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RADIO-FREQUENCY IDENTIFICATION (RFID) ITEM FINDER USING RADIO FREQUENCY ENERGY HARVESTING

Win Adiyansyah Indra, Adam Wong Yoon Khang, Yap Thai Yung and Jamil Abedalrahim Jamil Alsayaydeh
Centre for Telecommunication Research and Innovation (CeTRI) Fakulti Teknologi Kejuruteraan Elektrik and Elektronik (FTKEE), Universiti Teknikal Malaysia Malacca (UTeM), Melaka, Malaysia
E-Mail: adiyansyah@utem.edu.my

ABSTRACT

This paper investigates Radio Frequency Identification (RFID) finder powered by Radio Frequency Energy Harvesting. Misplaced and losing item is a normal situation that happens almost anytime and anywhere. When this problem occurs in situation during the emergency time or in hurry, panic will come and start searching around for that lost item from where it was last seen it or place it. RFID is a technology that is used for item identification. A RFID Item Finder is developed with the Radio Frequency (RF) Energy Harvesting technology. The Output of RF Energy Harvesting is used as the input source for the RFID Item Finder by converting RF signal source to DC source that needed by the Item Finder. A RFID tag is attached over the item so that it can be searched by using RFID reader which if the tag in a read zone of the reader, user can know whether the misplaced item is in that certain area by the communication between RFID tag and reader.

Keywords: RFID, RF energy harvesting, reader.

INTRODUCTION

Any Radio Frequency (RF) produces or generates an electromagnetic wave. The main fundamental of the Radio frequency identification (RFID) technology depends on that electromagnetic wave. The technology that uses the radio frequency as the medium to identify item or people in a certain place or ranges is called Radio frequency identification (RFID). This technology is usually used for the item tracking and identification process. A RFID tag and RFID reader are part of RFID system where the tag will contain the information that are stored on it chip. RFID tag is made up of a microchip that is used to store the data and information. An antenna is used to receive the radio frequency. Typically, passive and active tags are the two types of RFID tags used in a RFID system. Both tag used to store the information or data that assigned by the user but the differences between them are active tag consist of power sources for example a battery while for passive tag does not have the power sources. Passive tag will be powered up by RFID reader frequency.

A serial number was used as the information to identify or track an object or person was stored on the microchip in a RFID tag. The information on the microchip of a RFID tag will send to RFID reader by radio frequency wave that generate by the tag antenna. Radio frequency is the form of information or data will transmit and received by RFID reader from the RFID tag. The output of RFID reader will be digital information which it was convert from radio frequency to digital signal. User can modify or edit the digital signal received whether on computer or other devices [1].

Radio Frequency (RF) is a wireless electromagnetic wave that was assigned with the frequency range of 3kHz to 300GHz. Radio frequency can be used as the medium to transmit information from a gained interesting and attention from many people to innovate and enhance those energy. Harvesting energy are natural, environmentally friendly, reusable and it can obtain easily due to it was ambient energy moreover it was free to use. Typically, there are 4 type of ambient energy source which are solar type, mechanical type, thermoelectric and electromagnetic radiation.

In this study, radio frequency (RF) is the electromagnetic radiation type of harvesting energy used. In RF harvesting energy, the ambient and free space radio frequency was captured by the harvester antenna and will go through RF to DC converter which converts the radio frequency to the DC sources and through power conditioning process the DC voltage was regulated and amplified. Now the output DC voltage from the RF harvester was ready to store at battery and used by this item finder.

RADIO FREQUENCY ENERGY HARVESTING

Nowadays, green technology in term of research and development of this renewable and harvesting energy technology have been gains a lot of attraction and interesting from many people. For all the renewable ambient energy sources like solar, thermoelectric, wind, and radio frequency (RF) has been chosen as the main technology to be research and study. Ambient RF signal can be obtained easily at every way for example Television signal, AM and FM Radio signal, mobile phone signal and so on. RF power harvesting is the process where the radio frequency signal which emits by it source capture by antenna from the harvester circuit due to the electromagnetic field produces by convert the obtained radio frequency to DC voltage. RF harvesting is imparting itself as a feasible source of energy. Normally the power small systems

which use the limitless resources of energy to produces the electric energy is called energy harvesters or scavengers [2].

In our surrounding, there are many signals with various frequencies ranges may can reclaimed, despite the fact that some small amount of energy was deliver by those signals, studied for those energy with small quantity may have the possibility to charge and power up a microprocessor or microchip process can be perform [3]. The primary challenges on this RF energy harvesting field are the harvesters need to be design with low cost passive components as well as with low power consumption and in additionally need to be design in miniature. The source of energy which can be obtained through surround and renewable which are natural source of energy or green energy is called ambient energy. Generally ambient energy sources have been divided into 4 general type which are solar, thermoelectric power, electromagnetic radiation, and mechanical motion. These 4 types of the energy source have their own unique characteristic in the way of collecting and harvest the energy in term of its controllability, predictability, and magnitude.

One of the renewable energies that obtain directly from sunlight by using solar to electric converter is the solar energy. The most popular and widely used of the ambient energy sources is the solar energy. A photovoltaic cell was used to capture the light radiation of sunlight and converted into electric energy which can be store and used for electronic devices. Solar energy has the potentially to provide limitless quantity of power through the sunlight as it was obviously the power source that are most suitable for self- sustainable devices at outdoor environment. Although solar power has the infinite amount of energy but there are also many factors that will affect in term of the energy available of a solar energy to power on a device as well as the energy harvesting level from sunlight. A seasonal weather, time of the day, environment condition, the photovoltaic cells used characteristics and so on will affected the energy harvesting level [4]. Normally, solar-powered energy amount was measured in the order of 100 mW/cm^2. Radiation of solar are dynamic somewhat are uncontrollable but in some fixed situations it can be predictable. In most cases it was typically unpredictable. For the light energy source which can collected and detected at the indoor environments are illumination for example fluorescent lamp. In term of power density can be collected, although inside an indoor environment got illumination used as energy source but the power density is lower when compared to sunlight energy. The power energy strength collected is affected due to the distance between the illumination source and the solar energy harvester.

Energy produced from thermoelectric is used to obtain energy [5]. Especially, it was able to be stimulated by a circuit voltage which are between 2 different type of conductor materials used and at different temperatures junctions. From our bodies or machine, the temperature gradient can be obtained. The heat energy generate from human body can give approximately about 20–60 μW/cm^2 of the energy will be generated by the thermoelectric generator at room temperature about 18 °C–25 °C. In term to determine power densities of thermoelectric sources there are 2 aspect most used in most cases which are differences. These energies are particularly low and just from the range from 10 μW/cm^2 to 1 mW/cm^2. Constant in temperature difference and heat flowing can make thermoelectric devices to operate continuously. When compared to other energy harvesting devices, these harvesting devices may be commonly inflexible and weighty, for example solar cells which are small in size. In terms to generate useful amounts of energy that can be support and used by the thermoelectric energy-harvesting devices normally require relatively large amount of energy to be collect and used.

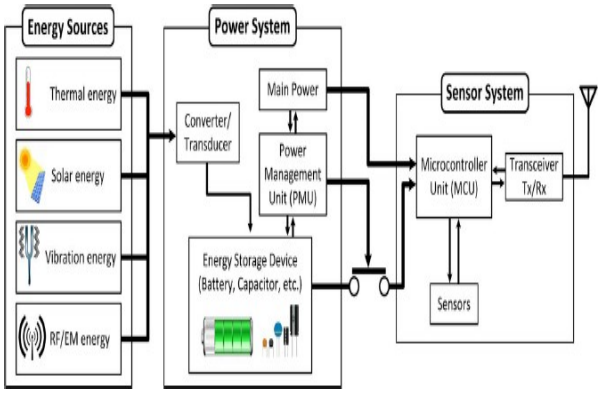

Figure-1. Energy Harvesting System Examples.

Electrostatic, piezoelectric and electromagnetic will be produced by producing the electric energy via a method called transduction methods. It is the process which it will extracting energy from a mechanical motion and vibration [6]. For electrostatic method, 2 electrodes of a capacitor may have the changes in distance and variant in voltage between then. So, from there a mechanical motion or vibration will occurs then current will be produces in a circuit. For piezoelectric method the energy was received through means of the piezoelectric materials. Next, for electromagnetic method, an AC current will be produced due to the relative motion between magnet and the metal coil in a coil. This process can be related to electromagnetic law which are the Faraday's law of induction. Piezoelectric effect was the effect in which electrical voltages and currents produces, consisting of vibration from a mechanical strain. Normally, a non-stop motion from mechanical, including noises created from acoustic as well as wind will activate the piezoelectric- based energy harvesters to keep generating energy. Besides from non-stop motion of mechanical, they also occasionally generate energy from desultory strains, for example human movement [7]. In term of the volume of power collectable form the piezoelectric, when

compared it with other energy harvesting devices generators it was comparatively small, and light. This is due to piezoelectric has a small crystalline structure that was capable to produce energy in these small and light configurations is the main reason. Besides, piezoelectric power generator when deal with irregular motions plus human motion this will cause it to have a large dynamic range which that 2- factor act as the driving force then applied to the system. Those piezoelectric generated power typically includes the excessive voltage and low in current produces. Those voltage and current could damage the suppliedcircuitor regulate the excessive voltage to becomes stable due to this problem it causing in system low efficiency [8]. Commonly, vibration and motion are the natural effects that will emerging randomly and cannot be control, wind and liquid flow is an example for natural vibration and motion. Beside that for controllable part such as human actions, example like blood pressure and heart beating. All specific vibration and motion energy sources have value form varied range due to each vibration and motion energy sources has the different power of density[9].

Electromagnetic (EM) radiation harvesting energy system has created attraction and increasing the number of attention because of it nature of wireless communications [10]. Electromagnetic energy (EM) sources are divided into 2 categories which near-field and far-field which depend on the short- distance and long-distance applications. For near-field applications, the electric power was generated inside a certain range and distance of a wavelength. A EM induction and magnetic resonance methods are generally exploited, and for this reason, the efficiency of energy transfer is not less than 80% in this near-field applications. [11] In far-field applications, it ranges of detection could be a few kilometers, radio frequency (RF) or microwave signals is the form the EM radiation appearing. The signal can be obtained through any antenna and has been converted to the power by means of rectifier circuits [12].

A beam forming signals can be the RF or microwave resources from the surrounding which will emitted via a recognized transmitter or ambient EM radiations. This type of energy is controllable and predictable, but in term of the receiving antennas power densities is affected by the available sources power as well as the signal propagation distance. Ambient RF energy have a particularly low in energy density with value 0.2 nW/cm^2 to 1 $\mu W/cm^2$ in comparison to other energy sources [13]. However, using a high gain antenna can be harvest a larger quantity of the total available power. The existing ambient energy sources was keep increasing due to the expanding and requirement of the wireless communication technology as well as the broadcasting infrastructure, for example AM or FM radio TV signal, and mobile networks.

The RF energy-harvesting technology give most benefit in powered up a low power consumption electronic device by charging its battery by radio frequency without any wire because there are tough to change the batteries in a device for example the deployed wireless network. It is a beneficial because in a difficult access area some wireless networks typically have been deployed. RF energy- harvesting could be operated as long as there is minimum amount ambient energy exist without any specific for what time of the day and what topology used. This RF energy-harvesting systems was easier to incorporated with any kinds of antennas used as well as other energy harvesting technology, for example solar cells [14].

RADIO FREQUENCY IDENTIFICATION (RFID)

Radio frequency identification technology nowadays has been evolved because it changes to as most of the devices used of it on ordinary applications which assist and speed up handling process for goods and materials at industry. RFID (Radio Frequency identification) has an advantage over the earlier bar-code although it has a distance limit but it as a most effect technology was used to support a large quantity of identification process compare to bar codes by using unique ID at each tag. RFID technology might comprise extra information which includes manufacturer name, product type, and also some of the environmental factors measurement detail for example temperature. Moreover, those RFID identification systems can operate without human assistance to determine large amount of tags which are in the same area or place for example workspace. In transferring power from the source to destination which are from reader to the tag in RFID system, there are 2 fundamentally exist which are called magnetic induction and another one is the electromagnetic (EM) wave. EM properties for example near-field and the far-field in which can related to a RF antenna are given an advantage for its design. Both near-field and the far-field transmission operation normally need around 10 µW and 1 mW to operate. So that it enough to transfer energy to a distant tag, relying for the tag type used. In term of transmit and receive data via diverse type of modulation methods is more in near-field and far-field-based signals [15].

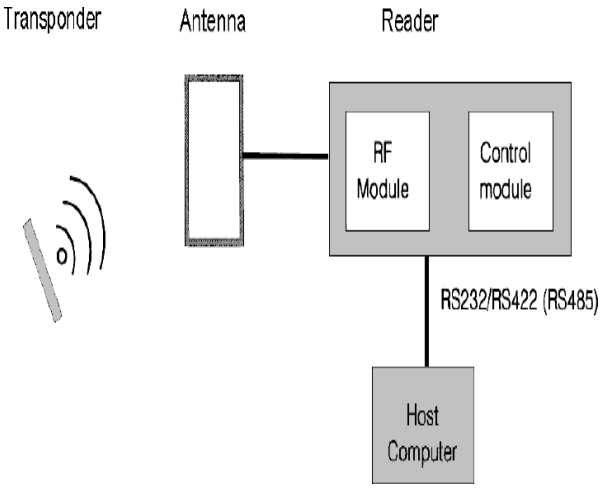

Figure-2. RFID System.

There are two types of RFID modulation technique which are near-field and far-field RFID. Magnetic induction which using the faraday law of principle was the intention for the coupling process in near-field among the RFID readers and tags. Discontinuous magnetic field will be created when a reader that pass a great alternating current via a reading coil. Tags which used of the near- field connection will deliver information by load modulation method will returned to the reader. A current of coil inside the RFID tag will be draw to supply as well as to increase the magnetic field of its own which will be opposed to the transmitter which are the reader field. When a current flows through the reader coil, it can stumble on this as small increase. The load was proportional due to that current to carry out to the tag's coil. Typically, in a transformer coil their primary coil will twine closer to their secondary coil of a transformer this is the step to assure the power transfer efficiency. This is because primary coil will create the magnetic field which will extends beyond it, for secondary coil with some of the this operation is also similar like a RFID reader and the RFID tags.

In order to get or receive better signal strength for the RFID reader, it can be done by monitor the changes in current thru RFID reader. An expansion in modulation encoding is a method that relying for the aspect for the bits identification range required, the transfer data rate, and to eliminate errors a redundancy bit placed within the code because of noise within the communication channel. Coupling in a Near-field was the straightforward approach that enforcing for the RFID passive system. Nevertheless, there are some physical limitations in a near-field system. The magnetic induction can be used to calculate the approximates range by using formula $c/2\pi f$. From the previous formula, c is defined as the speed of light which also is a constant of value 3x 108 m/s and the symbol f are the frequency. Therefore, due to this formula in a near-field coupling process it distance and the frequency are inversely proportional to each other. As the frequency increases but the distance will be decreases.

The distance for available energy that used for the induction process at the reader coil is a problem. Magnetic field will be drops off at factor of $1/r^3$, in which the separation between the RFID tag and their reader is label as the symbol r. So, as applications require extra identity bits in addition to discrimination among more than one tags for a fixed read time within the same zone, higher information rate was needed for each RFID tags and for that reason a higher frequency range was needed for frequency operating. New designed passive RFID tag was designed due to some of the design pressures but most of the designs was primarily based on the far-field communication.

For far-field RFID tags was the tag that collect the EM waves that will be propagated from a dipole antenna which was connected to RFID reader. RFID tag receives inside consist of a smaller dipole antenna which will received energy as an alternating capability difference that looks throughout the arms of the dipole. This capability was rectified by a diode and make connection to capacitor, so that it can bring the store of energy for an electronic device which enough to powerupit.

Back scattering is one of the technique that used to design a far-field RFID tags that to be commercialize [16]. An antenna of a tag can be design by refer to specific dimensions, so that it could modified to has a specific frequency and take in maximum amount of energy used that will reaches at that specific frequency range. Nevertheless, mismatch in impedance was the serious problem that if happen it will cause antenna to reflect some of the energy towards the reader. Those reflected energy can be detected by using sensitive radio receiver. By the way to change impedance value of the antenna over the time, RFID tags also can use to reflect the tag unique identity as the incoming signal in which follow the pattern that has been encodes. Guide for the normal tag design, the tags which has been design by using the far field principles are typically operate at frequency which not less than 100 MHz but inside the ultra-high- frequency (UHF) band which along with 2.45 GHz. For the frequency range that below the frequency state above is the RFID tag that used the near-field coupling principle. That was the limited range on a far-field system as the tag received the quantity receiver sensitivity to reflect back the signal.

As a result of attenuations, the return signal may be relatively small. This is because it was normally used of an inverse square law which the attenuation will happens first time as an electromagnetic wave was emitted from reader to tag, while the reflected waves from tag will be transfer back to the reader as the second attenuation. Therefore, the returning energy of the signal was 1/r4. Fortuitously, Moore's law and the shrinking characteristic of a semiconductor manufacture will cause decreasing in the energy required to powerup a RFID tag at a specific frequency range. So, with modern semiconductors, as increasing number of greater distances tags was design so that may be read at far as possible. Moreover, in improved the sensitivity to detect signals of a radio receiver was developed with an affordable price, with - 100 dBm of the power levels within the frequency band of 2.4-GHz. Basically, a normal far-field RFID reader can effectively receive and modify the tags with a 3m distance.

RESULTS AND DISCUSSIONS

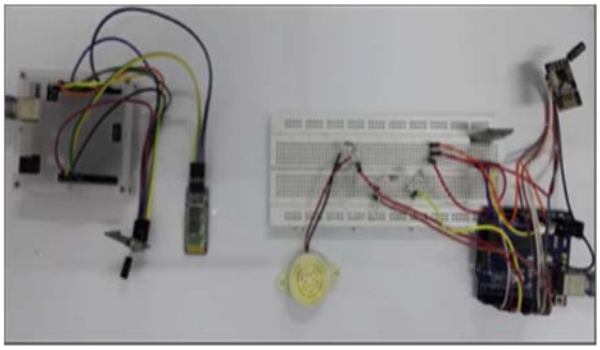

Figure-3. Active RFID Item Finder reader and active RFID tag.

This RFID item finder by using harvesting energy were used the component like 2 Arduino Uno, 2 NRF24L01+ RF module, HC 05 Bluetooth module, HC 06 Bluetooth module, 2 LED as indicate, and 1 buzzer used for alert user when nearing to the loss item. Both Arduinos are powered up and supplied the power to turn the both NRF24L01+ as well as HC 05 Bluetooth module and HC 06 Bluetooth module.

NRF24L01+ RF module was operating under a voltage range from 1.9V to 3.6V. So NRF24L01+ was connected to Arduino Uno power pin 3.3V to be operate while for both HC 05 and 06 Bluetooth module used 5V power pin form Arduino Uno to be operate. One for the LED and buzzer were assigned to Arduino digital output pin number 4. This LED and buzzer was used as the indicator that alert used the loss item is near or far away. Next, the last LED also used as the indicator which use for indicate the connection between both NRF24L01+, if them are connected and communicate the LED will beturn on, it will be off if the connection is lost due to far away or run out of power source of the NRF24L01+ RF module.

Figure-3 below shows the overall circuit design for are connected with 1 NRF24L01+ and a HC 05 for active RFID reader or HC 06 Bluetooth module for active RFID tags. Both reader and tag figure are shown in Figure-4 and Figure-5.

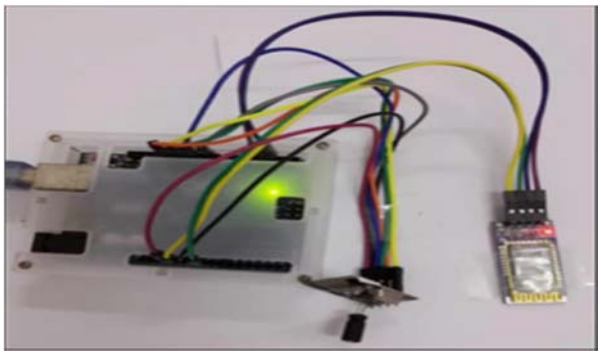

Figure-4. Active RFID Tag with NRF24L01+ and HC 06 Bluetooth module.

When the power source was turn on, there are two operations. First at the active RFID reader side, the NRF24L01+ will sent the signal to detect and connect the NRF24L01+ on the tags side, when the connection is successful the red LED will be turn on indicate the connection is make which indicate that the item is in this range. Next operation is HC 05 now will be searching surround to find the paired Bluetooth signal which is HC 06 signal. After in the range of 2 meter, the white LED will be light up. In this RFID item finder by using harvesting energy project, the output result besides can be determined by using LED and buzzer as indicator, it also can be obtained from the software part. Arduino Uno serial monitor is chosen as it was the open source software from Arduino IDE and is compatible to operate with any interface. From the serial monitor will show the detail for the results as will discuss at following. First finding state is the NRF24L01+ which will detect surround and searching for the required RF signal from the NRF24L01+ that attached on the loss item. If the item is in the range, at the Arduino IDE serial monitor will show the result “Got response: Item in range”, Next come to second finding state, when the item finder closes to the tag item with the range of 0.5 meter, at serial monitor will show the text mention that item is nearby within range of 0.5 meter. For the distance measurement is depending on the Bluetooth module RSSI signal. From the figure the line +INQ:98D3:31:F622D1, 1F00, FFE5 show the received information, which first one 98D3:31:F622D1 is address received from HC 06, 1F00 is the device class for HC 06 and third FFE5 is the RSSI signal strength received by HC 05 Bluetooth module. From the coding, it will do the calculation for the RSSI value.

This study of RFID item Finder by using harvesting energy showed that the item finder was enabled to detect and search for the lost item. User will be alert when nearing to the loss item by the buzzer sound and blinking of LED light. In this project, NRF24L01+, HC 05 and HC 06 Bluetooth module were used for 2 stages of searching process. First stage is the long range searching, searching will using HC 05 and HC 06 Bluetooth module. For the long distance, it was assigned for using NRF24L01+ and with a LED as the indicator to show the successful connection between 2 NRF24L01+ RF module. Both NRF24L01+ will be communicate to each other every 1 second, and if the connection is successful, at the Arduino IDE serial monitor will shown the result as written “Got response: Item is in range”. When the connection of both NRF24L01+ was successful, Arduino Uno microcontroller will send the command to light up the LED which assigned to the digital pin number 5 at Arduino Uno board. This NRF24L01+ is using the serial peripheral interface (SPI) to communicate with Arduino microcontroller. In short SPI is a communication interface protocol used for the short range of communication distance which with the pin like Master output slave in (MOSI) and Master Input

Slave Output (MISO) which available in this NRF24L01+ RFmodule.

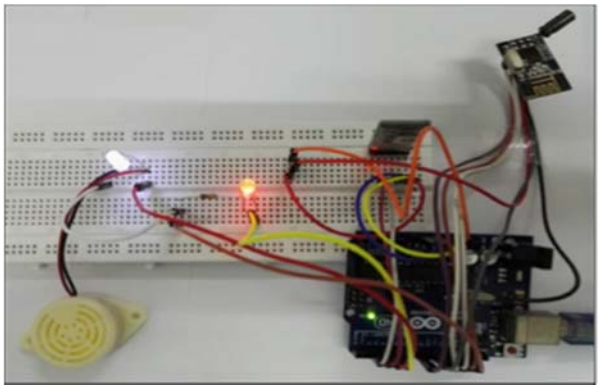

Figure-5. Active RFID Reader with NRF24L01+ and HC 05 Bluetooth module.

Communication between both NRF24L01+ are set through coding written at Arduino Uno which both NRF24L01+ are set using the same CRC configuration for NRF24L01+ default configuration. Both NRF24L01+ will be assigned to be role to transmit or receive signal. The role can be set in the coding part which set PRIM_RX bit into 1 for the receiver while set PRIM_RX bit to 0 is assigned the NRF24L01+ tobecome the role as sender. Now for the receiver need to disable the auto acknowledgement function at the addressed for a data pipe while at the sender auto retransmit count needed to be set to 0 which will give the function to disable the auto retransmit function.

The most important part in configure both NRF24L01+ is to set both NRF24L01+ to be same address width as well as the frequency channel. For example, the frequency range used for both NRF24L01+ is set todefault which are 2.4GHz, while the frequency channel for both NRF24L01+ are set to channel 1. This two parameter needed to be follow to make sure both NRF24L01+ can be communicate with each other. For the receiver the data pipe are needed to set with the correct payload and turn high for the Chip Enable (CE) while for the sender was configured to clock in the same length of the payload and CE was pulse to transmit packet to otherNRF24L01+.

After searching through the larger distance area between the loss item, now has come to the short distance searching stages. As mentioned before, this Bluetooth module. For HC 05 is command using the AT command by supplied the power to PIN 34 at the module to let it turn to high level as input to enter the AT command mode. For this 2 Bluetooth module, HC 05 was set as the master by AT command AT+ROLE=1 while for HC 06 is using command AT+ROLE=0. This command will set the HC 06 as the slave. Next, the command AT+CMODE=1 was used at first to make the module available to connect to all the Bluetooth module surround. After that the command AT+INQM1, 1, 9 is using to searching for 1 Bluetooth device with 1 Bluetooth devices data response for 9 seconds. Each Bluetooth module have it own address which it can be request by using command AT+ADDR? , and last after the command write AT+CMODE=1 again to make the Bluetooth module to remember the connection and search for the last paired module only until that particular Bluetooth module was be found. Else, the command AT+RMAAD can be used to delete all the authenticated device away from the pair list. The command AT+LINK, AT+PAIR and AT+BIND was used to connect 2 Bluetooth modules. AT+LINK=<Param> are the command used to connect to the wanted Bluetooth device, which by writing the Bluetooth address at <Param>. For the AT command AT+PAIR=<Param1>, <Param2>, it was used to pair 2 Bluetooth devices by writing the address of the wanted Bluetooth device at <Param1> and <Param2> is the timein second which indicate for the connection. AT+BIND<Param> was used when want to connect to a specified Bluetooth address by writing the address of the wanted Bluetooth address inside <Param>. After all the pair, link and bind command, now both the Bluetooth module will be connected when the power is turn on. AT+INQ was the command used to filter out and make inquire for the surround Bluetooth devices. In return, it will show 3 parameters and the last one is all we need which are the RSSI signal strength.

As for the RF charging board it is better to use an omnidirectional antenna compare to directional antenna. This is because the characteristic of omnidirectional antenna can receive the RF frequency from surround with 360o all direction but for directional antenna only received the RF frequency at certain direction. From the measurement, also show that the omnidirectional antenna have the better signal reception and more gain with higher output voltage compare to directional antenna.

CONCLUSIONS

The RFID item finder by using harvesting energy worked properly. There are two main hardware modules used in completing this study. First is the NRF24L01+, this NRF24L01+ was used as the active RFID which used to detect the longer range. Communication between them are act as the finding and determination process for the item or object tag with the NRF24L01+ as the active RFID tags while another NRF24L01+ will give the role as the active RFID reader. This active RFID reader will be controlled by Arduino Uno microcontroller. Next main module used are HC 05 and HC 06 Bluetooth module.

Both HC 05 and 06 module were used for short range searching. HC 05 will be given the role as master searching only for the HC 06 signal in the way to detect the item. An item will be placed with an NRF24L01+ RF module and a HC Bluetooth module for large and short distance finding process. Once the HC 05 detected the HC 06 signal, and measure the RSSI signal plus calculate, then it will alert user by showing the distance between user and the item. The short-range detection

range was fixed to 2m, 1m and at 0.5m a LED will be blinking, and buzzer sound will be heard as the item is near touser.

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