Rectifier for RF Energy Harvesting

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ABSTRACT

Wireless medical devices are used for monitoring a patient's health. These devices transmit patient's health data to external programming devices through communication links. Battery life is a significant issue with these wireless medical devices. This project proposes an energy harvesting system which scavenges energy from Radio Frequency (RF) electromagnetic spectrum and it is operated in GSM 900 band. In such systems, RF input energy is rectified using RF DC rectifier topologies. The RF-DC conversion is carried out using schottky diode. Impedance matching circuit is deployed between antenna and rectifier for maximum power transfer. The rectifying efficiency is found to be 72% for low input power. The proposed RF energy harvesting system is designed and simulated using Advanced Design System 2009 software.

Keywords

Energy harvesting, Health monitoring System, Half wave rectifier, voltage doubler rectifier, Bridge rectifier.

1. INTRODUCTION

Recently, interest in Wireless Sensor Devices has been rapidly increasing due to the advancement of wireless technology. Because of its position independent sensing capabilities, it is widely used for monitoring application like area monitoring, health care monitoring and Industrial monitoring etc. In health care systems, wireless Sensor Network have opened up many new opportunities by which thousands of wired devices are replaced by wireless medical devices. ECG monitors, pulse Oximeters, Spirometers and blood pressure monitors are some of the wireless medical devices [1][2].

Traditionally, the health monitoring medical devices are attached to the patient by wires; that makes patient discomfort. In addition, all monitoring devices have to be disconnected and then reconnected later, whenever the patient needs to be moved. With the help of wireless technology, these time-consuming jobs could be terminated and patients could be free from the wired instrumentation. The wireless medical devices capture the patient's health data and transfer that data to the external programming device through the communication protocol. This device connects to the medical centre's network with a gateway and transmits data to remote monitoring location.

Nowadays Continuous and pervasive medical monitoring is available in the wireless healthcare systems [3] [4]. With wireless continuous medical monitoring systems, patient health data such as blood pressure, heart rate, and ECG can be sent to medical centres to store and process properly for future applications. By regularly monitoring, medical emergencies can be detected earlier and proper treatment can be applied immediately. With the present of wireless communication technologies in health care effectiveness can be improved significantly.

Batteries are needed to power such wireless medical devices are either large providing a longer run time, but making the system less autonomous [5][6]. The Batteries need to be periodically recharged. Most often the charge relies on a wall plug charger, which somehow limits the portability of the wireless devices [6]. The availability, the reliability and the user friendliness of portable medical devices can be improved by wireless supply systems

There are several different approaches to wireless power supply. Near field inductive coupling works at very small distances, typically limited to a few centimetres [7]. Energy can also be transmitted based on radioactive High Frequency field. High power transfer over several kilometres has been achieved with efficiency sometimes in excess of 60 % [8]. This technique is used to supply UHF Radio Frequency Identification (RFID) devices at a distance of 10 m. The wireless energy transfer technique can also be applied in order to supply low power electronic devices using microwave beams [9] or by batteries that can be remotely recharged. [10] A source of constant energy is therefore required to power such system that could provide by RF energy harvesting. The power that RF transmitters scatter into the environment can be considered as ambient sources for harvesting. Recent advancements in technology made ambient energy harvesting a practical reality.

2. RF ENERGY HARVESTING SYSTEM

Radio frequency energy harvesting can be done from an ambient source in the environment [11]. It is used for energy generation. Here RF energy is converted DC voltage. The history of energy harvesting dates back to the windmill and waterwheel. Energy harvesting can be classified as large scale and small large. Wind and solar power plants are large scale harvesting. Harvesting energy from Human body and harvesting energy from ambient RF sources are small scale harvesting.

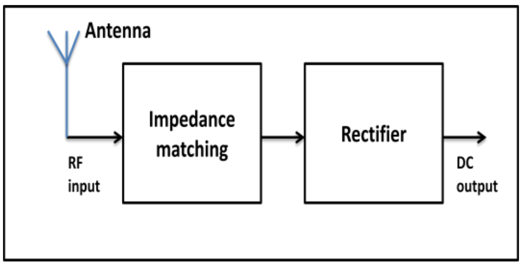

Figure 1. RF energy harvesting circuit

Due to the enormous development of wireless communication, the amount of electromagnetic radiation presents in our environment is increasing [12][13]. We are bombarded with Radio wave in our daily lives in the form of signal transmission from TV signals, wireless radio, Wireless network and cell phone towers. The energy transmits from these wireless sources is very high (KW) range, but only a small amount of this energy is received by the receiver. Remaining of the energy is dissipated as heat. This energy that is wasted can be harvested to generate electricity.

GSM 900/1800MHz, 2 GHZ and 2.4GHz are some of the frequency bands that are suited in the atmosphere. In which GSM900/1800MHz range radio frequencies are dominant. . A GSM-900 base station antenna transmits in the frequency range of 935-960MHz.[14] In urban areas measurement campaigns have shown that typical power levels 25–100 m from a GSM base station reach several µW/cm2.

Ambient sources can be considered as power that scatters from RF transmitter. The power that scattered is obtained by receiving antenna. The received power is input to the rectifier that convert RF signal into DC Power which is required to operate wireless medical devices. The RF energy harvesting system is shown in Figure 2. The input RF signal for the RF energy harvesting system is 945 MHz. The key element of the RF energy harvesting system is receiving antenna, matching circuit and the RF-DC conversion rectifier circuit.

2.1 Matching Network

The maximum power transfer theorem, states that the maximum power from a source will be transferred to its load if the load resistance is equal to the source resistance [16].

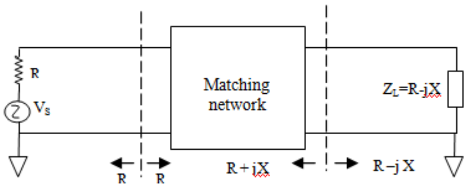

Figure 2. Matching Network

To maximize the power delivered to the load (R_L) X_L and X_S should be inverses so they sum to zero.Hence the maximum power from fixed source impedance to a load occurs when the load and source impedances are complex conjugates.

If there is any mismatch between the receiving antenna (source) and the rectifier, impedance matching circuit is required to match the antenna and the rectifier impedance. The main role in any Impedance Matching is to force a load impedance to look as if the complex conjugate of the source impedance, and maximum power can be transferred to the load[18]. When a source is matched to a load with passive lossless network, the source is conjugated matched to the input of the matching network, and also the load is conjugate matched to the output of the matching network.

There are several networks that could be used to perform the impedance matching function. They are a) Impedance matching using a shunt inductor. b) Impedance matching using a LC Network. c) Impedance matching using a transformer. d) Impedance matching using a pi-Network. e) Impedance matching using a T – Network. f) Impedance matching using a Transmission line.

In the RF energy harvester, a simple LC network impedance matching circuit is inset between the RF source and the rectifier because it reduce the number of required components of the circuit and thereby minimize the size of the device. . It consists of a inductor and a capacitor in the series-parallel configuration. This LC network matches the antenna impedance (50Ω) to the rectifier circuit impedance at 945MHz. The LC network also act as a low pass filter which passes RF energy at 945MHz and rejects the unwanted higher order harmonics. Thus the harmonics generated by the nonlinear rectifying diode.

2.2 Rectifier

The input RF signal received by receiving antenna is converted to DC supply voltage by the rectifier [17]. It consists of diode and capacitor. There are different types of rectifier (i) Basic rectifier (ii) Voltage doubler (iii) Voltage multiplier. In the basic rectifier circuit, the diode connected in series with load. Here capacitor is used for smoothen the output. This basic rectifier is also called as single stage rectifier. In the voltage doubler, two diodes and two capacitor are used for approximately double up the DC voltage[17].In the voltage multiplier, cascaded connection of diodes and capacitors are used to obtain higher order. . For typical 50Ω antenna, RF signal power received is generally smaller than the diode threshold . So diode with the lowest turn on voltage are preferable for the energy harvesting circuit. HSMS 285x schottky diode is suitable for the weak RF signal environment.

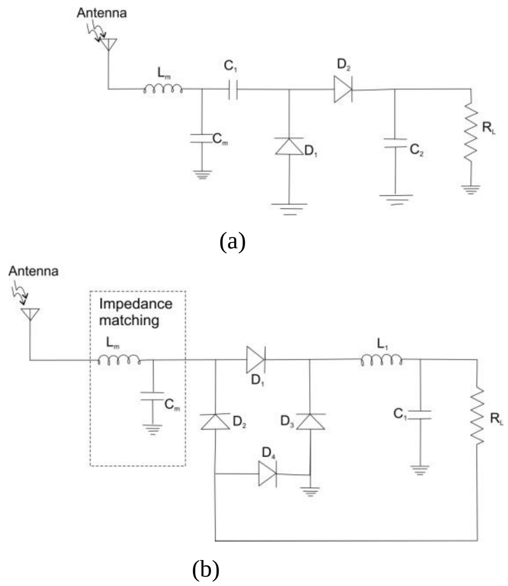

Figure 3. Rectifier circuit. (a) Voltage doubler Rectifier. (b) Full Wave Rectifier

3. SIMULATION AND RESULT

Simulation result of RF energy harvesting circuit is shown in this section. That should be done on Agilent Advanced Design System (ADS) 2009 software. In which S-parameter analysis is used for matching network and harmonic balanced analysis is used for RF-DC conversion. Power source P1_Tone (Power Source, Single Frequency) which is an Agilent device in ADS software for generating RF waves of 945MHz.

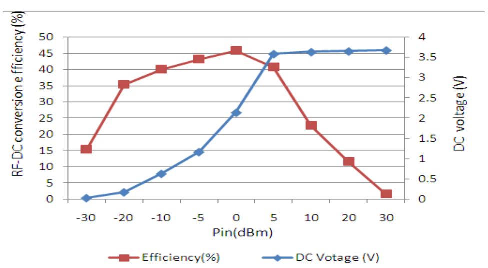

Figure 4. Schematic diagram of voltage doubler rectifier in ADS2009

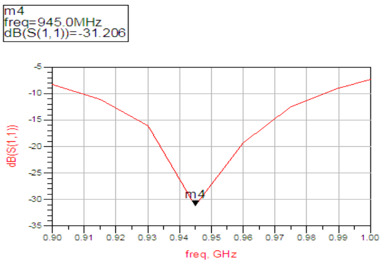

Figure 5. Simulates reflection coefficient of the voltage doubler rectifier

The simulated return loss responses of the voltage doubler rectifier are shown in the Figure 5. The rectifier resonates at 945 MHz for a 50Ω input source.

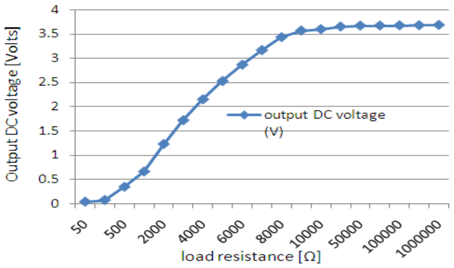

Figure 6. Simulated output DC voltage of the Voltage doubler rectifier versus the load resistance

The output DC voltage increases with increase the load resistance. The rising rate of the output voltage was higher at the lower value of the load resistance than the higher value of the load resistance.

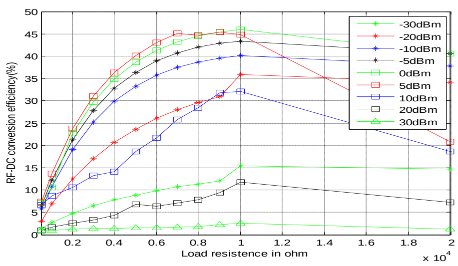

Figure 7. simulated RF DC conversion efficiency of the voltage doubler rectifier circuit with respect to the load resistance for the various input power.

The rectifier load has been tuned to obtain the maximum power point efficiency for a given input power. The efficiency reached the maximum value for the load resistance of 10kΩ.

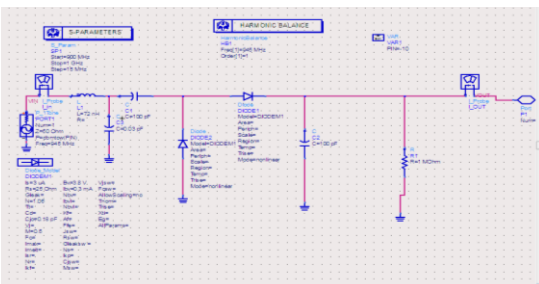

Figure 8. Simulated RF-to-dc energy conversion efficiency and measured output voltage of the Voltage doubler rectifier for a 10kΩ load .

Maximum efficiency of 35% and above is reached between -20dBm to 5dBm of incident power. The output DC voltage level of the voltage doubler rectifier is 178.6mV at -20dBm, 634mV at -10dBm, 1.17V at -5dBm, 2.143V at 0dBm and 3.591V at 5dBm.

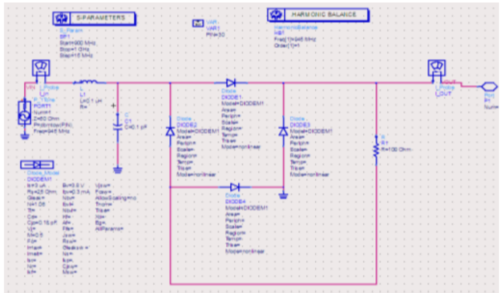

Figure 9. Schematic diagram of Bridge rectifier in ADS2009

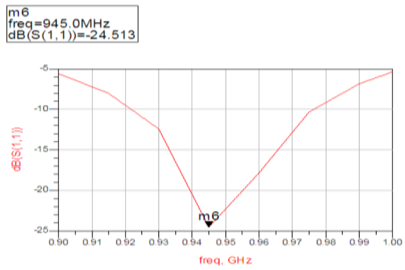

Figure 10: Simulates reflection coefficient of the Bridge rectifier

The optimum output DC voltage is obtained by stimulating the full wave rectifier with the various load resistance that should be shown in Figure 11.

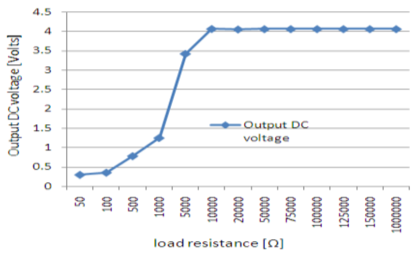

Figure 11. simulated output DC voltage of the bridge rectifier versus the load resistance

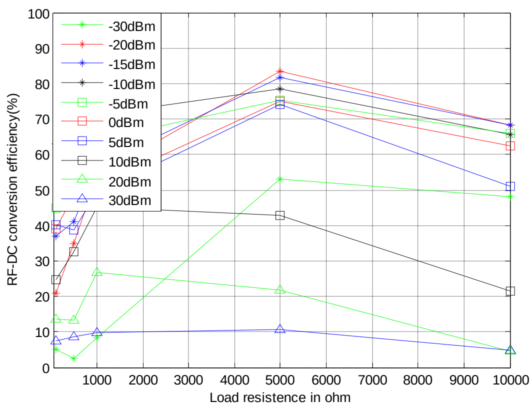

Figure 12. Simulated RF-DC conversion efficiency of the Bridge rectifier circuit with respect to the load resistance for the various input power.

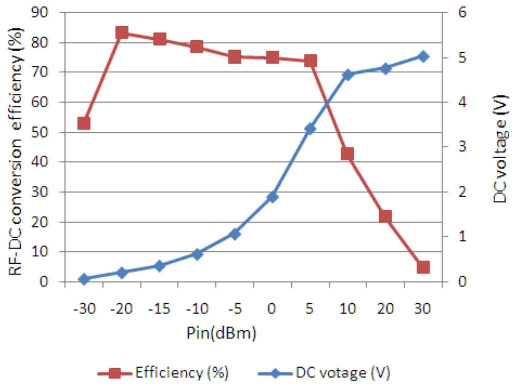

Figure 13. Simulated RF-to-dc energy conversion efficiency and measured output voltage of the Bridge rectifier for a 5kΩ load

The rectifier load has been tuned to obtain the maximum power point efficiency for a given input power. Maximum efficiency of 72% above is reached between -20dBm to 5dBm of incident power. The output DC voltage level of the Bridge rectifier is 204.3mV at-20dBm, 359.6mV at -15dBm, 617.5mV at -10dBm, 1.069V at -5dBm, 1.898V at 0dBm and 3.421V at 5dBm.

4. CONCLUSION

In this paper, we finally optimized the RF energy harvesting system to be able to power wireless sensor network. The whole work is done in the software called as Agilent ADS software where we have optimised the matching network and the rectifier by choosing Agilent schottky diode HSMS285X.

The RF energy harvesting system harvested power from a dedicated microwave source to operate a health monitoring system. The proposed system produced the DC output voltage of 4.039 v for the load resistance of 5kΩ. The power conversion efficiency of the proposed system is 72%. Further for increasing DC output voltage Broadband antenna will be designed for continuous receiving RF signal.

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