Energy Harvesting of Ambient E.M Waves by Employing Different Types of R.F. Antenna

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Abstract. Used to operate small electronic devices, such as the cell phones. This work will deal with the electromagnetic signals as a renewable energy sources. An analog circuit will prepare using diodes and a charged capacitance and antenna to convert the energy of ambient E.M. waves (Radio Frequencies RF) to a D.C. voltage. The measurements will be demonstrated using different kinds of antenna. In addition, the ambient RF frequency according to Iraq/ Babylon/ Hilla city will be collected from the communications tower and measured using a receiver circuit. In this paper used three kinds of antenna, wire antenna, air antenna, dish antenna. Measuring the DC Power, the amount of the DC Power that obtained using a dish antenna is approximate the energy that collected using an air antenna. The amount of the DC Power could be controlled by the charging time (RC) of the capacities.

1. Introduction
Finite electrical battery life enables businesses and researchers to come up with creative concepts and developments for an endless or increased period of time to operate electronic mobile devices. Popular resource restricted wireless devices that should be recharged when they run out of battery. We need the main supply and battery to charge empty cell phone batteries or any removable phone batteries for this kind of substance. It is not technically possible to bear chargers everywhere we go even to expect power supply availability anywhere. Any kind of alternative should be given to prevent these drawbacks, and it can be wireless charging of cell phones. If the smartphone can collect RF power signals from the mobile towers, this can be achieved by the RF energy harvesting system or technology called [1]. The RF wave energy used by systems can be harvested and used to perform more reliably and effectively [2], Ambient energy harvesting has been an attractive area of research due to its prospective applications in several modern low-power systems [3]. As this emerging technology enables proactive energy replenishment of wireless devices, it is advantageous in supporting applications with quality of service (QoS) requirements [2], radio frequency (RF) energy harvesting energy from ambient radio frequency signals radiated by different communication sources [3], this is the power to transform the RF signals received into electricity. A potential approach for powering energy-constrained wireless networks is this technique. Conventionally, wireless energy-restricted networks, such as wireless sensor networks, have a brief lifetime that largely limits the
efficiency of the network. [4]. In the other hand, the RF Energy Harvesting Network (RF-EHN) has a renewable energy source from the radio environment. The RF energy harvesting capability therefore enables wireless devices to harvest energy from RF signals for the processing and transmitting of their information. As a result, RF-EHNs have rapidly found their applications in diverse ways, such as wireless sensor networks [5]. In RF energy harvesting, radio signals with frequency range 300GHz to as low as 3kHz are used as a medium to carry energy in a form of electromagnetic radiation [6].

2. Implementation

Radio waves are available everywhere and they are used for Cable, radio, cell phone signal communications, etc. The key components used in communication systems to relay RF power in the KW range are Omni directional antennas. Energy harvesting from ambient electromagnetic (EM) waves is one of the most advantageous technologies for providing these standalone devices with continuous power. [5,6]. In fact, As the receiver sensitivity of cell phone antennas is very high, very little milliwatts of RF power can be extracted from the mobile communication environment. The major cause for such a significant reduction in the transmitted power is the absorption of bodies (i.e. obstacles) present in the path of the RF waves and also the lack of power in the form of heat in materials where it is present [5]. For their operation in sleep and active modes, most wireless devices such as cell phones use just microwatts to mill watts in the power spectrum. So, using the scavenging circuit, we can conveniently access the RF power available in the external world and use it to run our cell phones. Now, to achieve such features, we can see our proposed circuit [6]. The block diagram of different ingredients for the construction of our suggested circuit is shown in figure (1).

![Figure 1. Schematic view of a RF energy harvesting system.](image)

The block diagram displays the circuits that form the rectenna. The antenna signal received is balanced by the circuit of the voltage multiplier, then the circuit of the high output voltage multiplier is used [6]. It was proposed to supply electricity for wireless sensor nodes or other applications from commercial RF transmitting stations such as TV, WIFI, cellular tower or Radar[7].

In recent years, the concept of using A great deal of attention has been paid to radio frequency (RF) resources for low-power electronic devices. To substitute the battery and reduce maintenance costs, [8]. Multiple RF energy sources can be classified into three categories: intentional sources, expected sources for the atmosphere and uncertain sources for the environment. To start up battery-less devices directly and for battery activation, RF energy harvesting or RF energy scavenging may be used. It can also be used to recharge a remote batteryTo power wireless sensor networks (WSN) and to wake up sensors in sleep mode, like a mobile phone. [9]. Using a rectifying antenna called a rectenna, this can be done by translating the ambient EM waves to a workable DC voltage (i.e.,antenna rectifier) [10 ].
The energy supply for wireless sensor nodes or other devices has been suggested from commercial RF transmitting stations such as TV, WF, cellular tower or Radar. Figure (1) The DC power depends on the RF power and RF/DC conversion performance available. How to cope with the frequency-dependent impedance of the antenna and the rectifier is a big issue in the rectenna model. The impedance of an antenna must meet the impedance of the rectification circuit for optimal power transmission. As seen in Figure (1) A rectenna system can be divided into three parts, which are a transmitting antenna, a low-pass microwave filter and a rectifying circuit. The signal is received by an antenna, the operating frequency of which must be the same as that of the signal. The power of the RF incident signal is transformed by the rectifier circuit to a dc signal. An impedance balancing network of inductive and capacitive components is implemented between the antenna and the rectifier, That guarantees full power supply from the antenna to the rectifier[9]. The RF energy harvesting circuit is generally known as the impedance matching network and rectifier circuit. As seen in the diagram, a typical rectifying antenna device typically consists of five separate sections. [10,11].

1- A transmitting antenna that is designed to receive RF signals from random signals in the ambient environment (WEH). The input impedance of the antenna is normally calibrated to norm 50 Ω. The antenna is an integral part of the rectenna and should have some criteria for harnessing and translating the ubiquitous RF energy into a functional DC output voltage, so that the antenna can receive all the ambient RF energy available in the surrounding multiple frequency sources.

2- To reject the higher order harmonic signals produced by the rectifier by a band pass filter, Since the signals could be radiated by the antenna, which could decrease the overall efficiency of conversion and cause interference. The filter may either be combined with the antenna to create a filtering antenna structure [12].

3- An impedance matching network that is designed to adjust the rectifier's complex impedance to a resistive port (e.g. 50 Ω). The power of the received signals will then be entirely transferred to the rectifier. impedance-matching network is an integral requirement in a rectenna design , The Rectenna's RF-DC conversion efficiency relies strongly on its impedance-matching network. The layout of the matching network is difficult and requires many factors. This is due to the fact that both the rectifier circuit and antenna input impedance values change with frequency.

4- A rectifier that is tailored to change power from RF to DC. The rectifier's input impedance ranges in a wide variety of values and the impedance is very responsive to frequency, input power and load impedance variations, a rectifier should have good performance of RF to DC conversion. The choosing of diode is usually carried out by one or more diodes, since it can be significant reason for failure and its efficiency dictates the overall efficacy of the device[13].

5- A load that may normally be a resistor or a super capacitor for energy storage
A figure displays the high-level model flow for a simple RF energy harvesting circuit (2). This particular configuration flow is for the purpose of charging a Lithium Ion battery, but these measures are also required to feed a low-power system using RF energy harvesting. The architecture in this research focuses on the circuitry of processing, which includes filtering (C₃, C₄ and D₁, D₂), switch mode power conversion (C₁, C₂, and D₃, D₄). C₃,C₄=100 µF, C₁,C₂=20 nf .D₁,D₂,D₃,D₄= Single diode, C₁,C₂= electrolytic capacitor and C₃,C₄=ceramic capacitor

![Design RF energy harvesting circuit](image)

**Figure 2.** design RF energy harvesting circuit.

The circuit itself exhibits nonlinearity, because the energy harvesting circuit consists of diodes, which are nonlinear devices [13]. This ensures that the energy harvesting circuit's impedance changes with the amount of antenna power produced. Because when the circuit is combined with the antenna, the full power transfer occurs, the impedance matching is typically achieved at the same input power. The impedance matching network converts impedance to ensure optimal power distribution [14]. In the ideal case, the highest output voltage is achieved at the resonant frequency of antenna having inductance L [15].

\[ f = \frac{1}{2\pi\sqrt{LC}} \]

### 3. Experimental Results

#### 3.1. Without Antenna

Figure (3-a) shows the circuit connection without using an antenna, Figure (3-b) displays the amount of energy (DC. voltage) on the screen of the oscilloscope at T= 0 minute and Figure (3-c) shows the amount of energy T= 3 minutes. This is representative of the exponential recovery function, which is the predicted charging characteristic of the capacitor. These findings show the RF energy harvester's proof-of-concept, as well as validating the processing circuitry’s ability to rectify the RF signal received. These findings, however, indicate that the boost converter can not work as planned. The booster converter was engineered to output a voltage of approximately 5V, which is far higher than the real voltage calculated through the capacitor. The potential explanation why the booster converter does not produce the desired output is that the cool-start voltage of the converter is 215 mV and that the RF energy harvester is unable to reach this threshold due to the combination of the converter: insufficient power received poor power transfer.
Table 1. The amount of DC. Voltage.

| Antenna            | V(mv) | T(min) |
|-------------------|-------|--------|
| Without antenna   | 20    | 0      |
|                   | 22    | 3      |

3.2. With Wire Antenna:

The wire antenna has been suggested to get more energy from RF signal. Figure (4-a) show circuit design, and the amount of the DC voltage on the oscilloscope screen at time (0,3) minute shows in Figure (4-b, c) respectively. Although the input power obtained from the antenna varies over time, The RF energy harvester will have to sustain a voltage level of at least 625mV at the input of the boost converter even though the threshold is exceeded. Using an electrolytic capacitor for research is an added challenge that may restrict the maximum output voltage reached by the circuit. In a low power application like the one discussed here, the leakage current of the capacitor may have a substantial negative effect on the output voltage. If the output current decreases to a degree equivalent to the capacitor's leakage current, Then the capacitor no longer receives a charge. Many design changes are required to make the processing circuitry a feasible solution for the processing of RF signals obtained from an antenna for the purpose of charging a lithium-ion battery with all of the above problems.
Table 2. The amount of voltage.

| Antenna       | V(mv) | T(min) |
|---------------|-------|--------|
| wire antenna  | 50    | 0      |
|               | 75    | 3      |

3.3. With air antenna:
The results of air antenna recorded at t= (0, 3) min. as shown in Figure (5) and Table (3). The amount of voltage has been increased up to 400mv at t=0, and 700 mv at t=3min. That's because the air antenna has an ability to capture the ambient E.M. waves more than the wire antenna.

Figure 4. The circuit and the amount of the DC voltage on the oscilloscope screen (a) circuit design, (b) at time (0)minute and (c) after (3)minute.

Figure 5. The circuit and the amount of the DC voltage on the oscilloscope screen (a) air antenna, (b) circuit design, (c) at time (0)minute and (d) after (3)minute.
Table 3. The amount of voltage.

| Antenna    | V(mv) | T(min) |
|------------|-------|--------|
| air antenna| 400   | 0      |
|            | 700   | 3      |

3.4. With Dish Antenna:

The results of dish antenna have been recorded at $t = (0, 3)$ min. as shown in Figure (6) and Table (4). The amount of voltage has been increased up to 280mv at $t=0$, and 800 mv at $t=3$min. obviously, the value of the energy gain in this case is approximately equal the value of the energy gain in case of air antenna. It may be referred to the size of the dish antenna as compare as with the size of air antenna.

![Figure 6](image.jpg)

Figure 6. The circuit and the amount of the DC voltage on the oscilloscope screen (a) circuit design, (b) air antenna, (c) at time 0 minute and (d) after 3minute

Table 4. The amount of voltage.

| Antenna     | V(mv) | T(min) |
|-------------|-------|--------|
| Dish antenna| 280   | 0      |
|             | 800   | 3      |

4. Conclusion

1. The ambient RF frequencies are a considerable, powerful, and promised source of energy.
2. The amount of the DC. Voltage that collected from the RF frequencies without antenna can be consider and employed after using an amplifier circuit.
3. The wire antenna gives a significant improvement in the value of DC Voltage as compared with other kinds of antennas.
4. Although the air antenna raised the DC Power to a high level, the shape and the large size of the antenna could be limited to its use.
5. The amount of the DC Power that obtained using a dish antenna is approximately the energy that collected using an air antenna.
6. The amount of the DC Power could be controlled by the charging time (RC) of the capacities.

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