# Design And Development Of UAV Precision Localization Measurement Technique For Low Altitude Paddy Field Monitoring Application

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*Abstract*— **Over the years, a new modern technology has been adapted in their agriculture system to help saving cost on plantation management. The jobs of fertilizing the crops, pesticide control, crops monitoring and harvesting are all done using automatic machinery system. By this way the farmers can maximize their production and expense less on farm management for a long period of time. All these positive development are done using the help of modern technology especially with the help of using the Global Positioning System (GPS). One of the greatest achievements by using the GPS is that the GPS has the ability to map the agriculture field so that a machine can move or works autonomously inside an assign boundaries of the field. One of the favourite modern technologies that have been used in an agricultural field is using the Unmanned Aerial Vehicle (UAV) or sometimes they called it as the drone. The UAV has the ability to do lot more of things from the air. The UAV has ability to fly at low altitude to spray the fertilizer and the pesticide and the most important task is that it can monitor the crops from the air. The movement of the UAV is usually manual controlled by the user and sometime there are also an autonomous UAV. Both of the control type has the help of the GPS for their positioning. Using the light weight UAV with the GPS will become a problem. The problem is cause by the high power consumption of the GPS to operate. This will make the UAV less flying time because of the battery consumption. The other way for the UAV is to carry extra battery on-board that will significantly reduce the load for other goods. On this work, other low cost technique to compete the GPS is introduced. Two on ground beacon at a known distance using the radio frequency (RF) signal is built and tested. The beacons transmitted signals to the receiver will shows the received signal strength indictor (RSSI). The RSSI signal will be read and analysed using a C language algorithm on the receiver and the range will be calculated and estimated using trigonometry. All these functions are created, formulated and tested thoroughly in an integrated development environment (IDE) board system by using the ATmega328P on top of the Arduino Uno. The result shows that the technique successfully implemented and shows the range accurately with a margin about 5 percent between the real range and calculated range.**

***Index Terms***—**Distance Measurement, Localization, RSSI, UAV**

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## I. INTRODUCTION

The usage of modern technology surely can help farmers to improve their paddy output. The usage of the Unmanned Aerial Vehicle (UAV) [1],[2] or the drone can help the farmer to do a lot of things. The drones provide the farmers the cheapest way to view their crops from the air [3]. It does not need any pilot to fly around the field and take faster time to view the field. Drones can provide farmers with three types of detailed views. First, seeing a crop from the air can reveal patterns that expose everything from irrigation problems to soil variation and even pest and fungal infestations that are not apparent at eye level. Second, airborne cameras can take multispectral images, capturing data from the infrared as well as the visual spectrum, which can be combined to create a view of the crop that highlights differences between healthy and distressed plants in a way that cannot be seen with the naked eye. Finally, a drone can survey a crop every week, every day, or even every hour. All the combining data can create a time-series animation; the imagery can show changes in the crop, revealing trouble spots or opportunities for better crop management.

The UAV must first know the paddy field boundaries that it will work on freely. For outdoor purpose, usually the Global Positioning System (GPS) is used for the navigation and localization. The most widely used technology nowadays usually used to provide location information for so many different types of applications [4]. The implementation of the UAV detection using the GPS becomes the first choice because of the reliability and the effectiveness of the system in an outdoor nature environment that suits the usage of the GPS for measurement and coordination purpose.

The GPS has much basis strength depend on the application, but the accuracy becomes unreliable when the operation site is near an obstacle due to multipath reflections [5]. Referring to the horizontal position on the earth, the classic GPS would have only 95% of accuracy [6]. That is about a range of +-2.7 meter from the original point of position. The accuracy of the GPS cannot be guarantee at all-time where partial satellite occlusion and multipath effects in most working environments can prevent normal operation of the GPS receiver [7]. This means that using GPS alone cannot determine the real position or the exact point location on the land. Other than that, a GPS based system takes a lot amount of power to maintain its function in one period of time. To maintain the coordination for the UAV, the power it needs is far bigger than the battery of a small unmanned aerial vehicle can carry. For this reason, a backup positioning system using an odometry technique is commonly used in terrestrial robots approaches [8]. Implementing a GPS on a UAV to do the localization means that the usage of power on the UAV may not last for long. This means that the UAV must carry an extra power source to power the GPS receiver.

Because of the limitation, an alternative way of finding coordination and localization from the ground must be implemented. There are many other works that implemented other ways of replacing the GPS. One of the technique that has been implemented in [9] is by using the Geographic Information System (GIS) as the reference data replacing the function of the GPS. The system employed a visual-based system that compares the terrain and landmark from the GIS with the referral images map. Using this type of localization needs a very precise image processing system to identify all the object on the ground. A lot of technical issue and data must be done when using this technique. Another visual-based localization that can be implemented is by placing a camera on-board of the UAV. This another affordable way to implement cost effective technique on a UAV [10]. This technique is widely use nowadays as the price of the camera become less but it would be deficient if the UAV fly in low altitude condition altitude and the agriculture field is big enough that make it become a limitation for the camera to view the entire field using the low angle of the camera.

This paper is to develop an algorithm that can measure a paddy field boundary. The algorithm later on can be integrated as a part of the UAV main algorithm for the autonomous movement of a UAV in a low altitude flying condition without using a GPS. When an on-board camera of a UAV cannot be used to measure a long distance paddy field because of the low flying altitude, another solution must be used to overcome this problem.

## II. METHODOLOGY

In a paddy plantation jobs, the UAV has been playing a major role in monitoring, spraying pesticide and fertilizer. Usually this pilot controlled UAV is flown manually and depends on the GPS as their localization method. In this work, an on ground beacon for localization measurement technique of the UAV has been chosen so that the dependency on the GPS can be minimised. An algorithm is design and developed for an embedded system using the Arduino as the main controller. This algorithm can be used as the measurement technique that can be integrated as the UAV localization system. The proposed UAV precision localization measurement technique for low altitude paddy field monitoring application is tested base on Wireless Sensor Network (WSN) using the RSSI signal received from the Xbee devices. Even though this this paper are aiming for a two dimensional perspectives, the data that has been gathered are the real data that has been done in a paddy field. The result may contain the effect of natural environment interference. Lastly, the overall design and development is concluded at the end of this chapter.

### A. *Conceptual Frameworks*

The conceptual framework design and development of UAV precision localization measurement technique for low altitude paddy field monitoring application approach is clearly described in Figure 1.

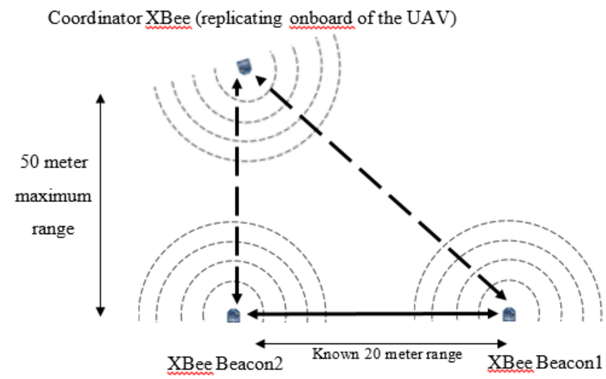


Figure 1 The conceptual framework of design and development of UAV precision localization measurement technique for low altitude paddy field monitoring application.

According to *Figure 1*, the whole test setup is built on an area with the dimension of about 50 meter in length and 20 meter in width. The test is done in 3 different open space ground environments to get the true picture of the signal changes. The test is done in an open field, watery paddy field with the paddy plant is just about 20 cm to 30 cm on top of the water and on a dry and ready to be harvest paddy field that the plant reaching the height of 1 meter from the ground. The test sequence is done systematically to make sure that the comparison between different conditions of the paddy field can be tested, thus ensure the validity of the result can be trusted.

The whole systems are built and develop using three Xbee module devices that is controlled using Arduino microcontroller circuit as a group of transceivers in the Wireless Sensor Network (WSN). Two of the Xbee module namely Beacon1 and Beacon2 is place on the firm ground. The two Xbee acted as a beacon. These two beacons is place in side by side of each other at one side of the paddy field. The placement of the two beacons is set at the range of 20 meters. *Figure 2* shows the real position view of Beacon1 and Beacon2 on the paddy fields.

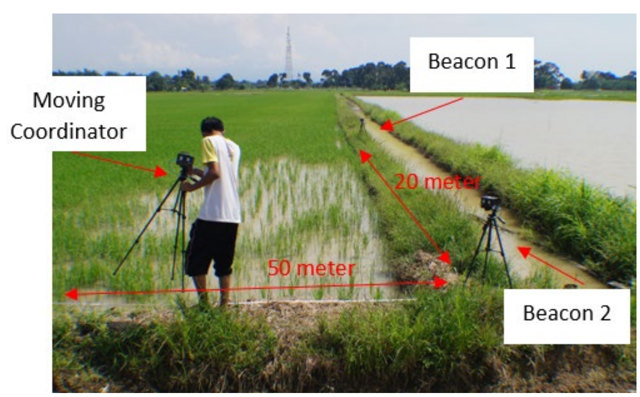


Figure 2 Real position view of Beacon1 and Beacon2 on the paddy field

In this setting, the Coordinator that is simulated to be built in the UAV will move freely inside an area with the dimension of about 50 meter in length and 20 meter width. All the beacons are placed on a tripod pole that has the height of about 1.3 meter above the ground. The purpose of using this kind of heights is to simulate the UAV low altitude flying condition above the ground. The position of Beacon1 and Beacon2 will be simultaneously searched and identify by the Coordinator in the WSN. This will give the Coordinator the current parameters estimation of the two beacons. These values will be compared and analyse using mathematics calculation to set the real position of the Coordinator. The parameters will be updated every time the Coordinator moved to a new position. However, to ensure that the entire conceptual framework is working well, some process and conditions are arranged to be fulfilled. The operations detailed can be seen in Figure 3.

According to the flowchart in *Figure 3*, the system starts when Beacon1 and Beacon2 sends a radio frequency signal (RF) to the Coordinator in the WSN. When the RF signal reached the Coordinator, the Coordinator will response to the signals. Precisely, Beacon1 and Beacon2 have their own Arduino circuit to control the process of sending and receiving the signal from the Coordinator. The Beacons sends a group of data that has been set for it to be sending to the Coordinator. Using the algorithm in the Coordinator's Arduino microcontroller, the signal is then translated to retrieved valuable information from the two beacons. There are three important parameters will be translated from every beacon, namely the identity of the signal sender, the data it brings and the most important is the RSSI signal. The RSSI is the short name for the Received Signal Strength Indicator that can show the signal strength of the received signal. In Xbee module devices, this function ability is built internally and can be access using algorithm.

The RSSI value that has been read by the Coordinator will be filtered by a basic algorithm filtering program. The filtration system will give one stable signal value that has been filtered from ten signal value that it is reading. The RSSI value that the Coordinator receive from the beacons is denotes by absolute power level measured in decibels and referenced to 1 milliwatt or in short, dBm [11]. From this signals, the signal strength is calculated using algorithm to estimate the distance in meter between the Coordinator and the beacon. This calculation are using custom mathematical formula that has been tested on three open space environment, in an open field, in watery paddy field with the paddy plant is just about 20 to 30 cm on top of the water and on a dry and ready to be harvest paddy field and the plant is reaching the height of 1 meter from the ground. So for every field condition will use different reference mathematical formula. From this point, the Coordinator already has two estimation reference ranges, namely the range between the Coordinator to Beacon1 and the Coordinator to Beacon2. The range The range between Beacon1 and Beacon2 is already known at 20 meter range (refer *Figure 4*)

From this three estimation reference value, the actual localization point can be determined. Referring to *Figure 4*, the figure shows the connection between all three values that already known from the algorithm. The calculated distance (d) is built from the position of the Coordinator to the point between Beacon1 and Beacon2. This coordination will form a full triangle that can be calculated using mathematical trigonometry formula. Wherever the Coordinator moves, the triangle formation will still intact. For a triangle that has three unequal sides, the best trigonometry formula that is the non-right triangle trigonometry. One thing to be bear in mind is that the position of the Coordinator is only moving at one side of the field as in *Figure 4*. It will only moves in the area between Beacon1 and Beacon2 to the far field of the paddy field area and will not be considering to cross over between Beacon1 and Beacon2. For that, there are no mirror for the Coordinator position.

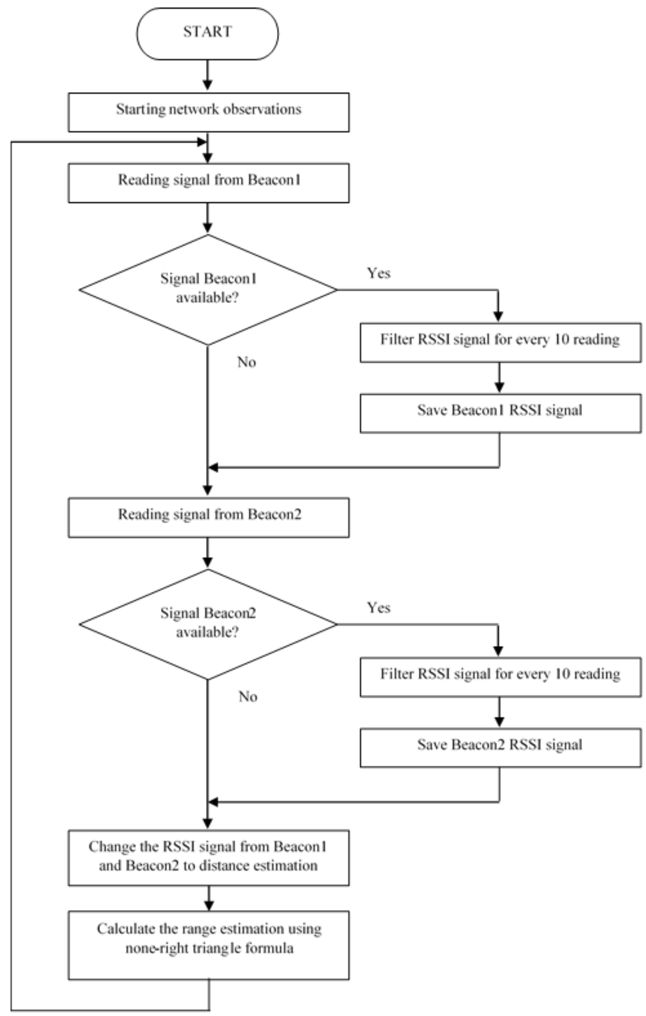


Figure 3 Flowchart of the whole process and condition to be fulfilled to complete the task

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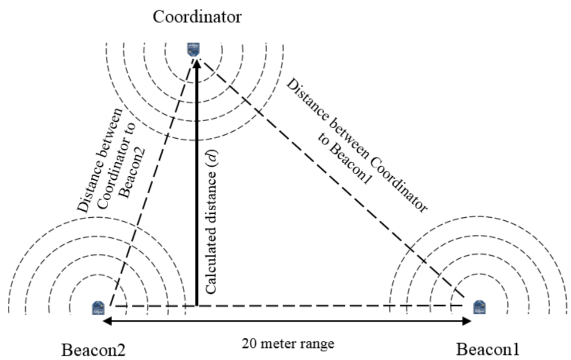

Figure 4 Mathematical configurations for calculating the localizations

## B. Hardware Development

The detailed involving the entire component for the Coordinator in the system is particularly depicted in *Figure 5*.

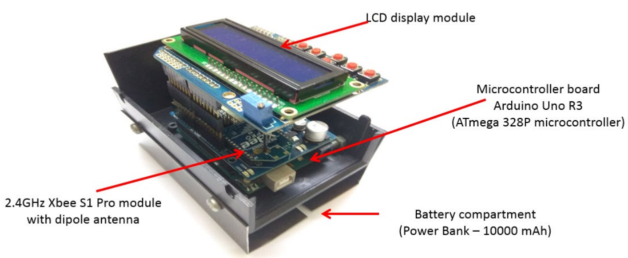

Figure 5 The Coordinator system component for the hardware development

The Arduino Uno R3 mircrocontroller board has been used as the main microcontroller for the sys XBee PRO S1 modules for the wireless system communication. The performance specifications and configuration of the Arduino Uno R3 can be seen in Table 1 and Table 2 respectively. In order to connect the XBee PRO S1 module to the Arduino herefore the XBee module needs to be used with the XBee expansion board to convert the voltage from 5 volt to 3.3 volt. Another advantages using this expansion board is that it has the ability to change serial data communication pin using software mode. In this work, the expansion board shield that is design for the Arduino Uno has been used. This will give the Arduino Uno microcontroller board the advantages of wireless communication capabilities. Because of the environment of the testing for system is without using any computer software display, some form of display must be used to display the measurement value. For this purpose, a 16x2 LCD display has been chosen to display all the data and information on board the Arduino Uno microcontroller board. An algorithm is built for the Arduino microcontroller making it as the master or the main coordinator in the network.

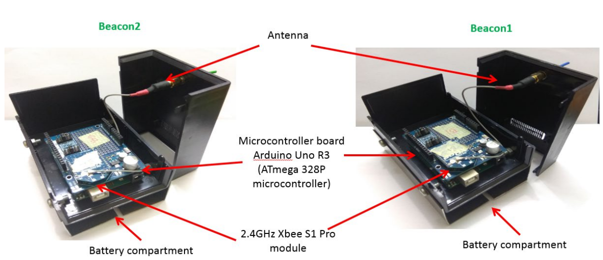

Figure 6 Entire system components for the hardware development for Beacon1 and Beacon2

Referring to *Figure 6*, this setup is use for the slave or the end device in the XBee network. The end device will read or scan the data in their neighbouring network. It can read the RSSI range between point to point in their network and send this information to the coordinator. The Arduino microcontroller board is used to control the end device for reading and sending the data to the Coordinator.

Table 1 Performance specifications of XBee PRO S1

| Specification | XBee PRO S1 |
|---|---|
| Standard | IEEE 802.15.4 |
| Frequency | 2.4 GHz ISM |
| Indoor/urban range | Up to 300 ft. (90 m) |
| Outdoor RF line-of-sight range | Up to 1 mile (1600 m) |
| Transmit power output (software selectable) | 63 mW (18 dBm) |
| RF data rate | 250,000 b/s |
| Serial interface data rate (software selectable) | 1200 bps - 250 kb/s (non-standard baud rates also supported) |
| Receiver sensitivity (typical) | 100 dBm (1% packet error rate) |
| Supply voltage | 2.8 - 3.4 V |
| Transmit current (typical) | 250 mA (@3.3 V) (150 mA for international variant) RPSMA module only. |

Table 2 The configurations of the Arduino Uno R3 microcontroller board

| Microcontroller | ATmega328P |
|---|---|
| Operating Voltage | 5V |
| Input Voltage (recommended) | 7-12V |
| Input Voltage (limits) | 6-20V |
| Digital I/O Pins | 14 (of which 6 provide PWM output) |
| Analogue Input Pins | 6 |
| DC Current per I/O Pin | 40 mA |
| DC Current for 3.3V Pin | 50 mA |
| Flash Memory | 32 KB (ATmega328) of which 0.5 KB used by bootloader |
| SRAM | 2 KB (ATmega328) |
| EEPROM | 1 KB (ATmega328) |
| Clock Speed | 16 MHz |

## C. Algorithm Design

A mathematical calculation is implemented on the algorithm inside the Arduino Uno R3 microcontroller. Mathematical calculation is used to filter the signal value that has been received by the Coordinator microcontroller. RF signal in the air are exposed to various type of loses and interference [12],[13]. Reflection, deflection and scattering are some of the sample of loses can be expected from the RF signal. By using a mathematical formulation, a sum amount of signals can be filtered to get the most stable signal that can get. A perimeter is set as the test area. A range of 50 meters long is set with a measuring tape to measure the distance. One beacon is set up at the start of the measurement point. Then, the coordinator Arduino is moved along the line and the mathematically filtered RSSI reading is recorded for every one meter in distance. Using the mathematical calculation, one stable RSSI reading is produce from the average of ten RSSI value that has been read by the XBee Pro S1. This experiment is done for both Beacon1 and Beacon2 at the same spot. Also this experiment is done in the open field condition that has been chosen, namely in football open field, watery paddy field with the paddy plant is just about 20 to 30 cm on top of the water and on a dry and ready to be harvest paddy field that the plant reaching the height of 1 meter from the ground. Using this mathematically filtered value that has been gathered, a graph is built to determine the normalise point for the RSSI signal. After that, a regression analysis is done to find the trend line for the RSSI signals and the range it is represented. This will determine the distance estimation for one beacon. Using the combinations from 2 beacons that is place in a different location, a triangle shape is form by Coordinator Arduino, the Beacon1 and Beacon2. This will be explained later on this chapter. Using the trigonometry of non-right triangles formula, the actual position of the Coordinator Arduino is determined. For every Beacon, each of every 1 meter range will have five different values taken. This means that Beacon1 and Beacon2 will have three tables for each of them. The signal that are recorded in a power ratio in decibels (dB) of the measured power referenced to one milliwatt (mW) or called dBm [14].

## D. *Regression Analysis*

Logarithmic regression is defined as a straight-line relationship that will be exhibit by a process data form by a graphed x values on a log scale and the Y values on linear scale [15]. The regression analysis is used to find as what called the trend line [16]. Author in [17] has given the logarithmic regression equation and it can be define in a general form of equation (1) below:

$$Y = A + (B)\ln(x) \qquad (1)$$

From the test value table, a graph in MS Excel is built using all the five readings for every Beacon. From the graph, the trend line for every RSSI signal is acquired. Using the trend line results, all the five RSSI reading for the Beacons will be recalculate to eliminate the noise signal and create an expectation signal value for every meter. A new graph table is built from this result. From the new graph that has been built using the new normalize value; the mean formula is used to choose the average signal strength for every meter in all five tests. This new centralized value between all the five test values will then form a news graph. The trend line from the last graph will be used as the reference formula to calculate the estimate range for one beacon. Using this method, Beacon1 and Beacon2 will have their own reference value base on the condition of the three field condition.

Figure 7 shows the process steps of the reference development technique for one beacon in one of the field condition.

## E. *Distance Range Calculation Modelling*

The position of the appointed beacon position is very important. In this work, the position that is pointed for the two beacons is at the end or at the starting area of the paddy field. It is also has been placed in a straight alignment line between them. The mirror point for the real position of the Coordinator has been discarded. This issue has been discuses before in *Figure 4*. After the consideration of this factor, a basic formulation for calculating the localization of the Coordinator is used. For the distance range calculation, the trigonometry of non-right angled triangles [18] formula is used. This formula has been chosen because of the triangle shaped caused by the position of the Coordinator, Beacon1 and Beacon2. The only different between this angle and the right angle triangles is that it is form by the combinations of two right angle triangles. This is the basic ways of determining the value of one length using two known reference range. *Figure 8* of a trigonometry of non-right triangle diagram. Referring to *Figure 8*, the range of "y" can be known if the range of "c", "a" and "b" is known. In his work, the range of "b" is set for 20 meters fixed. "A" is the unmovable position of Beacon2 and Beacon1 is in position "C". "B" is the movable Coordinator that is moving around an area of 50 x 20 meter diameter range. Throughout this setting, the targeted range of "y" as the final range estimation for the Coordinator position can achieve.

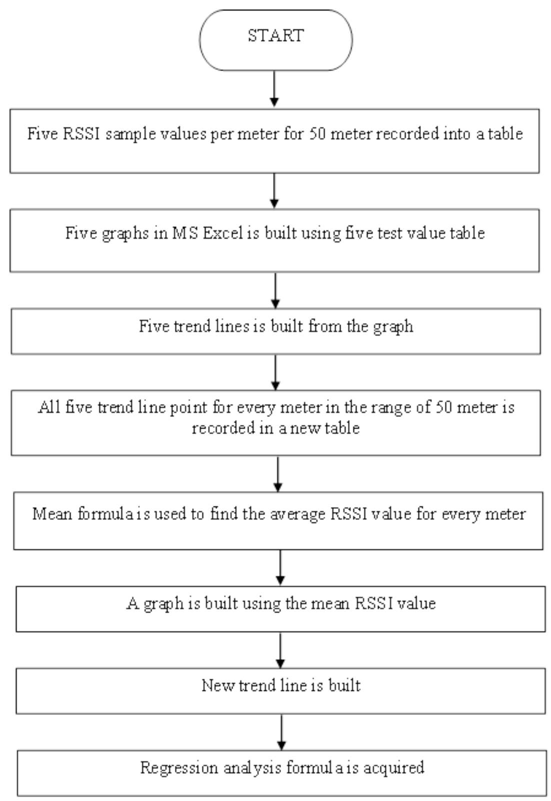


Figure 7 Process steps of the reference development technique for one beacon in one of the field condition

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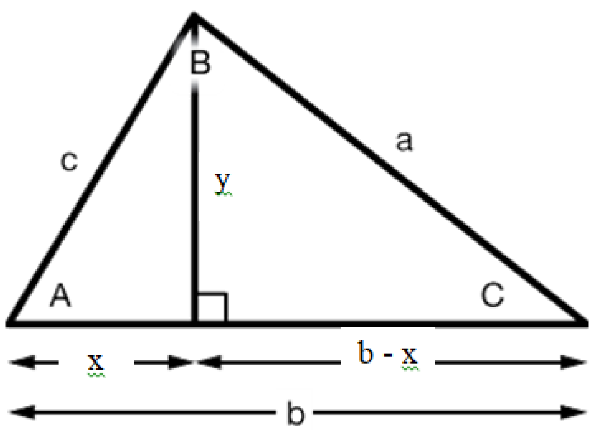


Figure 8 Trigonometry of non-right triangles diagram

Referring to *Figure 8* of a non-right triangle, derivation of the law of cosines can be used. A Pythagorean Theorem is used to derive two equations of right triangles. Using "c", "x" and "y", the first equation is as equation (2) below:

$$c^2 = x^2 + y^2 \quad (2)$$

Then, the second right triangles can be calculated using the line of "a", "y" and "b-x" as equation (3) below:

$$a^2 = (b - x)^2 + y^2 \quad (3)$$

From these two equation that has been interprets, something that can be noticed is that each of the equations contains "$y^2$". This value can be eliminated using the transitive property [19], [20]. The two equations can be rearranged to make it "y2" as the denominator.

$$y^2 = c^2 - x^2 \quad (4)$$

$$y^2 = a^2 - (b - x)^2 \quad (5)$$

From equation in (5), binomial theorem of the $(b - x)^2$ are done as below:

$$= (b - x)(b - x)$$
$$= b^2 - bx - bx + x^2$$
$$= b^2 - 2bx + x^2 \quad (6)$$

Now, equation in (6) will be inserted back in equation (5) and the results are as below:

$$y^2 = a^2 - (b^2 - 2bx + x^2)$$
$$y^2 = a^2\ b^2 + 2bx - x^2 \quad (7)$$

Next, equation in (4) will be matched with the equation in

(7) and the "x" is the denominators that are needed. The outcome is as equation (8).

$$y^2 = a^2 - b^2 + 2bx - x^2$$
$$c^2 = a^2 - b^2 + 2bx$$
$$2bx = c^2 - a^2 + b^2$$
$$x = (c^2 - a^2 + b^2)/2b \quad (8)$$

From equation in (8), the value of "x" is can be obtained. The value of "b-x" can be obtained from the equation below:

$$(b\text{-}x) = b - x \quad (9)$$

To get the value of "y", equation in (2) can be used as below:

$$c^2 = x^2 + y^2$$
$$y = \sqrt{c^2 - x^2} \quad (10)$$

In this equation, "y" is the value that is needed. Value of "y" is the estimation range that combines the two range measurement that has been recorded between Beacon1 to the Coordinator and Beacon2 to the Coordinator. The mathematical formula that has been derived in equation (8) and (10) are inserted to the Arduino microcontroller software algorithm to calculate the estimation range for the Coordinator to Beacon1 and Beacon2.

As stated before, the trigonometry of non-right triangles formula is used to estimate the distance. This step is very important to make sure all the value that has been collected will be calculated correctly by the algorithm. Mathematical value will be match with collected value from the XBee. Labelling is made as *Figure 9* to replicate the position of the Coordinator, Beacon1 and Beacon2 XBee in the field.

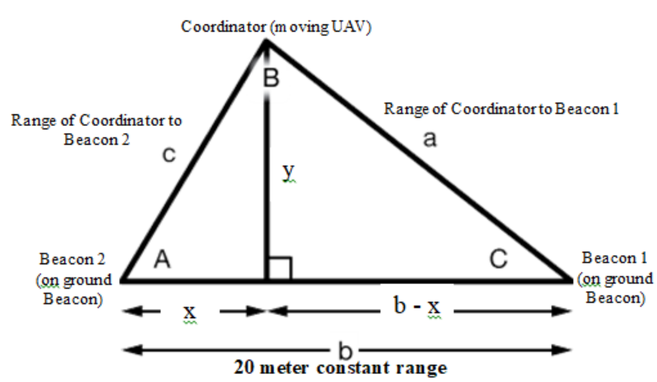


Figure 9 Coordinator, Beacon1 and Beacon2 placement in mathematical calculation

The reference point for the measurement is from the moving Coordinator and the line between Beacon1 and Beacon2 (point A to C). Referring to *Figure 9*, “a” will be RSSI signal from Beacon1. The length of “c” will be the RSSI signal from Beacon2. The length of “b” is the range between Beacon1 and Beacon2, the length between these two beacons has been set at a fix 20 meter in range. The “x” value will determine the Coordinator’s coordinate of x in the Cartesian coordinate system.

Every RSSI value from Beacon1 and Beacon2 are in dBm unit. Before the algorithm can calculate the estimated range, this value must be converted into a range unit namely as meter. For example, for Beacon1 conversion formula is taken from the regression analysis that has been done using all the data that has been collected. In this example, the range in meter can be taken from the equation (11):

$$x_1(Beacon1) = e^{\left(\frac{-y_1 - 30.716}{6.161}\right)} \quad (11)$$

where,
x1 = distance (meter)
y1 = RSSI value from measured value

This process will be repeated for Beacon2 range conversion using the regression analysis that has been done for Beacon2 RSSI value. After this conversion, the coordinate along Beacon1 and Beacon2 or the X value can be calculated using trigonometry of non-right triangles in equation (12):

$$X = \frac{\left(c^2 - a^2 + b^2\right)}{2b} \quad (12)$$

where,
$X$ = coordinate along Beacon1 and Beacon2
$a$ = distance between the Coordinator to Beacon1 in meter
$b$ = fix distance between Beacon1 to Beacon2 (20 meter)
$c$ = distance between the Coordinator to Beacon2 in meter

The Y value in the Cartesian coordinate or the estimated range of the Coordinator can be calculated using the formula derived from the trigonometry of no-right triangles as equation (13):

$$Y = \sqrt{c^2 - X^2} \quad (13)$$

where,
Y = distance between Coordinator to reference point
c = distance between the Coordinator to Beacon2 in meter
X = coordinate along Beacon1 and Beacon2

All these calculation will be done using the software algorithm in the Arduino microcontroller. The result will be display on a 16x2 LCD onboard of the Arduino microcontroller board. All the calculation then will be compared to a one of the popular calculations to estimate transmitted signal using the Friis Transmission Equation. In normal condition where there are no obstacle blocking the signal transmission in free space model, the receive signal $P_{re}(d)$ of the propagation is given by [21],[22] in equation (14):

$$P_{re}(d) = \frac{P_{tr} G_{tr} G_{re} \lambda^2}{(4\pi)^2 d^2 L} \quad (14)$$

Where $P_{re}(d)$ is the receive power at the receiver XBee. $P_{tr}$ is the power transmits by the transmitter, $G_{tr}$ is the transmitter antenna gain, $G_{re}$ is the receiver antenna gain. The two specifications can be referred to the XBee manual sheet. The $L$ is the loss factor that can be set = 1 and $d$ is the distance between the transmitter XBee and the receiver XBee. The $\lambda$ (lambda) is the wavelength of the RF signal.

## III. RESULT

The RSSI signal acceptance test has been done in all three different types of field. A measuring tape is put on the ground as a reference of the range that has been travelled. The Coordinator XBee is moved along the measuring tape line and for every 1 meter of range; the RSSI reading at the Coordinator XBee that has been transmitted by the beacons is observed and recorded manually. This test is done for Beacon1 and Beacon2, one at a time. Every test will measure the signal strength for every 1 meter for the maximum range of 50 meters.

Figure 10 and Figure 11 is the graph that has been build from Beacon1 and Beacon2 value taken in an open field. Figure 12 and Figure 13 is the graph that is build from Beacon1 and Beacon2 in a dry paddy field and the last two graph in Figure 14 and Figure 15 is taken from a watery paddy field for Beacon1 and Beacon2.

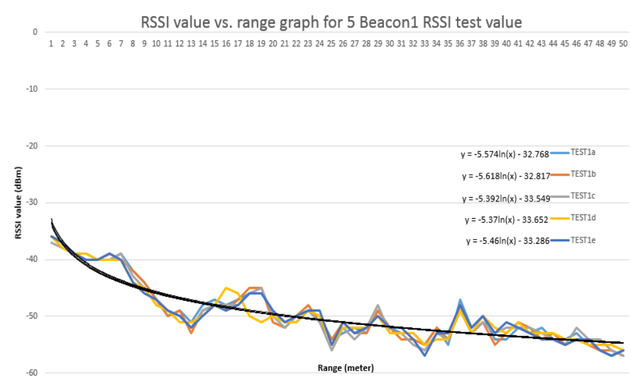


Figure 10 RSSI value versus range graph for 5 Beacon1 test value in open field

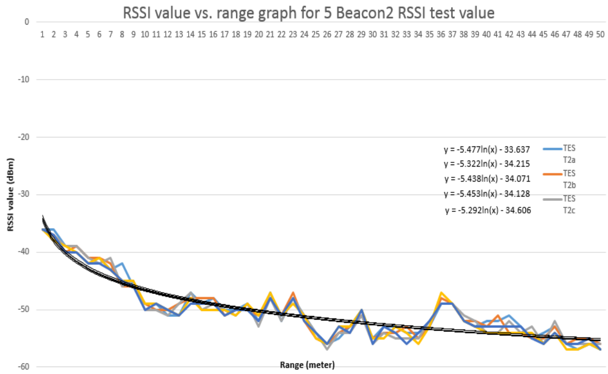


Figure 11 RSSI value versus range graph for 5 Beacon2 test value in open field

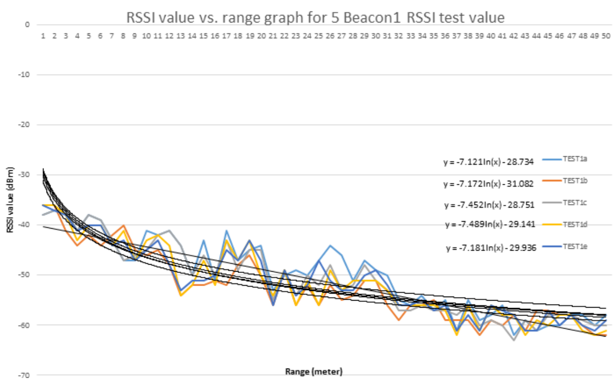


Figure 12 RSSI value versus range graph for 5 Beacon1 test in a dry paddy field

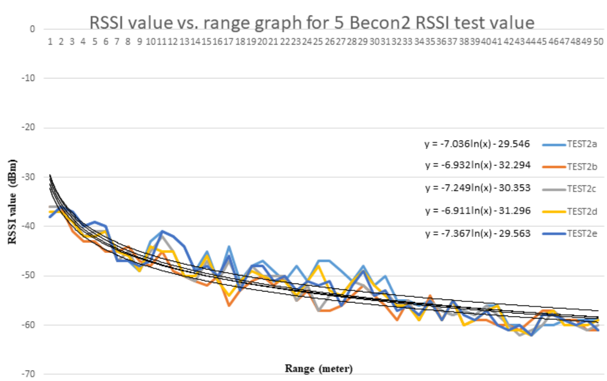


Figure 13 RSSI value versus range graph for 5 Beacon2 test in a dry paddy field

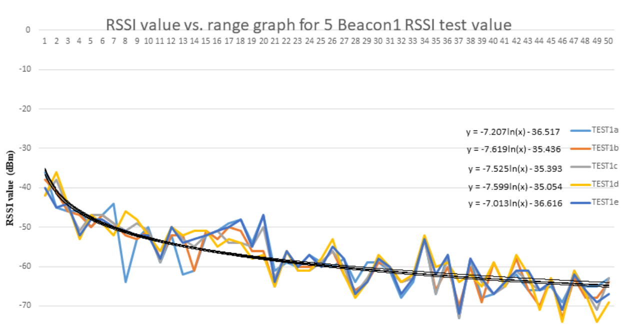


Figure 14 RSSI value versus range graph for 5 Beacon1 test in a watery paddy field

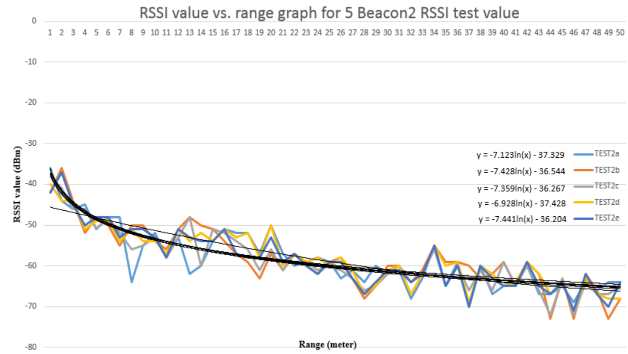


Figure 15 RSSI value versus range graph for 5 Beacon2 test in a watery paddy field

Referring to Figure 10 to Figure 15, can be seen clearly the different reading of RSSI signals in a different paddy field conditions. There are some gaps between the theory calculations using the Friis Equation for open space and the RSSI values that is built using the regression technique. This can be seen from *Figure 16*. The most different RSSI value readings are from the watery paddy field condition as expected before. From this result can be concluded that for different paddy field conditions, a different formula variable must be used to estimate the distance using the RSSI value between Beacon1 and Beacon2 to the Coordinator.

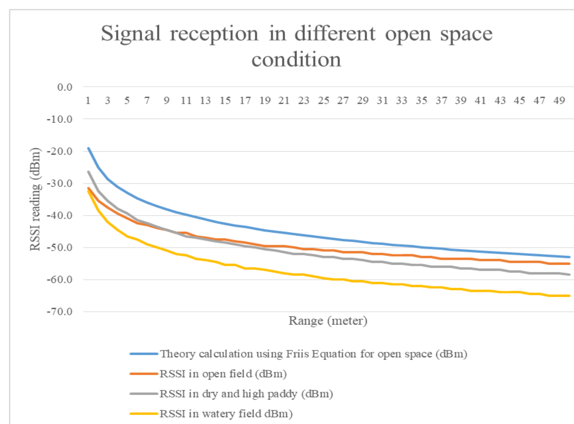


Figure 16 Graph of the signal reception in different open space condition

Referring to Table 2 to Table 4, the result sample is taken from ten randomly chosen ranges in the three area. The RSSI signal is taken in the area of 1000 square meters. The range between Beacon1 and Beacon2 is in a fix position. All the RSSI value is read and change to its estimated range value. From this value, the x and y position in a Cartesian chart can be obtained. The 'X' value represent the x coordinate position of the Coordinator between Beacon1 and Beacon2 and the 'Y' value represent the y coordinate point or the distance of the Coordinator to the line between Beacon1 and Beacon2. This means that 'Y' is the range of measurement that is used to measure the distance. All the value is taken using the algorithm that has been stored in the Arduino microcontroller board. To check the real differences between the real distance and the measured value using the algorithm, a measuring tape is used at every sample point that the data has been collected.

Table 2 Range estimation in open field using Arduino IDE algorithm calculation

| Bil. | Beacon1 RSSI (dBm) | Beacon1 (meter) | Beacon2 RSSI (dBm) | Beacon2 (meter) | Beacon1 to Beacon2 (fix distance) (meter) | Measured distance using measuring tape (meter) | X value (meter) | Y value (automatic calculation of distance using RSSI signal and algorithm in arduino) (meter) | Difference | Error Percentage (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -44 | 8.61 | -52 | 28.68 | 20 | 1 | 28.50 | 1.36 | 0.36 | 36.0 |
| 2 | -49 | 19.41 | -37 | 2.42 | 20 | 2 | 0.69 | 2.31 | 0.31 | 15.5 |
| 3 | -45 | 10.21 | -47 | 12.48 | 20 | 6 | 11.3 | 5.31 | -0.69 | -11.5 |
| 4 | -45 | 10.19 | -52 | 28.60 | 20 | 6.9 | 27.8 | 6.49 | -0.41 | -5.9 |
| 5 | -46 | 12.00 | -50 | 20.20 | 20 | 10.7 | 16.9 | 11.5 | 0.8 | 7.5 |
| 6 | -50 | 22.90 | -48 | 14.88 | 20 | 14 | 2.37 | 14.5 | 0.5 | 3.6 |
| 7 | -50 | 22.90 | -50 | 20.50 | 20 | 18 | 7.46 | 19.1 | 1.1 | 6.1 |
| 8 | -58 | 83.89 | -57 | 65.10 | 20 | 26 | -59.0 | 26.5 | 0.5 | 1.9 |
| 9 | -52 | 31.69 | -53 | 33.78 | 20 | 30 | 13.3 | 30.9 | 0.9 | 3.0 |
| 10 | -54 | 43.8 | -56 | 55.28 | 20 | 39 | 38.3 | 39.7 | 0.7 | 1.8 |

Table 3 Range estimation in dry paddy field using Arduino IDE algorithm calculation

| Bil. | Beacon1 RSSI (dBm) | Beacon1 (meter) | Beacon2 RSSI (dBm) | Beacon2 (meter) | Beacon1 to Beacon2 (fix distance) (meter) | Measured distance using measuring tape (meter) | X value (meter) | Y value (automatic calculation of distance using RSSI signal and algorithm in arduino) (meter) | Difference | Error Percentage (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -45 | -46 | 10.02 | 10.12 | 20.0 | 1 | 9.9 | 1.2 | 0.2 | 18.5 |
| 2 | -45 | -46 | 10.17 | 10.25 | 20.0 | 2 | 10.0 | 2.1 | 0.1 | 3.0 |
| 3 | -46 | -47 | 12.21 | 11.14 | 20.0 | 6 | 10.6 | 6.0 | 0.0 | 0.3 |
| 4 | -50 | -50 | 16.10 | 19.01 | 20.0 | 14 | 7.4 | 14.3 | 0.3 | 2.0 |
| 5 | -51 | -52 | 22.15 | 20.01 | 20.0 | 18 | 12.3 | 18.5 | 0.5 | 2.5 |
| 6 | -54 | -54 | 27.95 | 28.52 | 20.0 | 26 | 9.2 | 26.4 | 0.4 | 1.5 |
| 7 | -54 | -55 | 32.25 | 31.51 | 20.0 | 30 | 11.2 | 30.3 | 0.3 | 0.8 |
| 8 | -57 | -57 | 41.20 | 41.23 | 20.0 | 39 | 9.9 | 40.0 | 1.0 | 2.5 |
| 9 | -57 | -58 | 43.75 | 44.67 | 20.0 | 42 | 8.0 | 43.0 | 1.0 | 2.4 |
| 10 | -58 | -58 | 47.95 | 48.02 | 20.0 | 46 | 9.8 | 46.9 | 0.9 | 2.0 |

Table 4 Range estimation in watery paddy field using Arduino IDE algorithm calculation

| Bil. | Beacon1 RSSI (dBm) | Beacon1 (meter) | Beacon2 RSSI (dBm) | Beacon2 (meter) | Beacon1 to Beacon2 (fix distance) (meter) | Measured distance using measuring tape (meter) | X value (meter) | Y value (automatic calculation of distance using RSSI signal and algorithm in arduino) (meter) | Difference | Error Percentage (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -52 | -52 | 10.12 | 10.11 | 20.0 | 1 | 10.0 | 1.5 | 0.5 | 52.1 |
| 2 | -52 | -52 | 10.22 | 10.19 | 20.0 | 2 | 10.0 | 2.0 | 0.0 | 1.8 |
| 3 | -53 | -54 | 12.11 | 11.29 | 20.0 | 6 | 10.5 | 6.1 | 0.1 | 1.1 |
| 4 | -57 | -57 | 17.02 | 18.50 | 20.0 | 14 | 8.7 | 14.6 | 0.6 | 4.5 |
| 5 | -57 | -59 | 22.15 | 20.01 | 20.0 | 18 | 12.3 | 18.5 | 0.5 | 2.5 |
| 6 | -60 | -61 | 28.50 | 29.00 | 20.0 | 26 | 9.3 | 26.9 | 0.9 | 3.6 |
| 7 | -61 | -62 | 32.00 | 32.14 | 20.0 | 30 | 9.8 | 30.5 | 0.5 | 1.6 |
| 8 | -63 | -64 | 41.20 | 40.50 | 20.0 | 39 | 11.4 | 39.6 | 0.6 | 1.5 |
| 9 | -64 | -64 | 44.00 | 44.50 | 20.0 | 42 | 8.9 | 43.1 | 1.1 | 2.6 |
| 10 | -65 | -65 | 48.00 | 48.00 | 20.0 | 46 | 10.0 | 46.9 | 0.9 | 2.1 |

From the table can be seen that the majority of error percentage or the margin between the real measured value using the measuring tape and using automatic calculation of distance using RSSI signal and algorithm in Arduino are less than 15 percent. The first 1 meter error is high cause by the limitation that has been mention in [23]. This test basically shows that the RSSI value can be used to estimate the coordination of an object by combining two point of Beacons.

To see the gap between the distances that has been obtained using the algorithm in Arduino microcontroller and manual measurement using the measuring tape, Table 5 has been build. This table is showing the three different field conditions and has been measured using algorithm in Arduino against the manually measured range. Referring to Table 5, the average value in the table is derived from the three paddy field conditions RSSI value. The differences value in the table is derived from the differences in average table and the measured range using measuring tape in meter. The percentage is used to see the differences in percentage between the manually measured range and the measurement using the algorithm in Arduino and this percentage is as a whole conclusion for the three field condition. All the differences also can be seen as a graph depicted in Figure 17.

Table 5 Measurement result between using measurement tape and measurement using algorithm in Arduino in measuring different ground condition.

| Measured Range using measuring tape (meter) | Y value (open field) | Y value (Dry condition paddy field) | Y value (Wet condition paddy field) | Average | Differences | % |
|---|---|---|---|---|---|---|
| 1 | 1.36 | 1.2 | 1.5 | 1.4 | 0.4 | 26.1 |
| 2 | 2.31 | 2.1 | 2.0 | 2.1 | 0.1 | 5.8 |
| 6 | 5.31 | 6.0 | 6.1 | 5.8 | -0.2 | -3.8 |
| 14 | 14.50 | 14.3 | 14.6 | 14.5 | 0.5 | 3.2 |
| 18 | 19.10 | 18.5 | 18.5 | 18.7 | 0.7 | 3.5 |
| 26 | 26.50 | 26.4 | 26.9 | 26.6 | 0.6 | 2.3 |
| 30 | 30.90 | 30.3 | 30.5 | 30.5 | 0.5 | 1.7 |
| 39 | 39.70 | 40.0 | 39.6 | 39.8 | 0.8 | 1.9 |
| 42 | 42.00 | 43.0 | 43.1 | 42.7 | 0.7 | 1.7 |
| 46 | 46.80 | 46.9 | 46.9 | 46.9 | 0.9 | 1.9 |
| | | | | Accuracy (meter) | 0.5 | |

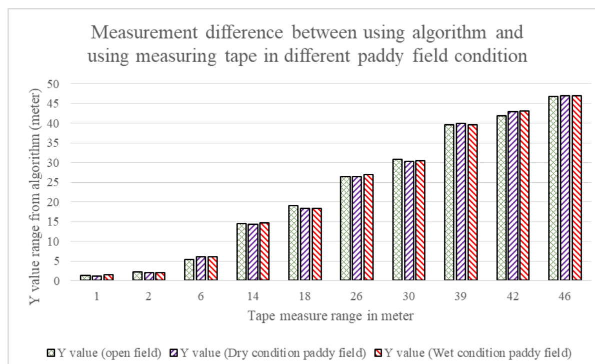


Figure 17 Measurement difference between using algorithm and using measuring tape in different paddy field condition

## IV. Conclusion

This work is targeted for the use on an Unmanned Aerial Vehicles (UAV) that will run in a paddy planting field. The algorithm and the hardware of the technique have been designed base on a microcontroller technology that is very popular nowadays. The ability of the XBee that can measure the RSSI signal in the communication line is the biggest advantages.The whole setup for this work is based on these two components.

Basic concept for the whole system is to build a beacon or more beacon point on the paddy field that can transmit a signal to the receiver. Using this concept, the receiver will measure the RSSI signal from each of the beacon. Overall, this study has significantly helped to develop another ways of measuring the position and the distance of the UAV in the paddy field, not only depending on using the GPS for localization. This technique also reduce the power consumption on board of the UAV by introducing the circuit that used less power consumption.

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