Effect of Obstacle Angles on Signal Strength for Different Mounting Elevations of XBee Pro Module in Viral Advertisement System

M.R. Yaacob[1,a], L.W. Teck [1,b], N.S.N. Anwar[1,c]

[1]Faculty of Electrical Engineering, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia

[a]rusdy@utem.edu.my, [b]limwt@utem.edu.my, [c]syahrim@utem.edu.my,

Keywords: XBee, signal, obstacle

Abstract. This paper presents a study on the effect of obstacle angles on signal strength for different mounting elevations of XBee Pro module. The study has been conducted by using two units of XBee Pro modules which each represents a receiver and a transmitter. The transmitter is mounted in three different elevations which are 0.5, 1.5 and 2.5 meter from the ground while the receiver is fixed at the same elevation but at different positions which yield to different angles. When the transmitter continuously transmits the wireless signal carrying its particular address, the receiver will detect the signal address once the range of communication of both receiver and transmitter intersects. The results obtained are the values of signal strength, in percentage, with respect to the obstacle angles between receiver and transmitter for different mounting elevations of transmitter. These data are then converted into graph that illustrates the signal strength characteristics for each mounting elevation. Finally, the best mounting elevation is to be identified based on the result obtained.

Introduction

In the development of advertisement system, the importance of having wireless technology is significantly increasing especially in the scenario where the information is dynamically changing over the time. This is because wireless advertisement allows the flexibility in sending and displaying the information as well as modifying it when necessary. Despite it also solves the environmental issue from the usage of papers which are going to be dumped later on.

There are several types of protocol that can be used for a viral advertisement system. The one that could be very common nowadays is Zigbee protocol. The information is wirelessly transmitted within the range of the XBee device. How much is the strength of the signal which carries the information, is still a question that needs to be figured out. This is because the obstacle that exists between the two points will result in different effect. Hence this study is done to provide a better understanding in term of explaining the behavior of the signal strength over the obstacle angle between transmitter and receiver.

Previous researches have been done which employ Zigbee protocol in transferring data between different points. Researchers from Anna University of Technology have come out with their research regarding the study on Zigbee technology. The study discusses the characteristics of Zigbee like the power consumption, data rate, cost and time delay [1]. However the signal strength over obstacle angles did not come into consideration.

Another research was done by researchers from Akita, Japan regarding the flexible bus system using Zigbee as the communication medium [2]. In their research, experiments were done to study the detection range as well as data transfer involved. Therefore, it is proven that Zigbee can be used in bus transportation system. This is a good motivation for a new research on the viral advertisement system which utilizes bus as the information carrier to spread out the advertisement. However in this research, the effect of obstacle was not taken into consideration.

In this paper, we will further discuss on the measuring principle in Section 2. Section 3 describes the experimental setup used for the signal strength measurement and finally in Section 4, we will thoroughly discuss the results obtained from the experiments.

Measuring Principle

I.   XBee Module

XBee is a flexible wireless communication device that can be connected with microcontroller, computer or any system with serial communication. It is a product produced by Digi and can be divided into two types which are XBee and XBee Pro. XBee Pro has been chosen as the communication medium for this project with regards to its wider range compared to the normal XBee [3].

Fig. 1 XBee Module

There are several types of XBee addressing mode for it to communicate with the other module. The one used in this project is the transparent mode. This connection mode only communicates two XBee modules by pairing its destination and its own address. For example, if there are two modules (XBee1 and XBee2), the DL (destination address) and MY (its own address) addressing are shown in Table 1.

Table 1 XBee addressing for Transparent Mode

Address	MY	DL
XBee1	2222	3333
XBee2	3333	2222

For the analysis of the system, transparent mode will be used because the experiment only involves two points and it supports the Zigbee point-to-point communication principle which is further discussed in the next part.

II.   Zigbee Point-to-point Communication

A viral advertisement system for this project is accomplished by employing the point-to-point communication using Zigbee. In general, a point-to-point communication refers to the communication connection between only two networking nodes. Information transmitted by one node can be received by the other node, which is contrasted with a point-to-multipoint or broadcast communication where many nodes can receive the information.

In this viral advertisement system, the information transmitted and received is the advertisement ID itself. A bus plays the role as the information carrier that carries the advertisement ID and transmits it to the respective bus top. Note that the advertisement ID was sent from the mall to the bus beforehand. The scenario is illustrated in Fig. 2. In this case, the point-to-point communication is employed between the bus and the mall as well as the bus and the bus stop.
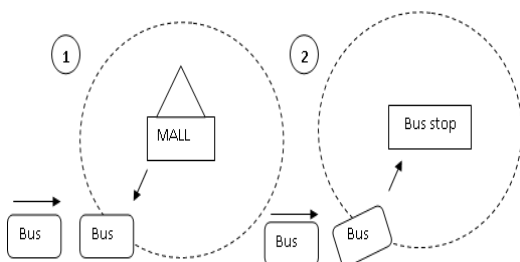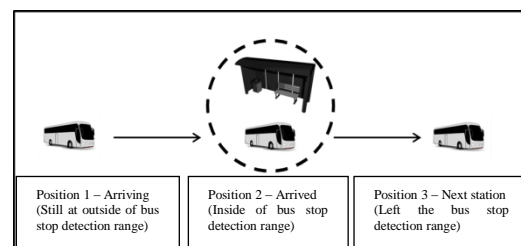

Fig. 2 Viral advertisement system

Fig. 3 Point-to-point communication

To further explain on the point-to-point communication, let us consider Scenario 2 from Fig. 2 only. It involves the communication between bus and bus stop as depicted in Fig. 3. The bus is now carrying the advertisement ID and approaching the bus stop but still in Position 1 which is outside the communication range. Once the bus entering the range as in Position 2, it will transmit the advertisement ID to the bus stop which is also equipped with computer and LCD monitor to display the information from the advertisement. The next experimental setup will only cover the measurement of signal strength from bus to bus stop only in order to study the effect of obstacle angle on the signal strength.

Each bus and bus stop is equipped with an XBee Pro module to support the Zigbee wireless protocol. The connection between the bus and the bus stop is accomplished right after the range of the module on the bus intersects with the range of the module at the bus stop. Each advertisement has its own unique ID which is recognized by the XBee module at the bus stop.

Experimental Setup

To perform the range test experiment, the loop back tests was implemented in measuring the percentage of the send and receive data. For this experiment, hardware modification on the receiving end of the XBee must be done where the Tx and Rx pin on the XBee board must be short circuit in order to make sure the data receive is transmitted back to the original transmitter. This is because the range test experiment is conducted based on the amount of data that are successfully arrived at the original transmitter. The original transmitter will flow the data into the laptop that is connected to it and the X-CTU software will rise the amount of data receive in the good signal panel.
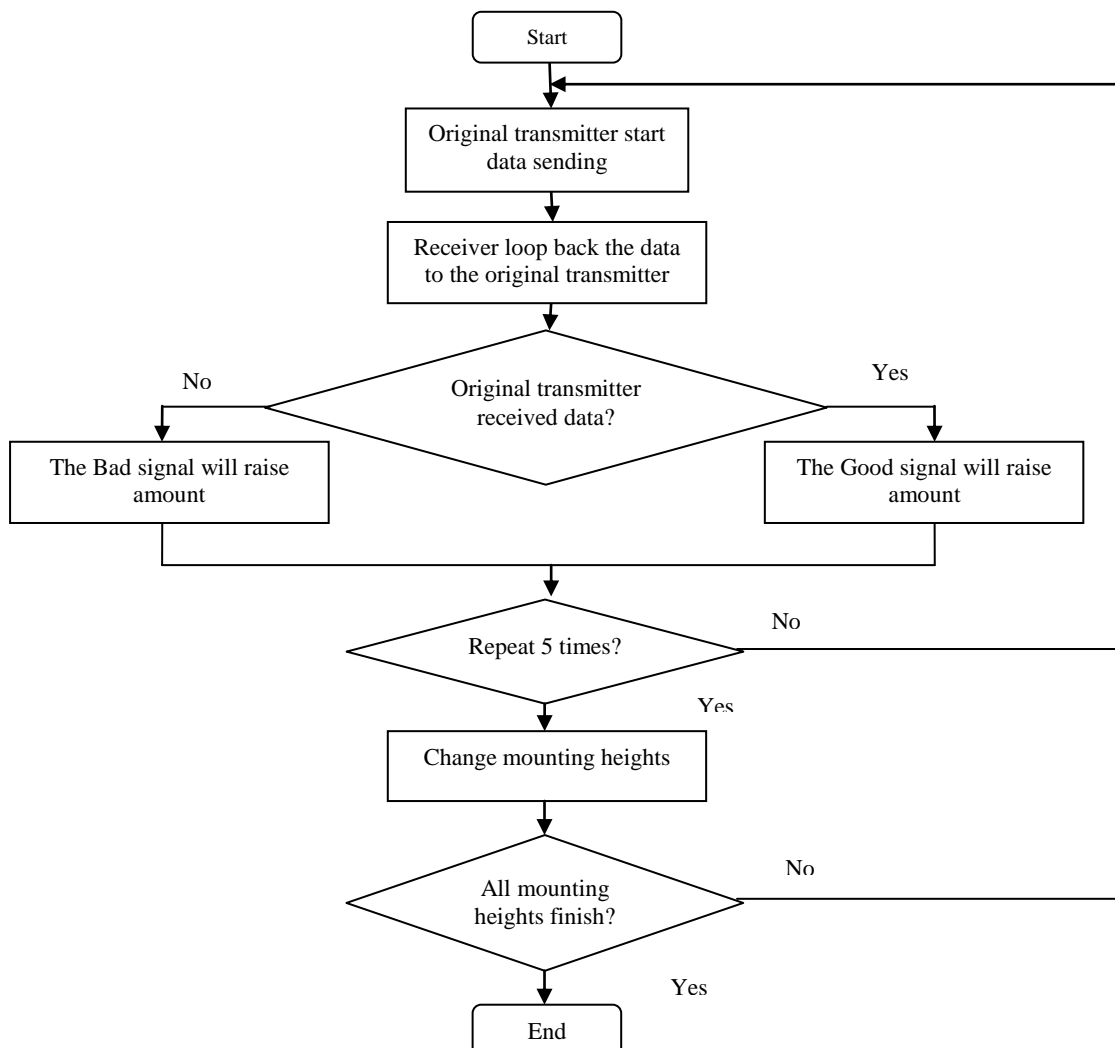

Fig. 4 The flow chart of loop back range test

If the data sent is successful, the blue bar will rise and good signal indicator will counting up but if the data sent is not received, the bad signal indicator will counting up. Each of those conditions is illustrated in Fig. 5 and Fig. 6, respectively, from the X-CTU software.
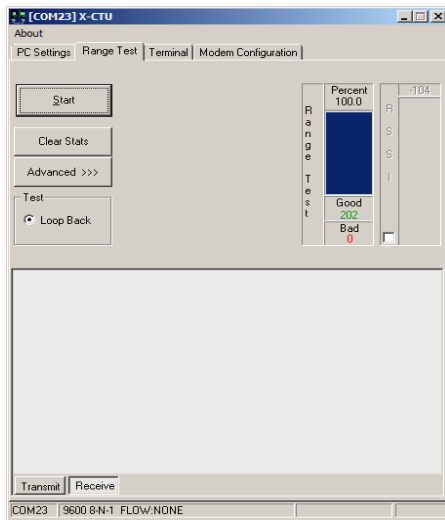

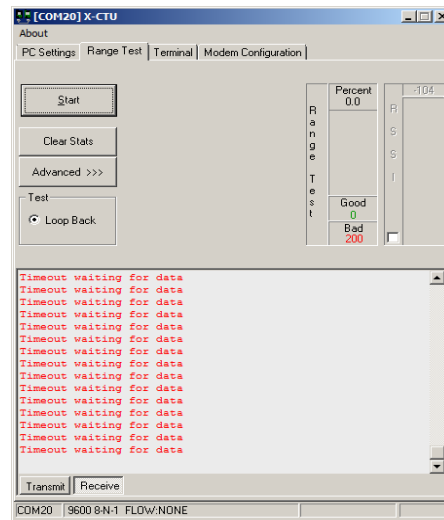Fig. 5: Data sent successful indicator

Fig. 6: Data not sent indicator

Obstacles range test was done to acquire the farthest signal that the XBee modules can achieve with solid building as obstacles with the mounting heights of the modules as the manipulated variable. The experiment is done by implementing the loop back test as depicted in Fig. 4. The location of experiment was at Taman Tasik Utama residential area and the experimental setup is as shown in Fig. 7.
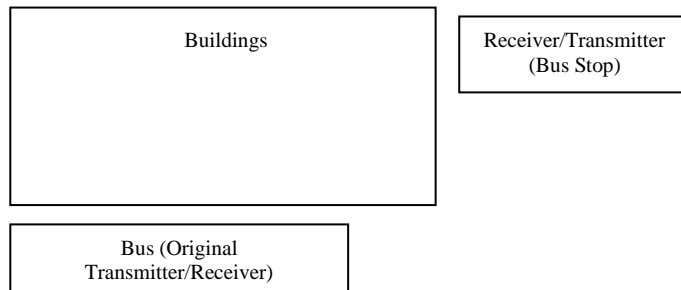
The distance increment is calculated by implementing the Theorem Pythagoras in the experiment setup. The transmission angle is taken as the direction of the connection between the transmitting modules and receiving modules. Fig. 8 shows the implementation of the Theorem Pythagoras in the experimental setup and the calculation involve in determining the direction angles and distances are shown below:
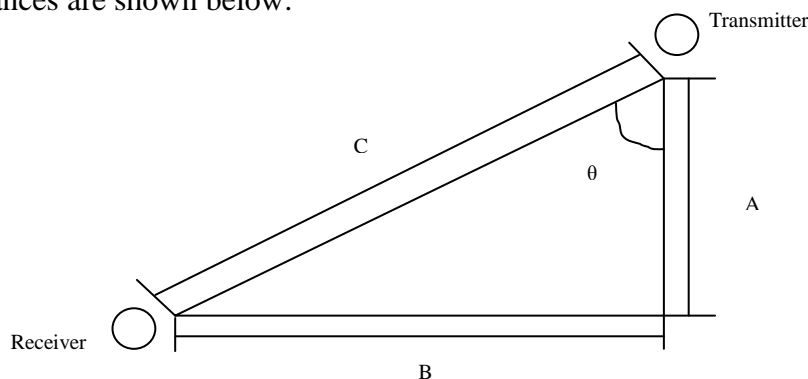

Fig. 8: Pythagoras Theorem in the obstacle experimental setup

A = Fixed distance of 30 meter

B = Calculated distance where:

$$B = \left(\sqrt[2]{C^2 - A^2}\right)^2 \quad \text{------------------------------ (1)}$$

C = Value of distance increment, as example: 100 meter, 200 meter

θ = Direction degree of transmitting module where:

$$\theta = \cos^{-1} \frac{A}{C} \quad \text{-------------------------- (2)}$$

Sample calculations for B and θ:

For C = 50 meter;

$$B = \left(\sqrt[2]{50^2 - 30^2}\right) = \left(\sqrt[2]{250 - 90}\right) = 49.69 \text{ meter} \approx 47 \text{ meter}$$

$$\theta = \cos^{-1} \frac{A}{C} = \cos^{-1} \frac{30}{50} = 53.13\,^\circ \approx 53^\circ$$

The calculation were also done for other values of C which are 100, 150, 200 and 250 meter and the values of angle were then included in Table 2.

Result and Analysis

After getting done with the calculations for the distance, B and angle, θ, an experiment was done for three different mounting elevations and the results are recorded in Table 2 before finally converted into a graph as depicted in Fig. 9. To have more precise result, the data was recorded five times before taking the average value as the final result for each distance and mounting heights.

Table 2 Measurement for different mounting elevations

Distance (m)	Direction (Θ°)	Elevation (m)	Average Signal Strength (%)
50	53	2.5	99.26
		1.5	98.12
		0.5	64.28
100	72	2.5	97.92
		1.5	97.44
		0.5	32.3
150	78	2.5	74.92
		1.5	69.08
		0.5	12.4
200	81	2.5	43.2
		1.5	21.7
		0.5	8.2
250	83	2.5	0
		1.5	0
		0.5	0

From the graph, it is observed that the signal strength decrease as the obstacle angle increase for all three mounting elevation. However, the signal strength for 0.5 meter mounting elevation has the lowest signal strength reception compared to other two. In this experiment, the obstacle angle, θ is showing the thickness of the building that acts as the obstacles. The decrement of signal strength for both 2.5 meter and 1.5 meter mounting elevations started at 72˚ obstacle angle.

The decrement of the signal strength for this test happened because of the thickness of the building. As stated in the experimental setup, the buildings chosen for the experiment were houses area. With the increment of the houses thickness, it makes more difficult for the XBee modules to communicate with each other. Other than that, there exist disturbances by other electromagnetic

waves where the source is from the building's electrical appliances. Hence, electrical appliances such as television, radio, and Wi-Fi that emits the electromagnetic waves cause disturbances in the communication between the transmitter and receiver since XBee is also using the same radio wave frequency usage as other electrical appliances [4].
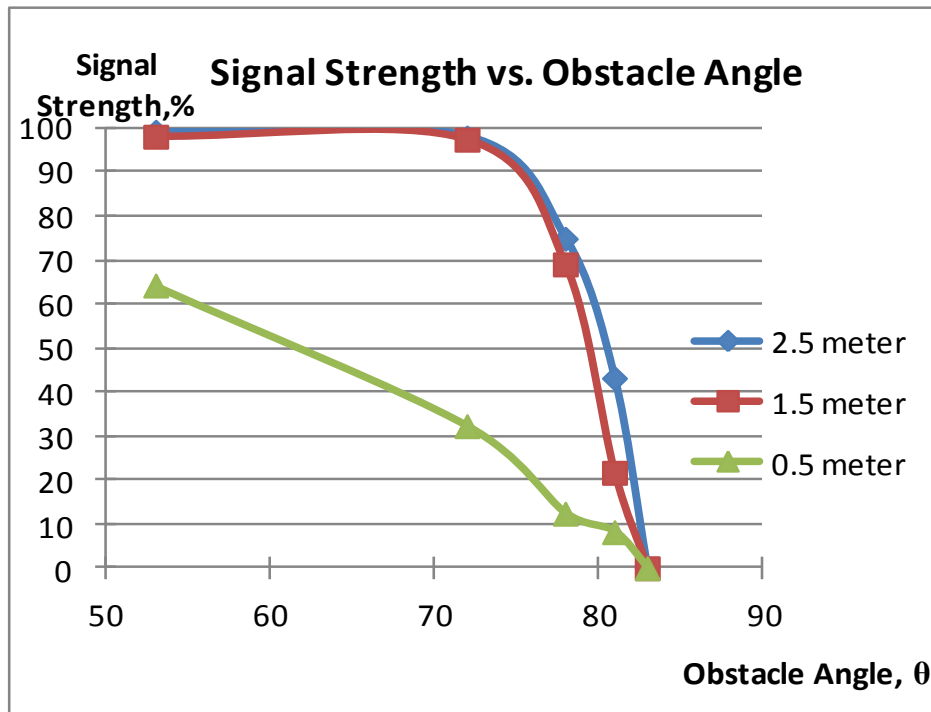

Fig. 9 Graph for obstacles range test with three different mounting heights

After this experiment was done, the suitable height that can be implemented to real-life application is from 1.5 meter and higher with direction angle of 78˚ and smaller. This is the minimum proposed specifications for the XBee Pro successful communications with obstacles. If the specifications chosen are vice versa from the proposed minimum requirement, the signal strength will be lower and may cause the data transferring to suffer data loss or no data transfer at all.

Conclusions

As a conclusion for obstacle range test part of analysis, the transmission of data can be done by the XBee modules with stable signal by having mounting heights at least 1.5 meter or higher and with direction angle of 78 ˚ or smaller.

References

[1] Muthu Ramya. C,Shanmugaraj. M, Prabakaran. R, Anna, "Study On Zigbee Technology," University of Technology, Tiruchirappalli (India), 2011.

[2] Razi Iqbal, Yukimatsu, Tatsuya Ichikawa, "The Flexible Bus System Using Zigbee as a Communication Medium," Akita (Japan), 2011.

[3] Cytron Technologies [Online] Viewed 2011 September 20. Available: http://www.cytron.com

[4] S. Misra, C. Ruf, R. Kroodsma, "Detectability of Radio Frequency Interference due to Spread Spectrum Communication Signals using the Kurtosis Algorithm," University of Michigan, 2008.