A SIMPLE CONCEPT OF ENERGY HARVESTING USING RADIO FREQUENCY

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Abstract

Energy harvesting is a process where certain sources is extracted and converted into DC output by connecting relevant circuits. This energy harvesting technique can reduce the usage of electricity for small power consuming devices. Some of the techniques of energy harvesting is solar energy, wind turbine, radio frequency and vibrations. Radio frequency energy harvesting can be done from the surrounding sources or from dedicated sources. This energy harvesting consists of several stages processing which starts with a 50ohms radio antenna, matching network and rectifier circuit and end as product of DC output. The proposed technique of energy harvesting is by connecting the radio antenna to an L-matching network and then to a single

stage rectifier circuit to test the output obtained. The output is test using the digital multimeter in milliVolt (mV).

Keywords

RF Energy Harvesting, DC power, Matching Network, Rectifier Circuit, Frequency Modulation

1. Introduction

Energy harvesting is a process that captures small amounts of energy that would otherwise be lost as heat, light, sound, vibration or movement. Energy can be harvest in various ways. The energy harvested has can be used as batteries for small and low power electronic devices. Energy-harvesting opportunities are being enabled by new circuits that can capture and store these small energy packets and convert them into useful output. An electric field dependably creates an attractive field and a period variable attractive field dependably delivers an electric field. The prompting law of Faraday portrays the adjustment that an attractive field will impel in an electric current. Thus, the condition of Ampere-Maxwell expresses the change created by an electric field into an attractive field. There are now a few sorts of electrical generators that utilization mechanical vibrations, including the individuals who are available in watch and radio recurrence circuits. These can utilize the vitality recuperated from the common habitat. There are two sorts of mechanical generators: the individuals who utilize the relative movement of articles in which the era framework is associated and those that utilization inflexible body movement (Paulo, J., & Gaspar, P. D., 2010).

2. Literature Review

A RF vitality gathering system has a manageable force supply from a radio domain. Hence, the RF vitality reaping capacity permits the remote gadgets to gather vitality from RF signals for their data preparing and transmission. Thus, vitality gathering have discovered their applications rapidly in different structures, for example, remote sensor systems (Nishimoto H. et al.) wireless body networks (Zhang, H.et al.), and wireless charging systems. With the inexorably rising uses of RF vitality collecting/charging, the Wireless Power Consortium is additionally trying the endeavors of building up a global standard for the RF vitality reaping strategy. Radio

recurrence (RF) vitality reaping requires adequate levels of encompassing RF vitality thickness to be successful.

2.1 Circuits

The voltage level of the RF signal usually varies from 0.15V to 1V respectively, which is not sufficient to drive any device. The topology used for our rectifier is Greinacher voltage doubler circuit. It is also known as single stage Cockroft-Walton voltage multiplier circuit. Fig 1 shows the schematic diagram of Rf energy harvesting circuit.
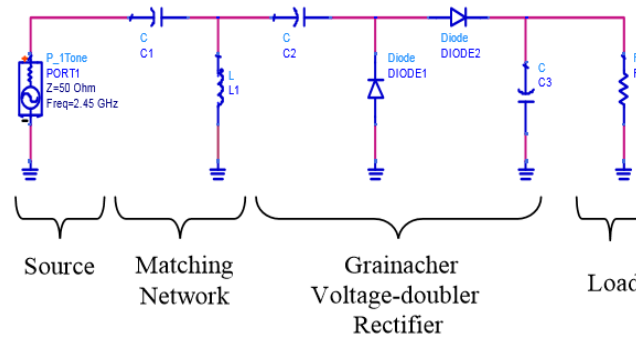

Figure 1: *Radio Frequency energy harvesting circuit*

2.2 Antenna

An antenna is an electromagnetic radiator; it makes an electromagnetic field that returns out from the transmitting receiving wire to the collector's reception apparatus, which then changes over the electromagnetic wave into electrical signs that are connected to the recipient's info stages. The reception apparatus has the undertaking to gather the episode electromagnetic waves that are spread by a RF transmitter. On the one hand, the gain of the antenna should be as high as possible to increase the received power. The impedance of the antenna is 50 Ω, which is the same value typical RF measurement devices have (Merz, C., et al.)

2.3 Matching Network

The coordinating system comprise of a capacitor, which has an estimation of 2.2nF and an inductor of 100mH. This coordinating system is to guarantee that there is most extreme force

dispersed from the radio wire to the rectifier circuit. A minimum estimation of inductor is picked together with a slightest estimation of capacitor. This is to make it as an impedance coordinating system. At whatever point a wellspring of power with settled yield impedance such as an electric signal source, a radio transmitter or a mechanical sound works into a load, the most extreme possible power is conveyed to the heap when the impedance of the heap is equivalent to the complex conjugate of the impedance of the source.

2.4 Rectifier Circuit

The rectifier used for this experiment is a single-stage Greinacher Circuit. This circuit consists of two Schottky Diodes and two capacitors. The Schottky Diode that has the serial number of IN5822. With the utilization of capacitors and diodes, these voltage multipliers can venture up low voltagesto high voltages, while in the meantime being far lighter and less expensive than transformers. The greatest preferred standpoint of such circuits is that the voltage across every phase of the course is equivalent to just double the crest information voltage in a half wave rectifier. The circuit redresses the approaching sign as well as duplicates the top adequacy. With expanding stages, the yield DC voltage gets higher, however the misfortunes additionally increment with every stage. Fig 2 shows the Single-Stage Greinacher Circuit.
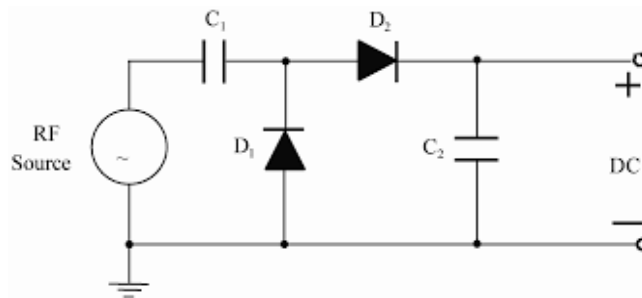

Figure 2: *Single stage Grenache Circuit*

3. Methodology

The significant objective in outlining an effective RF reaping framework is to deliver DC yield power. Different natural RF vitality wellsprings of various frequencies are gathered by a properly outlined receiving wire, and conveyed to the amendment circuit by means of a

multiband coordinating system. The amendment circuit changes over the mix of RF signs into DC for low power application. The general block diagram for the proposed system is shown in the Figure 3.
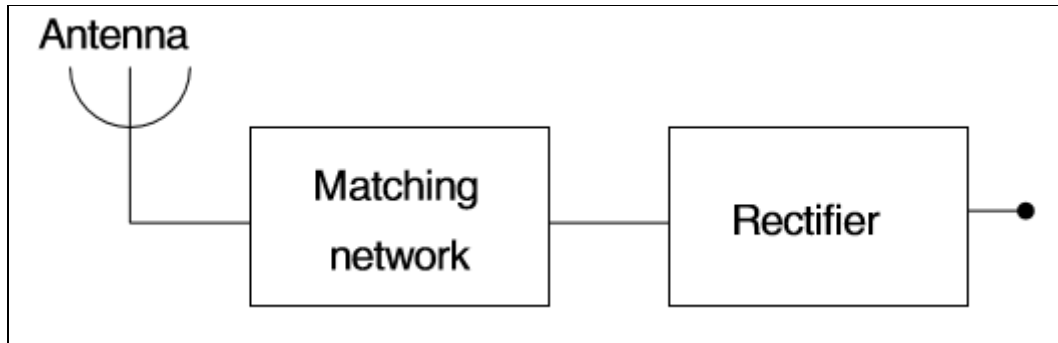

Figure 3: *Block diagram of RF Energy Harvesting*

3.1 Antenna

The reception apparatus utilized for this circuit is an ordinary radio receiving wire which has resistance if 50 Ohms. The receiving wire of the transmitter radiates high recurrence vitality into space while the radio wire of the recipient gets this and proselytes it into power. These time-changing fields emanate far from the receiving wire into space as a moving transverse electromagnetic field wave. On the other hand, amid gathering, the swaying electric and attractive fields of an approaching radio wave apply power on the electrons in the reception apparatus components, making them move forward and backward, making wavering streams in the receiving wire. A radio reception apparatus was connected to jumper by patching. It is less demanding to interface with the bread board for circuit association and testing.

3.2 Matching Network

Matching network connection that has selected for this experiment is L-matching network. The matching network consists of a capacitor which has a value of 2.2nF and an inductor of 100mH. This matching network is to ensure that there is maximum power dissipated from the antenna to the rectifier circuit. A least value of inductor is chosen together with a least value of capacitor. This is to make it as an impedance matching network. For two impedance to be perplexing conjugates their resistances must be equivalent, and their reactance must be equivalent in size however of inverse signs. In low-recurrence or DC frameworks (or frameworks with absolutely resistive sources and loads) the reactance are zero, or sufficiently

little to be disregarded. For this situation, most extreme force exchange happens when the resistance of the heap is equivalent to the resistance of the source.

3.3 Rectifier Circuit

The rectifier used for this experiment is a single-stage Greinacher Circuit. This circuit consists of two Schottky Diodes and two capacitors. The Schottky Diode that has the serial number of IN5822. The value of capacitors that has been used is equally 470uF. Utilizing just capacitors and diodes, these voltage multipliers can venture up generally low voltages to amazingly high values, while in the meantime being far lighter and less expensive than transformers. The greatest favorable position of such circuits is that the voltage across every phase of the course is equivalent to just double the top information voltage in a half wave rectifier. The circuit redresses the approaching sign as well as duplicates the top adequacy. With expanding stages, the yield DC voltage gets higher, however the misfortunes likewise increment with every stage.

3.4 DC Output

The frequency produces values for every testing that is carried out. To obtain the values of DC voltage that has been produced, a digital multimeter is used. The output is differentiated with red and black jumpers. The multimeter is probed at the output side to check the DC obtain. For every test carried out, three values are taken and the average is calculated for comparison and to sketch a graph. The digital multimeter is set to milli-Volt for the readings.

4. Results
4.1 Indoor Testing

The proposed circuit is connected which consist of an antenna, matching network and rectifier circuit. The output is tested using the digital multimeter.

The complete circuit test has been carried out using the digital multimeter to measure the value of DC output. In this test, the entire component such as capacitors and inductor are connected. The test is carried by tuning a transistor radio to certain frequency and probing the output to the digital multimeter. The FM signal is attracted with the antenna that has been connected to the

circuit. It produces output according to the frequency tuned. The readings were taken three times for an average value because of the fluctuating output due to the vary signal strength.

The output is listed in a table with the respective frequency tuning. Table 1 shows the frequency tuned and the respective output measured from the experiment that is carried indoor.

Table 1: *Results of Indoor Testing*

F(MHz)	V1(mV)	V2(mV)	V2(mV)	V(mv)
88.6	0.6	0.6	0.6	0.6
89.9	0.7	0.7	0.6	0.67
90.2	0.8	0.9	0.8	0.83
92.8	0.8	0.8	0.7	0.76
94.5	0.8	0.9	0.9	0.86
97.1	0.9	0.9	0.9	0.9
98.9	1	0.9	1	0.96
99.3	1	1	1	1
102.4	1.1	1.1	1.1	1.1
103.5	1.2	1.1	1.1	1.13
105.3	1.2	1.2	1.2	1.2
106.9	1.3	1.3	1.3	1.3

From the data collected, a graph is constructed with the frequency tuned and the average value obtain as shown in Figure 4.
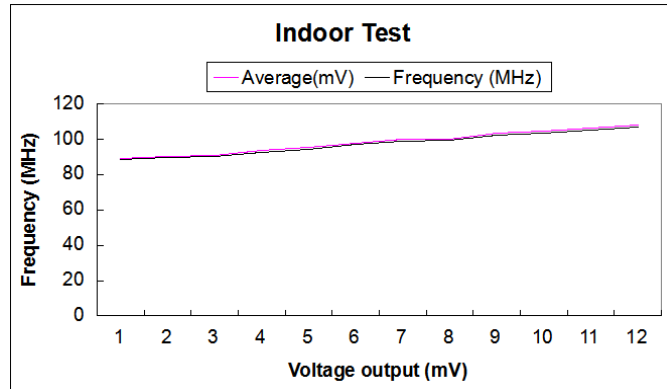
Figure 4: *Graph of Indoor Test*

The graph shows that the output increases as the frequency increases. There is a very slight change in the output for every frequency tuning. The lowest frequency tested was 88.6MHz and the average DC output obtain is 0.6mV while the highest frequency tested was 106.9MHz and the average DC output is 1.3mV. In the difference of 18.3MHz, the difference in DC output is 0.7mV.

4.2 Outdoor Testing

Another test is carried out at an open space. The circuit is place on a table in the field. The complete circuit is tested with the multimeter. The list of frequency tested and the respective DC output is listed in a table for comparison. Each frequency is tested three times for average values.

From the test, a table is constructed to compare the values obtain. The average is calculated and a graph is plotted from the table.

Table 2: *Results of Outdoor Testing*

Frequency (MHz)	V1(mV)	V2(mV)	V3(mV)	Average
88.6	1.5	1.4	1.6	1.5
89.9	1.2	1.2	1.5	1.3
90.2	1.5	1.7	1.8	1.67
92.8	1.8	1.6	1.9	1.77
94.5	1.8	1.8	1.8	1.8
97.1	1.9	1.9	2	1.93
98.9	2	1.9	2.2	2.03
99.3	1.9	2	2.3	2.07
102.4	1.8	1.9	2.2	1.97
103.5	2	2.1	2.4	2.17
105.3	2.2	2.2	2.5	2.3
106.9	2.3	2.2	2.6	2.37

From the table, it is observed that the values obtain at outdoor testing is higher than other test. This shows that the signal is higher at outdoor as it does not interfered by anything.

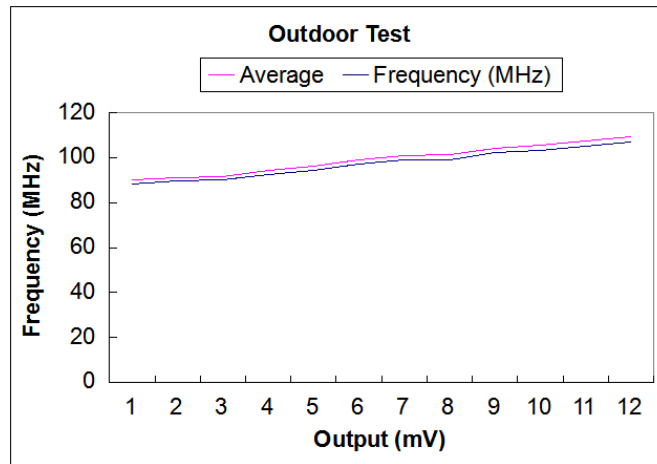The graph in Figure 5 shows the values obtain as the signal is tuned.

Figure 5: *Graph of Outdoor Test*

4.3 High Amplitude Testing

When the amplitude increase, the strength of signal reduces. In other words, the frequency is inversely proportional to the amplitude thus the DC output gets lower when the signal strength is lower. A test was carried out without the inductor at the matching network at Penang Hill, which is at the height of 712m above sea level. The frequency and output obtain is listed in table.

Table 3: *Results of High Amplitude Testing*

Frequency (MHz)	V1(mV)	V2(mV)	V3(mV)	Average
88.7	0.6	0.5	0.5	0.53
89.9	0.8	0.7	0.8	0.76
90.2	0.8	0.9	1.1	0.93
92.8	1.1	0.9	1.2	1.07
94.6	1	1.3	1.5	1.27
97.1	1.2	1.3	1.5	1.33

98.8	1.2	1.4	1.5	1.37
99.3	1.1	1.4	1.6	1.37
102.4	1.6	1.3	1.6	1.5
103.6	1.7	1.5	1.8	1.67
104.4	1.7	1.6	1.9	1.73

It is observed that the DC output increases as the frequency increase. But somehow, the values are still less because the signal strength decreases as the amplitude increase. The maximum DC obtains is 1.73mV average. This proves that the signal strength is lower at higher amplitudes. Figure 6 shows the graph obtained.
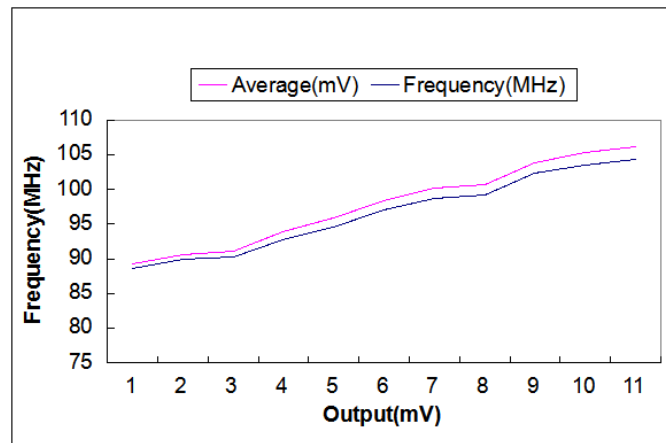

Figure 6: *Graph of High Amplitude Test*

5. Conclusion

DC energy can be produced by various techniques of energy harvesting from environment. The output for RF energy harvesting is very low. For DC output of the harvested energy, there are many factor that affects the power obtain. The output differs when there is a change at the place of testing. By comparing the values that has been tested at several places, the

values are very low and changes according to the places. For an example, the value obtain when tested inside a building is different from the values obtain while tested at outdoor. The reason for this issue is, the radio frequency (FM) gets refracted when it hits a building. From this, we can conclude that the FM signal travels in a straight line and refracts as it hits buildings.

These days there are a dynamic examination territory exploring a number approaches to concentrate vitality from the earth sources and change over it to electrical vitality to control an electronic gadget. It is normal that vitality reaping will have critical part in future microelectronic gadgets for various reasons. Energy can be harvested in various ways. Every way of energy harvesting has their own technique and output according. For RF energy harvesting, a simple antenna, L-matching network and rectifier circuit can produce a very low DC output. A matching technique using a simple L-network has been used in order to boost the efficiency of RF harvesters at low power levels.

RF energy harvesting is affected by many surrounding factors. The signal strength at indoor is lower than outdoor. This is because FM travels in a straight line and refracts as it hits building. Besides that, the signal strength reduces as the amplitude increase. This can cause the FM to be very low and interrupted thus the energy harvested is very low. The values keep fluctuating because the signal varies continuously. Ambient energy harvesting can also provide an extended lifespan and support to conventional electronics systems.

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