].

The total efficiency

$$\eta = \frac{\text{DC Output Power}}{\text{Incident RF Power}} \quad (1)$$

Conversion efficiency is given by

$$\eta_c = \frac{\text{DC Output Power}}{\text{Incident RF Power} - \text{Reflected Power}} \quad (2)$$

To design the rectenna, CST Microwave Studio software [6] is used. Computer Simulation Technology (CST) Microwave Studio is a software package that is fully featured. Electromagnetic analysis and design in high frequency range can be done using CST. The software comprises of four different simulation techniques (transient solver, frequency domain solver, Eigen mode solver, modal analysis solver). The most versatile and flexible is the transient solver tool, which can obtain the broadband frequency behaviour of the simulated device. The properties of the antenna such as

reflection coefficient  $S_{11}$  and Gain are determined with the help of CST Software.

The proposed rectenna design consists of RMPA and a half wave rectifier circuit.

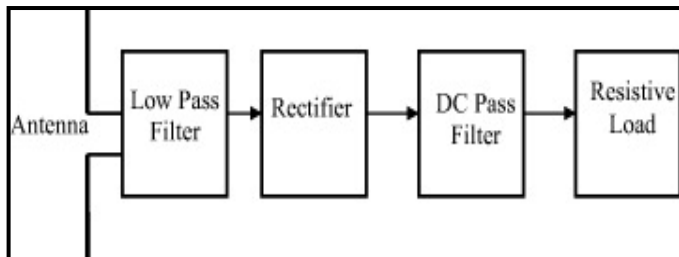


Fig -1: Basic Rectenna block diagram

## 2. METHODOLOGY

### 2.1 Antenna Design and Fabrication

Fig.2. shows the basic rectangular patch antenna. The reflection coefficient, radiation pattern, gain, directivity and VSWR are found by simulating the antenna on CST and measured by spectrum analyzer.

The front view of the proposed rectenna is shown in Fig. 4. It consists of a rectangular microstrip patch antenna operating at resonant frequency of 900 MHz with 50Ω microstrip line feed. The rectenna is printed on a FR4-epoxy substrate having relative dielectric constant  $\epsilon_r = 4.3$  and thickness  $h = 1.6$  mm.

In the fabrication and designing process of rectenna initially we design the RMPA at desired frequency of 900 MHz. Fig. 3 shows the designed patch antenna on CST at 900 MHz.

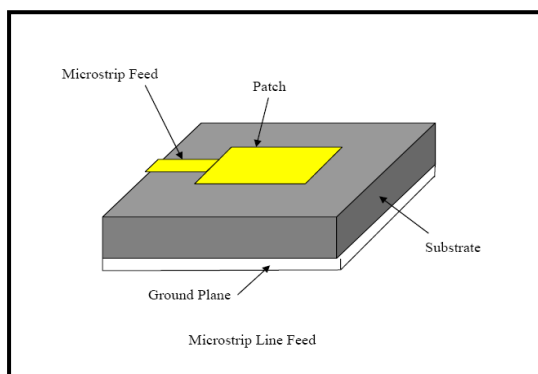


Fig -2: Rectangular Microstrip Patch Antenna

Table -1: Parameters and Design Specifications of Antenna

S No.	Antenna Parameters	Values
1.	Resonating Frequency	900 MHz
2.	Dielectric Constant(relative)	4.3
3.	Substrate Thickness	1.6 mm
4.	Loss Tangent	0.02

Table -2: Calculated dimensions of Patch Antenna

S No.	Antenna Parameters	Values in mm
1	Patch width	86
2	Patch height	80

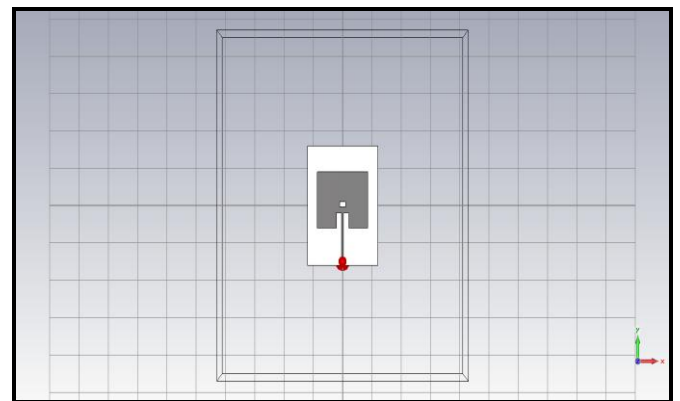


Fig -3: CST view of Rectangular Microstrip Patch Antenna

### 2.2 Rectifier Designing

A rectifier is a device that converts bidirectional alternating current (AC) to unidirectional direct current (DC). The process is known as rectification. A basic half wave rectifier is considered in this paper. Fig. 4 shows a half wave rectifier circuit used in this design.

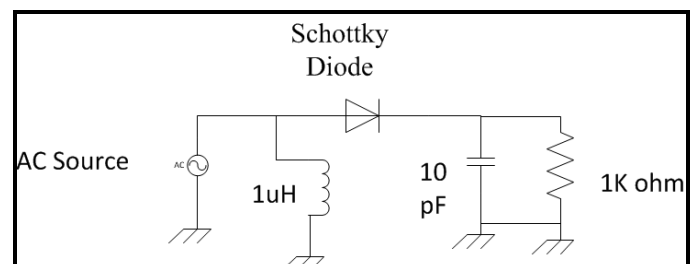


Fig -4: Rectifier circuit

In this circuit we have used a capacitor of 10 pF, a schottky diode and a resistor of 1 KΩ. Instead of a semiconductor-semiconductor junction, Schottky diode use a metal-semiconductor junction thus allowing the junction to operate at a much faster rate. It gives a forward voltage drop of as low as 0.15 V.

In the proposed rectifier circuit, HSMS 282C Schottky Diode is used. Avago’s HSMS-282x family of zero bias Schottky detector diodes has been designed and optimized for use in small signal. They are ideal for RF Tag and RFID applications where primary (DC bias) power is not available [7].

A linearly polarized microstrip patch antenna (86 mm x 80 mm) has been associated with the rectifier to obtain the complete rectenna. The antenna simulation was carried out using the electromagnetic simulator CST v.10 [6]. The antenna has been achieved and measured in a first time. A good input matching level is seen at 900MHz.

Fig.5 below shows the final design of integrated rectenna in CST software which is now ready for final simulation. Fig.6 shows the back view of the rectenna where the ground has been defected to obtain better results.

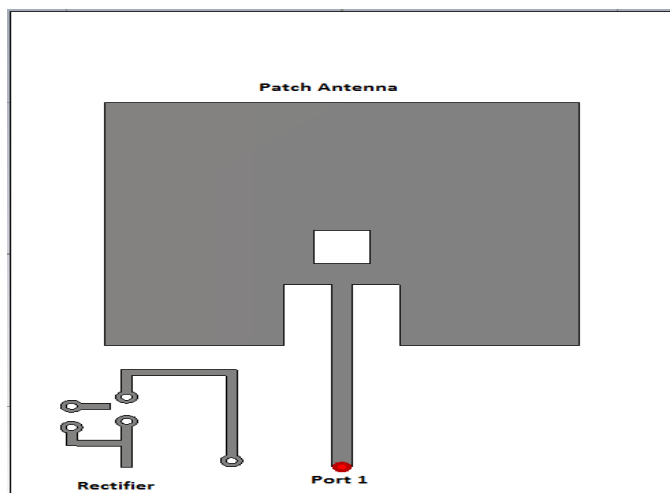


Fig -5: Front view of 900 MHz Rectenna

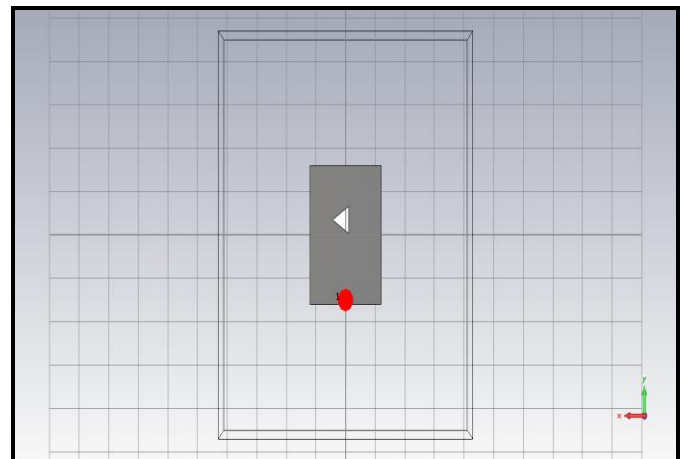


Fig -6: Back view of integrated Rectenna

### 3. RESULTS

Fig. 7 shows the simulated result of designed antenna without rectifier. Fig. 8 shows the simulated result of antenna integrated with rectifier. It shows -11 dB at 900 MHz for patch antenna without rectifier, while -17 dB at 900 MHz for antenna with rectifier integrated on it which is quite improved result for rectenna.

Fig.9 shows the comparison of reflection coefficient for both antenna as well as rectenna. It can be seen that there is evident reduction in return loss of designed rectenna when rectifier is integrated into the patch antenna. This rectenna can then be used for harvesting RF energy from mobile phones in GSM 900 band.

Fig.10 shows the radiation pattern of the rectenna. The radiation efficiency is found to be -2.548, thus rectenna has 55.61 % radiation efficiency.

Fig.11 shows the gain of proposed rectenna. Gain of 3.4 dBi is seen for the design. Also directivity of 5.972 dBi is obtained which can be seen in Fig. 12.

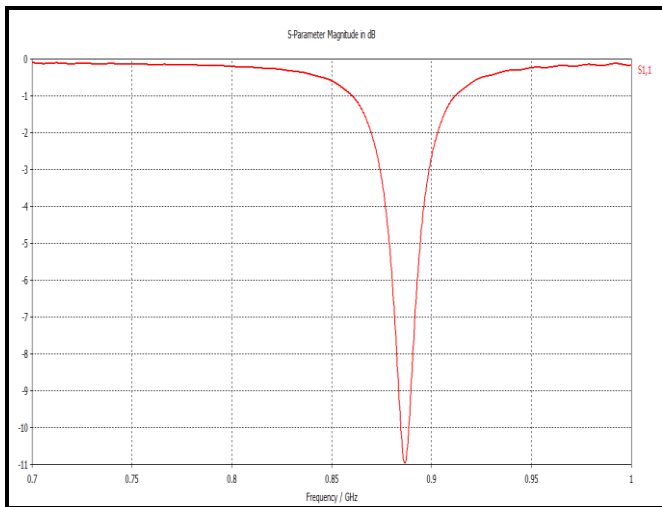


Fig -7: Simulated S11 of the patch Antenna

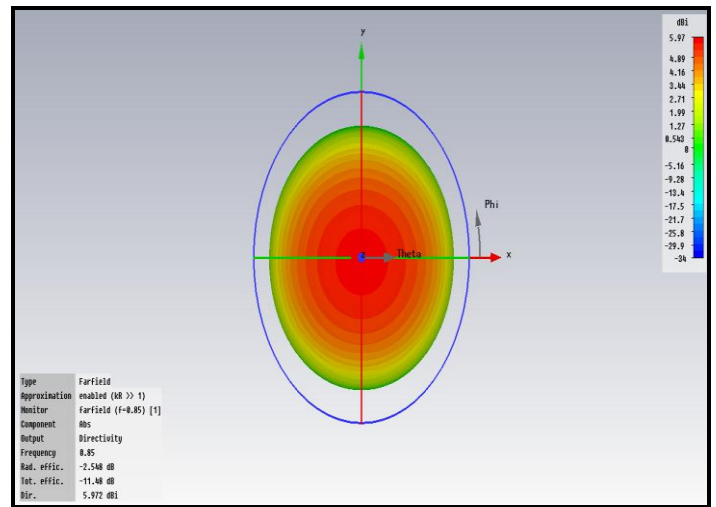


Fig -10: Radiation pattern of the designed Rectenna

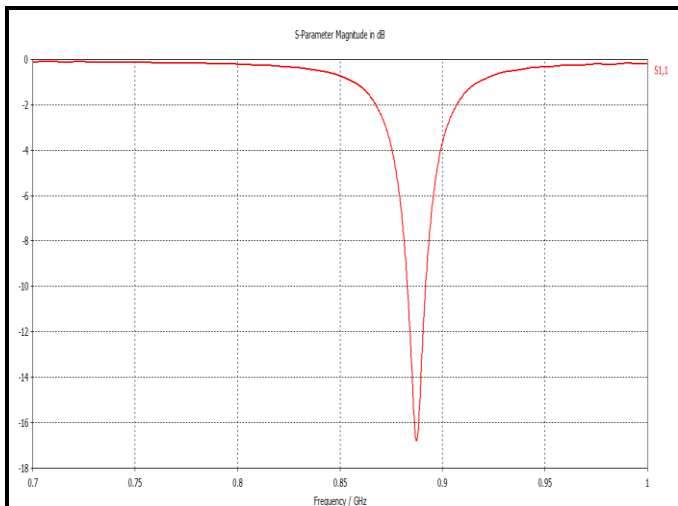


Fig -8: Simulated S11 of the designed Rectenna

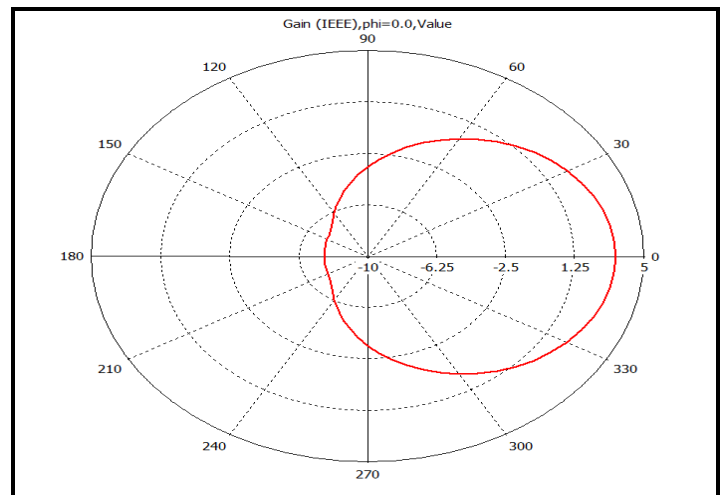


Fig -11: Gain plot of the designed Rectenna

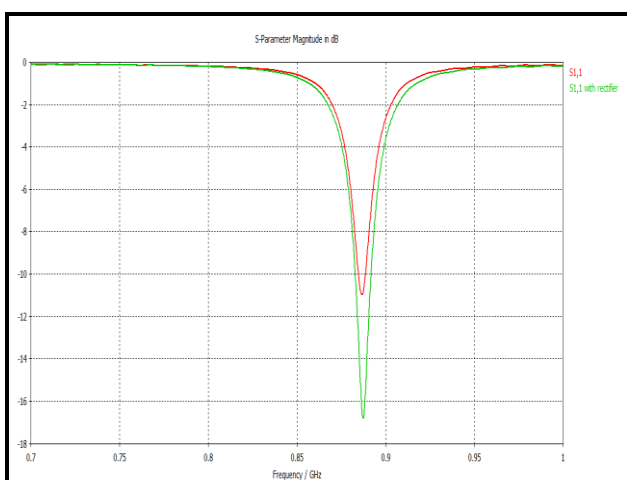


Fig -9: Comparison of S11 for patch antenna and rectenna

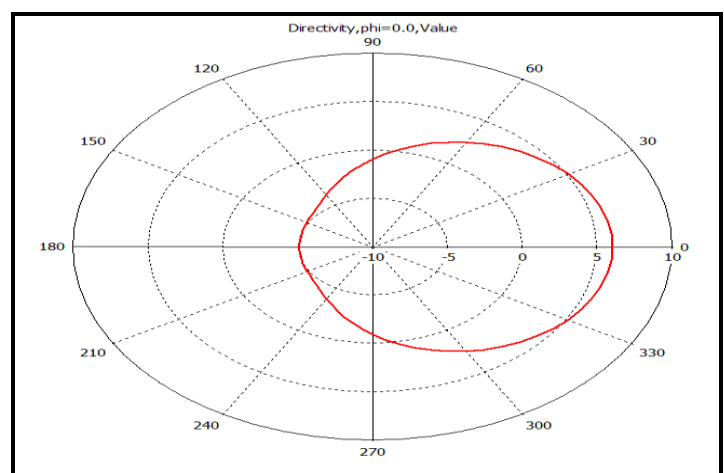


Fig -12: Directivity plot of the designed Rectenna

#### 4. CONCLUSIONS

In this paper, a rectenna is fabricated using a RMPA, matching network and single stage half wave rectifier circuit. Here a compact, planar rectenna is designed for wireless power reception in GSM 900Mhz frequency band of operations.

The system consists of 3 major blocks. (i) Antenna which is used for receiving the signal is operated in the far field region.(ii) Impedance matching circuit which is used for matching the antenna with the rectifier. (iii) A half wave rectifier is used to convert the AC to the DC. These blocks are individually and integrally verified using simulations and measurements successfully.

There are some improvements which can be done in the future work. (i) The rectifier can be replaced by the full wave rectifier for higher efficiency. (ii) The impedance matching here is generally done for the first harmonics and the other harmonics are filtered out. Instead of filtering them, they can also be matched for good impedance matching. (iii) A rectenna array can be used to increase the DC signal received at the output.

The circuit can be used to capture the RF energy from a RF sources by placing it adjacent to RF source (wireless routers, mobile handset etc.). The circuit can be implemented in mobile handsets, wireless sensor nodes etc.

This technique can be helpful in recharging of cell phone (primary device) by placing another cell phone (secondary device) to be charged very close to completely charged mobile handset and draining energy from primary device for charging the secondary device. Multiple stages of the voltage multiplier circuit can be used to increase the output voltage level of the proposed design.

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#### BIOGRAPHIES



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