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# Energizing Low Power Devices by Harvesting Energy from Ubiquitous Electromagnetic Wave Resources

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**Abstract:** *In the recent years most of the devices are designed with low power consumption such as wearable devices, remote monitoring sensors, sensors used in fashionablecities. However, even long lasting batteries have a limited lifespan and must be replaced every few years. Replacements of batteries become costly when there are hundreds of sensors in rural areas.Technologies of Energy harvesting, on the other hand, provide infinite operating life of low-power equipment and avoid the need to replace batteries where it is costly, impractical or hazardous. Energy Harvesting (EH) is a process wherein the sources such as mechanical load, vibrations, temperature gradients and light, etc., serve as the resource from which the energy harvested and transformed to obtain relatively small levels of power in the range of nW-mW. The transducer converts one form of energy to other form usually electrical signal. The output obtained from the RF antenna is sent for power conditioning to ensure the operating frequency, voltage and current. The received RF signal is given to the matching network to provide proper impedance matching between the antenna and the signal conditioning circuit. The received RF signal is rectified and passed through the voltage multiplier circuit. In order to get sufficient output voltage to drive the device voltage quadrupler is used in the proposed system. As electromagnetic wave is available in surplus in our surrounding, it can be an uninterrupted resource for the energy generation for the device. Energy storage device is associated with the energy scavenging circuitry to enable the energy scavenged to be utilized for future purpose. The proposed system meets the state-of-the-art in the field of energy harvesting for low power devices using the RF energy harvesting.*

**Keywords:** Energy Harvesting, RF Source, Electromagnetic Field, Low Power Device

## I. Introduction

The process of collecting the energy from the ambient sources in the environment such as heat energy, thermal energy, light source, vibrations, etc. and converting it into electrical energy for the use of energizing and powering the low power electronic devices is called as scavenging of energy or energy harvesting [1]. There are different types of techniques in capturing the energy from the external source of environment such as RF signals, thermoelectric conversion, pressure gradients, solar energy conversion and vibrational excitation. Here the RF (Radio Frequency) signals are used as the input source which has been captured from the ambient surrounding which is freely available in the surplus surrounding. The main sources of RF signals are local wireless network, radio transmitting tower, mobile phones and cordless phones. The Radio Frequency signal is used to transport the information or data from one point to the other. It has a good impact in the portable electronic devices and cellular phones. The ubiquitous electromagnetic wave resource from the radio frequency signal is converted into usable source of electricity. Radio frequency is the rate of oscillation of an AC (alternating current or alternating voltage) along with the electric, magnetic or electromagnetic (EM) field. This radio frequency signal has the frequency ranging from20 kHz to around 300GHz. Batteries play a key role in powering the electronic devices [2]. But the main drawback in using the batteries is that it should be recharged frequently whenever needed and power supply is also required to charge the batteries. It is not possible to get power supply wherever we go. In this the need for batteries are eliminated.

This method of RF energy harvesting requires a capable antenna combined with the efficient circuit which has the capacity to convert RF signals into DC voltage [3]. This energy harvesting has been a prospective technology applied in the several modern low power devices. Such examples of low power devices are fluorescent lamp, light emitting diodes (LEDs), fitness trackers, health care sensors, infant sleep position sensors, notebook processors, etc. The detailed analysis of this proposed

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system is discussed in this paper with the design methodology, block diagram and the description of the system with the output and result.

## II. Methodology

- Selection of RF antenna to receive the Radio Frequency(RF) signal at frequency of 2.4GHz
- Design the matching circuit for providing proper impedance matching between antenna and power conditioning circuit.
- Integrate the rectifier and quadrupler circuit to obtain the desired signal level from electromagnetic wave from the free space.
- Store the output of power conditioning circuit in supercapacitor or utilize the harvested energy for the application (low power electronic device).

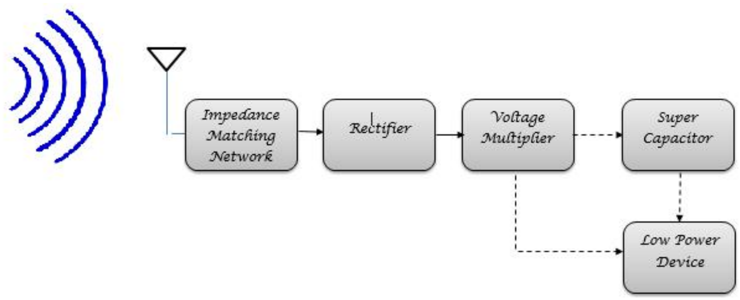


**Figure 1:** Block diagram of the Energy Harvesting (EH) System

### 2.1 Helical Antenna

A helical antenna is a specialized antenna used for both transmitting and receiving RF signals with a frequency of 2.4GHz and Voltage Standing Wave Ratio (VSWR) less than 1.5. At this frequency the gain of the antenna is 1.8dB and has the power handling capacity of 10W. The operating temperature of this helical antenna is -10 to 40ºC.

### 2.2 Impedance Matching Network

Power transfer is maximized by the impedance matching network. An LC network is used to match the antenna terminating impedance and the rectifier circuit. The selection of the impedance network depends on the receiver signal strength [4]. By providing an appropriate impedance matching network, the reflection from the terminating end can be avoided and maximization of the load power is achieved.

### 2.3 Rectifier/Voltage Multiplier

Rectifier converts the AC output from the matching circuit to a pulsating DC voltage. Schottky diode is used for the rectifier circuit making because even at high frequencies it has low energy loss. Output voltage of the rectifier is multiplied using voltage multiplier circuit. There are many types of voltage multiplier, they are: Voltage doubler, voltage tripler and voltage quadrupler. Voltage quadrupler multiplies the input voltage four times and is used in the proposed system. Fig. 2 illustrates the performance of the voltage multiplier circuit.

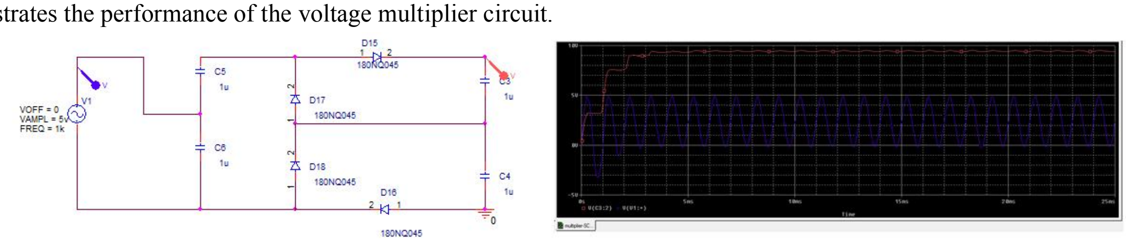


**Figure 2:** Circuit diagram and Simulated output of voltage multiplier


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### 2.4 Power Management

Supercapacitor is a passive element capable of storing electrical energy when connected across the battery or voltage generators. It can replace the rechargeable battery in the system [5]. The harvested energy can be utilized directly for the low power devices or it can be stored in the supercapacitor. It works well in the low voltage range, the charging and discharge is very fast. In the proposed system the supercapacitor range used is 4.7µF to 10µF, mainly for the purpose of future utilization of the harvested energy and to operate the low power electronic devices.

## III. Literature Review

### 3.1 Wireless Network with RF Energy Harvesting

In 2015, X. Lu, P. Wang, D. Niyato, D. I. Kim and Z. Han[6] proposed a RF energy harvesting method in the paper 'Wireless network with RF energy harvesting'. The authors studied a unique case dynamic power splitting by close examination. The receiver is divided into two modes by on-off power splitting policy. The RF energy harvester receives all the RF signals in off mode and the receiver is operated according to the power splitting policy. This policy is favourable for co-located and integrated receiver by the policy of power splitting.

### 3.2 Energy Harvesting through Acoustic Field for Powering Low Power Electronic Devices

In 2017, Sudensa Pattanaik, Samikshya Mishra, Sarbasri Halder and Satyanarayanan Bhuyan [7] proposed a paper 'Energy harvesting through Acoustic Field for powering low power electronic devices'. The authors undergone a systematic enquiry on energy harvesting from sound. This energy harvester constitutes of a metal slit with a metal screen and at the bottom a piezoelectric component is placed. This sound field is converted into electrical energy by the piezoelectric component. The output of this system depends on the shape, size and material of the piezoelectric component and is used for low power devices.

### 3.3 State-of-the-Art Techniques in RF Energy Harvesting Circuits

In 2021, Ionnis D. Bougas, Maria S. Papadopoulou, Acilles D. Boursianis, Konstatinos Kokkinidis and Sotirios K. Goudos [8] proposed a paper 'State-of-the-art techniques in RF Energy harvesting circuits'. In this system the RF antenna captures Electromagnetic wave and is given to an impedance matching network. Output of the impedance matching network is passed through the rectifier which converts the AC voltage to DC voltage to drive the low power battery operated devices.

### 3.4 Energy Harvesting of Ambient EM Waves by Employing Different Antennas

In 2021, Ibetsam O. Radil, Samira A. Mahdil, H.J.Motlak [9] proposed a paper 'Energy harvesting of ambient EM waves by employing different types of RF antenna'. The rectenna in this circuit that tackle and converts ubiquitous RF antenna into DC output voltage. The impedance matching network matches the impedance of rectifier. A load such as supercapacitor and resistor can be used for energy storage.

### 3.5 RF Energy Harvesting and Management

In 2021, Y. Huang, A. Athalye, S. Das, P. Djuric and M. Stanacevic [10] proposed a paper 'RF energy harvesting and management for Near-Zero power passive devices'. This system contains an energy harvesting circuit and a power managing strategy for near-zero power passive devices with backscattering based methods.

## IV. Results And Discussion

To illustrate the operation of the proposed energy harvester simulations of the circuit is performed using PSPICE by using AC source as an input instead of RF signal received via an antenna. In the real time implementation the antenna is used to receive the RF signal from the free space which in turn is couple to the Harvesting circuit via the impedance matching network. In an urban environment based on the RF signal the output voltage of the rectifier is 0.7v. Output of the rectifier is passed to the voltage multiplier in order to boost the output voltage wherein it have to drive the low power device, especially the wearable devices. The output of the voltage multiplier or the final output of the proposed system is 3.2v. This voltage is sufficient to drive the low power device.

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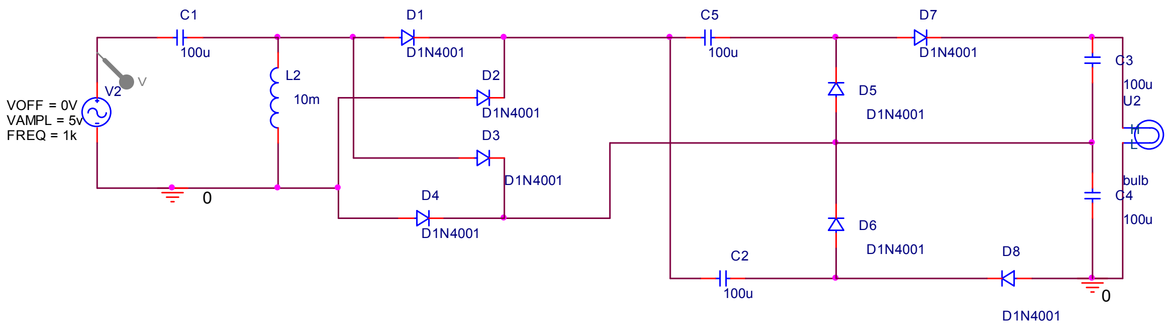


**Figure 3:** Circuit diagram of the proposed system

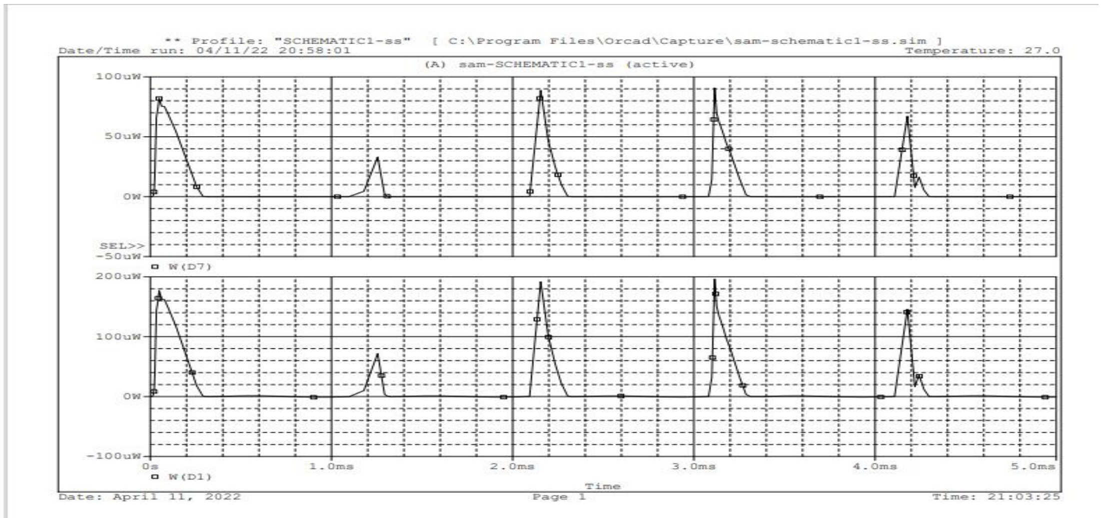

**Figure 4:** Simulated output

## V. Conclusion

The harnessing energy from our surrounding is appealing enough to stimulate the interest from researchers regardless of the obvious challenges of low power levels, low RF-DC conversion efficiency. With the emergence of applications in the field of Internet of Things the EF energy harvesting plays a vital role by providing energy from the environment to the edge devices.RF energy harvesting provides potentially low cost and enduring substitute to batteries especially for sensors used for remote monitoring and health care applications. Efficient multiband antennas, rectifiers tolerant to input power and frequency variations and multiband matching networks are few of the ongoing areas of focus,to enhance the performance of the RF energy harvesting used for real life applications.

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