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Design of Self Powered System Prototype Based on Radio Frequency Energy Harvesting

Perancangan Prototipe Sistem Bertenaga Mandiri Berbasis Pemanenan Energi Frekuensi Radio

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Abstrak

Perangkat elektronik umumnya ditenagai oleh sumber daya seperti stopkontak AC atau sumber daya DC seperti baterai. Baterai memiliki masa pakai yang terbatas, sehingga perlu diisi ulang jika baterai tersebut dapat diisi ulang. Dalam makalah ini, kami menyajikan perancangan sistem daya independen di mana daya tidak berasal dari stopkontak AC, melainkan daya diperoleh dari hasil pemanenan energi frekuensi radio. Frekuensi yang dipilih adalah frekuensi untuk seluler yang dipancarkan dari Sistem Transfer Basis Operator Telepon Seluler. Sistem Pemanenan Energi Frekuensi Radio menangkap sinyal RF menggunakan antena monopole, kemudian sinyal RF tersebut diubah menjadi tegangan DC (konverter RF ke DC) oleh rangkaian pompa pengisian daya yang juga berfungsi sebagai penguat yang dirancang untuk pengganda tegangan 5-tahap. Sistem ini terintegrasi dengan regulator penguat untuk menaikkan level tegangan dan mengatur tegangan konstan. Tegangan yang dihasilkan dari sistem adalah 300 mV pada jarak 100 m dari BTS dan 3,9 V pada jarak 30 cm dari telepon seluler. Pengujian lain dilakukan dengan indikator LED dan memasok daya untuk proses pengisian daya ke baterai AAA Ni-MH isi ulang.

Kata kunci: antena monopole, frekuensi radio, pemanenan energi, seluer, sistem daya independen.

Abstract

Electronic devices are generally powered by a power source such as an AC socket or a DC power source such as a battery. Batteries have a limited lifespan, so it is necessary to recharge the battery if the battery is rechargeable. In this paper we present a design for an independent power system where the power does not come from an AC voltage socket, but the power is obtained from the results of radio frequency energy harvesting. The selected frequency is the frequency for cellular that emitted from the Cell Phone Operator's Base Transfer System. The Radio Frequency Energy Harvesting system catch RF signal use monopole antenna receiver, then the RF signal converted into DC voltage (RF to DC converter) by a series of charge pump that also serves as amplifier which designed to 5-stage villiard multiplier. This system integrated by boost regulator to raise the level of voltage and regulate constant voltage. The voltage result from system is 300 mV at 100 m from BTS and 3,9 V at 30 cm from mobile phone. Another test with a LED indicator and suplying a power for charging process to battery AAA rechargeable Ni-MH.

Keyword –cellular, energy harvesting, independent power system, monopole antenna, radio frequency.

1. Introduction

Electronic devices, including mobile phones, have evolved rapidly since their commercial introduction in the 1980s, driven by technological advancements and the number of users. The smartphone era has made mobile phones essential, constantly accompanying every human activity. When using a mobile phone, it's impossible to be without a power source. It's a shame if a phone's mobility stops when the battery runs out and it's difficult to recharge due to distance from a power source. Various solutions have emerged, ranging from increasing battery capacity, producing power banks, and various other solutions, including utilizing renewable energy.

Energy harvesting is the process of taking energy from one or more environmental (solar, wind, radio frequency, etc.) or other energy sources (body heat, finger strokes, foot strikes, etc.), accumulating them and converting them into usable electrical energy[1]. Thus energy Harvesting can be also called the process of collecting or harvesting of ambient energy[2]. Refers to [3], RF energy harvesting has the following characteristics:

- RF sources can provide controllable and constant energy transfer over distance for RF energy harvesters.
- In a fixed RF-EHN, the harvested energy is predictable and relatively stable over time due to fixed distance.
- Since the amount of harvested RF energy depends on the distance from the RF source, the network nodes in the different locations can have significant difference in harvested RF energy.

Radio Frequency (RF) is a potential ambient energy sources that support mobility and availability energy. The RF waves are available twenty-four hours and cover large areas and used on variety of modern human life technologies. Base Transceiver Station (BTS) and mobile phone are the source of RF waves. If this RF wave can be harvested and used, it will be obtained an alternative energy source that is available continuously and available anywhere and anytime. Thus it can replace battery resource or can be used to fill up the battery on a mobile phone device. It means that self powered system has been established. The system can supply a power without connected to AC power socket or a system capable to self-producing power.

A mobile phone device can utiliy BTS both of as a base of sending and receiving telecommunication data and as a source of energy. Based on the reason, the research interested in designing a self powered system prototype based on radio frequency energy harvesting.

2. Research Methodology

As follow is the research methodology that is used, those are system modelling, requirements analysis, system design and simulation, system implementation, and system testing.

2.1 System modelling

In the system modelling here, the system that is going to design is presented using a block diagram, as shown in Figure 1 as follow.

Figure 1. System modelling block diagram

From figure 1, it can be seen that the system has three main blocks, namely antenna, power harvester (rectifier and voltage doubler) and load (system load). All of these parts are the basis for the performance of an independent power system with a 900 MHz GSM signal as the energy source to be harvested.

2.2 Requirements analysis

Based on the system modelling above, the first need to build an RF energy harvester is an antenna. The antenna is needed to capture RF wave on the air.

The second need is a power harvester. The power harvester is needed to rectifies the power captured by the antenna (conversion from AC signal to DC signal) and increases its value by the power harvester circuit. This DC signal is increased so that it reaches the constant voltage value needed to carry out the battery charging process.

The last need is a load. The load is a block of parts that is used as an indicator of system execution results and acts as a result of device performance so that it can be used as a comparison with the results of design simulations. In this research, the load from the system output is a battery storage medium for the recharging process.

2.3 System designed and simulation

There are some activities in system design, those are Selection of antenna type and field of work, Determining the power harvester arrangement, Calculation and selection of power harvester Components,

1. Selection of antenna type and field of work

The antenna used is a monopole antenna which has the ability to pick up cellular signals with a frequency width of 900 MHz (GSM 900). In Indonesia, the GSM 900 uses frequencies ranging from 890 - 915 MHz which are paired with 935 - 960 MHz [11], (1), so a receiver antenna with a bandwidth of 70 MHz is needed to capture the entire GSM 900 signal. The next consideration for choosing the type of antenna is ease and simplicity in design and manufacture. Special antenna design requires more attention so that it will guarantee an antenna with better performance and efficiency. The antenna specifications are shown in table 1 as follows.

Table 1. The antenna specifications

No	Parameter	Value
1.	Frequency	900 MHz
2.	VSWR	≤ 5 dB
3.	Antenna Type	Monopole
4.	Impedance	50 Ω

To determine the length of the antenna, information about the wavelength is required so as to meet the equation [6]:

$$\lambda = \frac{c}{f} \tag{1}$$

where λ= Wavelength (meters), c= Velocity of wave propagation in the air (m / s), f= frequency (hertz)
If the frequency used is GSM or F = 900 MHz, the wavelength is

$$\lambda = \frac{300 \times 10^6}{900 \times 10^6} = 0{,}33 \text{ meter}$$

The dimensions of the antenna used are monopole antenna 1/8 λ, then found the length of antennas of the antenna Dimension used is monopole antenna 1/8 λ, then found the antenna length is

$$L = \frac{1}{8} \times 0{,}33 = 0{,}04125 \text{ m} = 4{,}125 \text{ cm}$$

The antenna dimension used is 1/8 λ monopole antenna, the antenna length is

$$L = \frac{1}{2} \times 0{,}33 = 0{,}165 \text{ m} = 16{,}50 \text{ cm}$$

So the required antenna length is ± 4.13 cm or ± 16.50 cm.

2. Determining the power harvester arrangement
   This power harvester circuit is a voltage multiplier circuit with n stages. The use of a voltage multiplier circuit can be done in several forms, some of the well-known arrangements are Dickson, Villiard, and Heinrich. Based on the article published by Kavuri in [14], the Villiard arrangement is used in this system. The optimization carried out makes the Villiard arrangement relatively more suitable for use in low voltage input systems which will be used as independent power systems with RF energy harvesting.

3. Calculation and selection of power harvester Components
   Diode selection: The diode type and specification are shown in table 2 as follows.

Table 2. The diode type and specification

Diode type	Specification		
	BAT 63 diode	Schottky HSMS-2820 diode	Zero Bias HSMS-2850 diode
Work frequency	Up to GHz	<4,0 GHz	915 MHz to 5,8 GHz
Maximum Forward Voltage	300 mV	340 mV	150 mV (0,5 A) 250 mV (1,9mA)
Maximum Reverse Voltage	3 V	1 V	-
Voltage Sensitivity	-	-	40 mV/µW (915 MHz)
Typical Tangensial Sensitivity	-	-	-57 dBm (915 MHz)
Junction Capasitance	0,85 pF	0,7 pF	0,18 pF
Resistance Series	30 Ω	6,0 Ω	25 Ω

Stage capacitor value: Stage capacitance is a very important parameter sensitive. Small changes in a capacitance can cause changes very drastic output voltage. These capacitance parameters are described in equation 2 as follow

$$Q = C\ (Vt) \tag{2}$$

Where Q = Charge on the capacitor (coulombs), C = Capacitance in the capacitor (Farad), V = Voltage through the capacitor (volts)

In this equation, the voltage through the capacitor is proportional to the magnitude of the capacitance. With the same input voltage value, the capacitance value must be smaller to produce a larger voltage through the capacitor. The use of stage voltage multiplier capacitors generally uses two types of magnitude variations, the first variation is that a different capacitor capacitance is used for each stage, in this variation the stage size is large. used is half the capacitance of the previous stage. While the second variation uses the same capacitance size on each stage, in this study the same capacitor size is used on each stage. The capacitance calculation uses the following equation 3.

$$V_{out} = 3V_{in} + \frac{2\,I_L\,T}{c} \tag{3}$$

Where I_L = Current flowing on diode (in datasheet), T = Periode or $\left(\frac{1}{F}\right)$, C = Capacitance on capacitors (Farad)

So to get the voltage out 5 volts at a frequency of 900 MHz with a large current of 500 mA that through the diode Schottky HSMs 2850, and the power input 0.5 V obtained:

$$c = \frac{2\,I_L\,T}{V_{out} - 3V_{in}} = c = \frac{2\,.\,500\,.\frac{1}{900\times10^6}}{5-3\,.\,0{,}5} = 317\times10^{-9}\text{F}$$

Based on the large calculation of the stage capacitance is 317 nF while the capacitor fabrication sold in the market is 330 nF. With this method of interlink approach is ignored, the reason remains within the tolerance range.

Determining Number of stages: Determining the number of stages uses the Villiard equation principle multiplier. This equation is used because the voltage multiplier circuit used is a development from Villiard. Number of stages used greatly affects the resulting voltage. In general, the output voltage can increase if the number of stages increases or is greater. However, in practice there must be a limit on the number of stages used. The equation for determining many stages can be seen in equation 4 as follows.

$$N_{Optimum} = \text{INT}\left(0{,}521\,.\frac{V_{out}}{V_{in}}\right) \tag{4}$$

Where: N = Number of Stages, Vout = Output Voltage (volts), and V_{in}= Voltage Input (Volt).

The input voltage in the system is the RF with the AC signal captured by the antenna. This AC signal has a very small value. The value of the AC signal is obtained using the Friss equation in the equation 5 as follows.

$$P_r = P_t G_t G_r \frac{\lambda^2}{(4\lambda)^2 r^2 L} \tag{5}$$

$$P_r = P_t G_t G_r \frac{1}{16\,r^2 L}$$

The known parameters to meet the equation calculation above are:
Transmitter Power (Pt) = 4.5 Watt (assuming GSM BTS power level expected according to WHO standard for 900MHz frequency)
Gain antena transmitter (G_t) = 18 dBi = 63,1 mW
Gain antena reciver (G_r) = 5 dBi = 3.16 mW
Distance Tx with Rx (r) = 100 meter
System losses (L) = 1 (No Losses)
AntennaImpedance (Z)= 50,0 Ω

$$P_r = 4{,}5\text{x}\,10^3\ .\ 63.1\ .\ 3.16\ \frac{1}{(16)\,(100)^2 1}$$

$$P_r = 5{,}61\text{ mW} = 0{,}005\text{ watt}$$

$$V_{in} = \sqrt{P_r\,.\,Z} \tag{6}$$

P_r = Power of receiver
Z = Impedance or Capacitance

$$V_{in} = \sqrt{0{,}005\,.\,50} = 0{,}5\text{ volt}$$

Thus, the optimal stage count based on equation 2 is obtained to produce an output voltage of 5 volt.

$$N_{Optimum} = \text{INT}\left(0{,}521\,.\frac{5}{0{,}5}\right) = 5$$

The 0.005 watt value that has been calculated is an ideal theoretical power value considering the power level assumption and assumption of power gain transmitter of the BTS acceptable antenna without calculating losses. This value will change if large losses due to power transmission in the air, poor antenna

performance after fabrication, the effect of impedance maching between antennas with voltage multiplier circuit which is slightly difficult to count mathematically. Thus, for a large calculation of the AC signal voltage is carried out an approach by assuming the input power received the antenna as a source system voltage of-10 dBm up to 0 dBm. The value of this assumption will also be used as reference to the simulation process as a comparison of manual calculations.
Based on calculation, the optimal stage number of the series is 5 stage multiplier. And according to the analysis of the needs, the components that have been used is active components and passive components,. Shown in the table 3 as follows.

Table 3. Voltage Multiplier Design Components

Component	Label	Value
Capacitor Stage	C_1-C_{10}	330 nF
Dioda Stage	D_1-D_{10}	HSMS 2850
Capacitor Filter	C_{11}	100 nF
Resistance	R_1	100 kΩ

4. Determining system load specifications (Load)
The type of mobile phone used as a test is the Nokia Lumia 630, where this mobile phone functions as a transmitter and comparator in the charging process that can be carried out by the system. Regarding specifications, this mobile phone has a maximum talk time (when connected to a 3G network) of 13.1 hours, a maximum dual SIM standby time of 25 days and has a 1.2 GHz Quad-core processor. Talk and standby times are appropriate with the specifications listed on the official Nokia website. Actual time is affected by network conditions, device settings, features in use, battery condition and temperature. Meanwhile, the battery used is a 1430 mAh/3.7V Lithium-ion battery. Based on this information, the amount of energy that can be stored in the battery is calculated using equation 7 as follow.

$$W = Vit \tag{7}$$

W = work (joules or watt hours), V=Voltage (volts), i = Current (amperes), and t = time (seconds)
Thus W = 3,7 x 1,43 x 1 = 5,291 Wh.

5. Simulation
The energy harvester use a voltage multiplier simulated using software as shown in Figure 2 as follows.

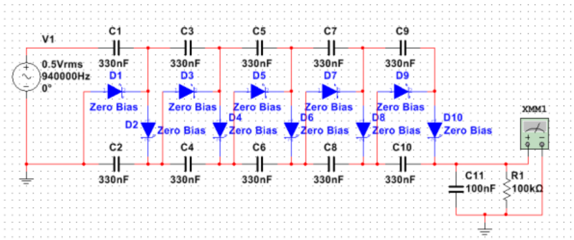


Figure 2. Voltage Multiplier 5 Stage Villiard

The simulation result will be the influenced of stage number, stage capacitance and output capacitance. Input voltage is output obtained by antenna, assumed between-10 dBm to 0 dBm. Thus, the output of the simulated series using two different input is-10 dbm and 0 dbm. When viewed in the conversion Table dBm to Volt then obtained voltage of 70.711 mV to-10 dBm and 223.607 mV to 0 dBm. 9

Based on the simulation with the number of 1 stage to 5 stages produce voltage and current output as listed in the table 4,5,6 as follows.

Table 4. Vout with input 0,5 V

Number of Stage	Vout min	Vout max
1	1,129 V	1,181 V
2	2,109 V	2,292 V
3	3,007 V	3,368 V
4	3,724 V	4,419 V
5	3,773 V	4,420 V

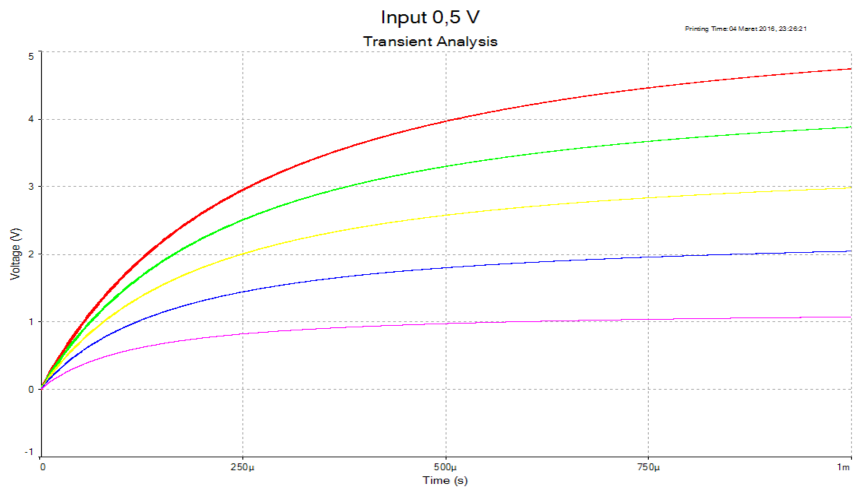
Table 5. Vout with input -10 dBm

Number of stage	Vout min	Vout max
1	46,746 mV	100,116 mV
2	62,552 mV	180,012 mV
3	69,085 mV	247,927 mV
4	25,656 mV	307,536 mV
5	25,219 mV	360,908 mV

Table 6. Vout with input 0 dBm

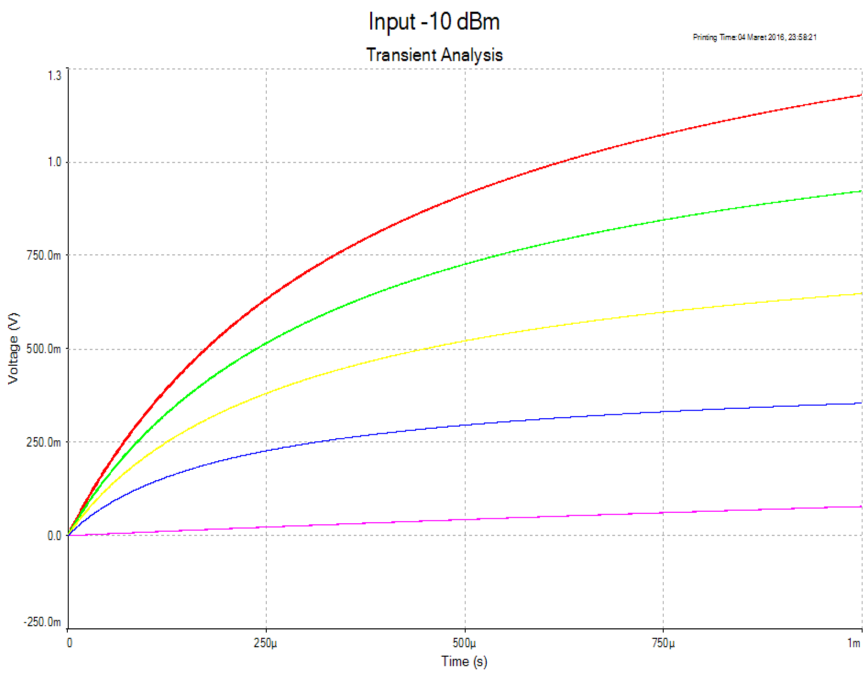
Number of Stage	Vout min	Vout max
1	394,552 mV	460,901 mV
2	690,17 mV	874,962 mV
3	581,454 mV	1,262 V
4	593,464 mV	1,632 V
5	582,947 mV	1.989 V

Meanwhile, for the output voltage of the design is shown in the transient analysis chart, where the output voltage is shown according to time. The result of multiplier output graphs of each input are listed in Figure. 3(a), 3(b), 3(c) as follows.



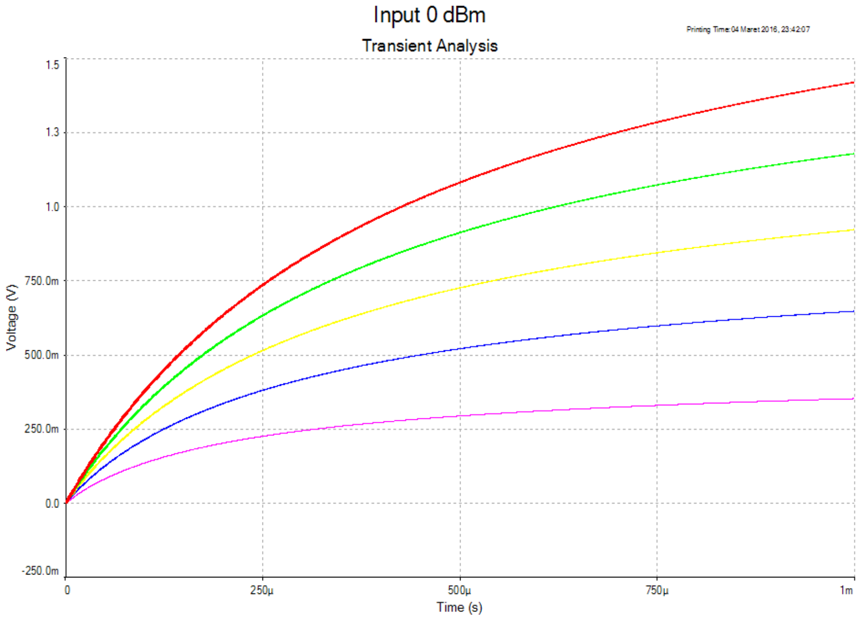
1 Stage 2 Stage 3 Stage 4 Stage 5 Stage

Figure 3(a). Transient Analys Graph Vin 5 V



1 Stage 2 Stage 3 Stage 4 Stage 5 Stage

Figure 3(b). Transient Analys Graph Vin 10 dBm



1 Stage 2 Stage 3 Stage 4 Stage 5 Stage

Figure 3(c). Transient Analys Graph Vin 0 dBm

It can be seen that more and more stages are used higher as well as the voltage produced. The increase in voltage will meet the peak saturation point depends on the number of the Stagenya, the more the number of stages the longer the voltage is increased.

6. Schematic diagram

The schematic diagram for voltage multiplier is shown in Figure 4 as follow.

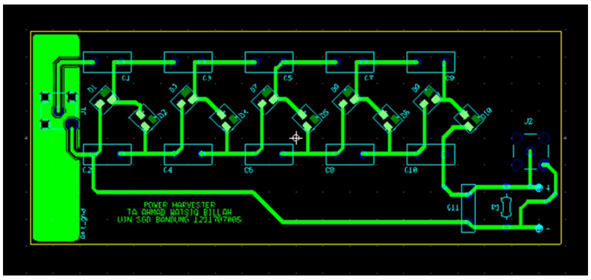


Figure 4. Voltage Multiplier Blueprint Layout

2.4 System implementation

To implement the system, a PCB is manufactured according to the draft layout that has been produced. The material for producing PCB is FR4 with a thickness of 1.6 mm and the dielectric constant 3.9. The dimensions of this design are fabricated 100 mm x 40 mm. The implementation of RF energy harvester are shown in Figure. 5 and Figure. 6 as follows.

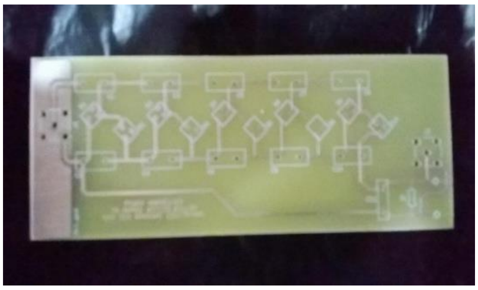


Figure 5. Print layout results

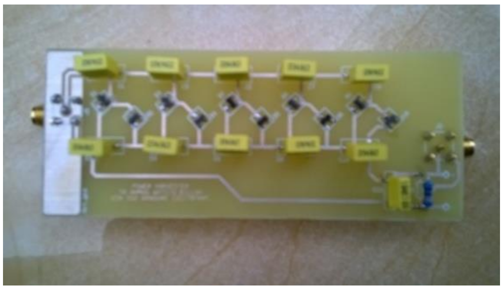


Figure 6. RF Energy Harvester

PCB Circuit printed with upper side design, so that the soldering component is done facing up. This upper side design selection considers the use of SMD components on the circuit. On the circuit the performance depends and is affected by the frequency of the effort to not have a link in the form of jumper. With this consideration so it is not used double side on the design circuit. SMA connector is used on input and output of PCB, SMA on input is used for antenna liaison while the output is used to carry out measurements.

2.5 System testing

The testing of the tools conducted on this research included the measurement of power harvester discharge voltage which is the input for the battery, and testing with LED indicator. The test was done by carrying out 2 antennas and 2 sources of transmitter with an environmental experiment. The following schemes for experiments are conducted. Figure.7 shows the experimental schemes with BTS input and the distance between system and BTS is 100 m. Figure. 8 shows the experimental schemes with a mobile phone input and the distance between system and mobile is 30 cm.

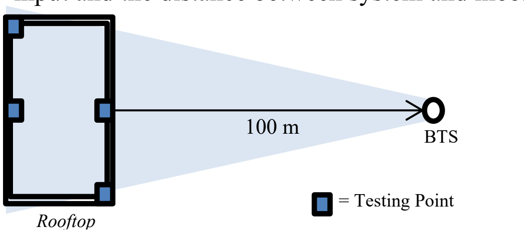


Figure 7. Experimental schemes with BTS inputs

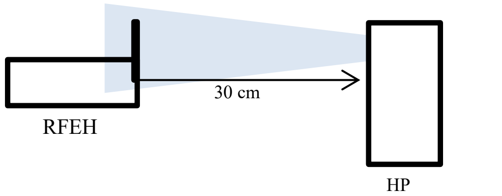


Figure 8. Experimental scheme with Mobile phone Input

Testing is done according to the test scheme that has been established as shown in Figure 7. Measurements are performed at intervals from 06.00 to 16.00. Testing was conducted in two testing phases, each piloting test using two different antennas. Figure 9 shows a data sampling with BTS transmitter input and Figure 10 shows a data sampling with mobile phone transmitter input.

In Tests with BTS transmitter sources are performed on a rooftop to minimize attenuation caused by buildings or settlements.

Being on testing using a mobile phone transmitter is performed with several handpone working conditions that will be analyzed later.

Figure 9. Data sampling with BTS transmitter inputs

Figure 10. Data sampling with Mobile phone transmitter inputs

3 Results and Discussion

Power harvesting test results, based on good measurement results with BTS transmitters and mobile phones obtained fluctuating data. By multiplying the data retrieval obtained the average output voltage generated powerharvester. The Data is captured with the test sampling timing parameter change.

With a distance of 100 meters from the BTS transmitter by using the GSM module antenna as shown in Figure. 11, obtained an average voltage of 0.15 volts and at a distance of 30 cm from the mobile phone transmitter as shown in Figure. 12, obtained an average voltage of 3.21 Volt.

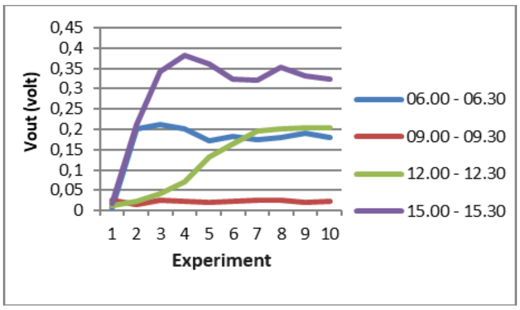


Figure 11. Graph Vout Power Harvester antenna GSM module at distance 100 m from BTS

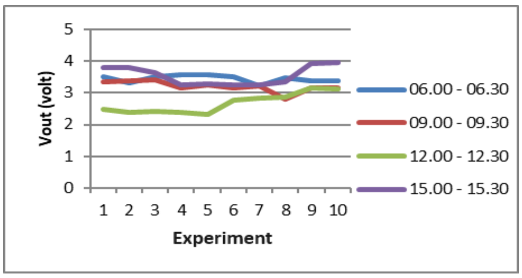


Figure 12. Graph Vout Power Harvester GSM modules antenna at a distance of 30 cm from Mobile Phone

Power harvester output voltage with GSM module antenna and BTS transmitter at a distance of 100 meters obtained maximum voltage of 0.38 volt and a minimum voltage of 0.008 volts. At 15.00 The resulting voltage is greater and has a more derastical increase compared to 09.00.

Power harvester output voltage with GSM module antenna and mobile phone transmitter at a distance of 30 cm is achieved maximum voltage of 3.9 volts and minimum voltage of 2.3 volts. From the data results it appears that the output voltage between times is more similar. However, the exit voltage remains volatile.

With a distance of 100 meters from the BTS transmitter using an Indoor GSM antenna as shown in Figure. 13, obtained an average voltage of 0.26 volts and at a distance of 30 cm from the mobile phone transmitter as shown in Figure. 14 obtained an average voltage of 2.56 volt.

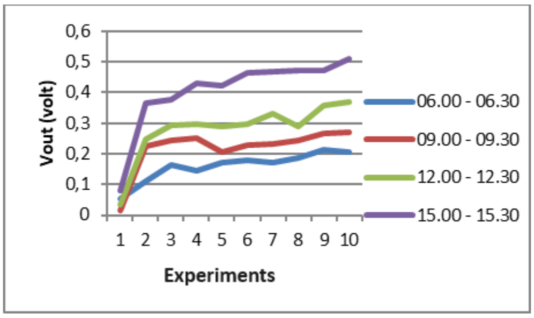


Figure 13. Indoor antenna Vout Power Harvester graph at distance 100 m from BTS

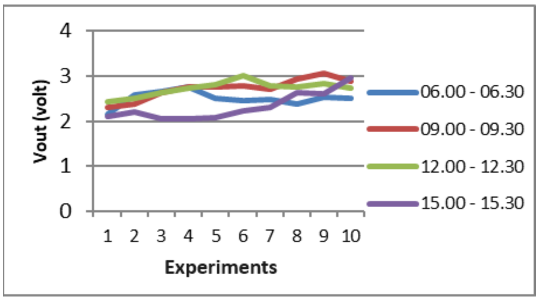


Figure 14. Vout Power Harvester antenna of Indoor types at a distance of 30 cm from Mobile Phone

Power harvester output voltage with indoor type antenna and BTS transmitter at a distance of 100 meters obtained maximum voltage of 0.47 volt and a minimum voltage of 0.05 volts. As with the GSM module antenna, in 15.00 hours the resulting voltage is greater and has a more derastis increase compared to 09.00.

A power harvester output voltage with an indoor type antenna and a Mobile phone transmitter at a distance of 30 cm was obtained a maximum voltage of 3.01 volts and a minimum voltage of 2.05 volts.

3.1 Test results with LED indicators

The next testing phase is testing Power harvester with LED indicator. When considering the test results at the previous stage found that with the use of BTS transmitters, the resulting voltage is still very small so that it can be concluded that the resulting voltage has not been able to turn on the LED indicator. Thus, the testing using a BTS base station is not performed, so testing using only the mobile phone transmitter as shown in figure. 15 as follow.

Figure 15. RFEH When the Mobile phone is Standby conditions, the LED indicator illuminates

On the test found the LED light illuminates when the mobile phone is standby and brighter when the mobile phone is used to call or use the data package. The LED condition is explained in the Table 7 as follow:

Table 7. Power Harvester testing using LED indicators

No	Mobile Phone Condition	LED Condition
1.	Standby	Dim
2.	Calling	Very Bright
3.	Receiving calls	Very Bright
3.	Sharing Hotspot	Bright
4.	Streaming Youtube	Very Bright
5.	Download Process	Very Bright

3.2 System Efficiency Analysis

System efficiency is obtained from a large comparison of power in power out. So if it is written mathematically

$$\eta = \frac{P_2}{P_1} \tag{5}$$

In the analysis of the power efficiency is used two observations, namely the efficient powerharvester without storage media and with storage media.

First, the efficiency of powerharvester obtained by comparing the receiving power of the antenna with the power issued Powerharvester. With a BTS transmitter source located 100 m from the system produces an average voltage 0.2663 V found the following results:

$$\mathrm{P} = \frac{\mathrm{V}^2}{\mathrm{R}} \tag{6}$$

Where P = Power(joule/sekon atau watt), V = Voltage (volt), R = Resistance (ohm)
Thus:

$$\mathrm{P} = \frac{0{,}2663^2}{50} = \mathrm{P} = 0{,}00142 \text{ watt}$$

Obtained the power received by the antenna of 0.005 watts, hence the efficiency of the power system that has not integrated storage media by using the source of BTS transmitter by 28%.

While using a mobile phone transmitter source that produces an average voltage of 3.2175 V found the following results:

$$\mathrm{P} = \frac{3{,}2175^2}{50} = \mathrm{P} = 0{,}21 \text{ Watt}$$

Thus, obtained efficiency of 42%

Second, the efficiency of the system has integrated storage media by comparing the power generated power harvester with power stored on the temporary storage media.

With the source of a voltage BTS transmitter that can be stored in a storage media of 0.04 V within 3 hours of testing, the stored power is:

$$\mathrm{P}_2 = \frac{\mathrm{W}}{\mathrm{t}} = \frac{0{,}04 \times 1{,}2 \times 1}{6} = 0{,}008 \text{ Watt}$$

Thus the efficiency of the storage media system amounted 5.63%

Meanwhile, with the source of Mobile phone transmitter voltage that can be stored in the storage media of 0.87 V within 3 hours testing, the stored power is:

$$\mathrm{P}_2 = \frac{\mathrm{W}}{\mathrm{t}} = \frac{0{,}87 \times 1{,}2 \times 1}{6} = 0{,}174 \text{ Watt}$$

Thus, the efficiency of the storage media system amounted to 0.82%.

Total efficiency of the system by calculating the performance calculation of powerharvester efficiency with the storage media using a BTS transmitter source of 0.15% and using a mobile phone transmitter of 0.34%.

By looking at these efficiency values found the conclusion that power systems with storage media are not yet efficient. Moderate power system without integrated storage media with a mobile phone transmitter source is quite efficient.

3.3 Mobile Phone Battery Charging analysis directly

On mobile phone charging directly, analysis of battery charging time is possible. The time it takes to supply the battery power varies depending on the battery power, the location of the charging and the source of the transmission. To supply the 1430 mAh battery using a BTS transmitter source is 100 m from the system that produces an average voltage of 0.2663 V, according to the equation 5.4 found power output of 0.00145 Watts then, the time required for the process 5.291 Wh battery charge, it is found:

$$\mathrm{t} = \frac{\mathrm{W}}{\mathrm{P}} = \mathrm{t} = \frac{5{,}291}{0{,}00142} = \mathrm{t} = 3726{,}05 \text{ jam}$$

Judging by the length of time required for the filling process, the standalone power system is not yet efficient to charge the battery when using a BTS transmitter source.

While the time required by using a mobile phone transmitter source that generates an average voltage of 3.2175 V with an average power of 0.21 watts, for the battery charge process of 5.291 Wh through equation 5.4 is found:

$$\mathrm{t} = \frac{5{,}291}{0{,}21} = \mathrm{t} = 25{,}19 \text{ hour}$$

If viewed from the mobile phone specifications that have a maximum talk time of 13.1 hours, it can be concluded that this standalone power system is capable of charging the battery when using the mobile phone or storing the power of the device on Storage media. Comparing the usage time to the battery charge process will appear a power percentage filled in the battery of 50%.

4 Conclusion

Based on the results of the design, testing, measurement and analysis of parameters of self Powered system base on Radio Frequency Energy Harvesting, can be taken the following conclusions:

1. Power Harvester is able to turn the RF signal into DC voltage. The research gained 300 mV for power coming from BTS base stations and 3.9 V for power coming from mobile phones.
2. After using the boost regulator that is integrated with the battery, the system is capable of charging 0.04 volts for resources originating from BTS and 0.87 volts for resources derived from mobile phone with a monitor time of 6 hours.
3. Efficiency of Power Harvester to carry out storage media 3 volt/1200 mAh with the use of BTS transmitter sources by 28% while the efficiency of Power Harvester by using the source of mobile phone transmitter of 42% and efficiency of the system To perform mobile phone charging of 50%.

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