Propagation Modelling in Durian Orchard for Wireless Sensor Network at 2.4 GHz

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1. Introduction

The study of radio-wave propagation phenomena in the forest environment is required for increasing the potentialities of RF communications such as Wireless Sensor Network (WSN), Wireless Local Area Network (WLAN) and others. In the WSN application, it is aimed to monitor and detect the desired parameters such as cars in car-park management systems, traffic in the intelligence transport system (ITS) and others depending on sensor type of sensor nodes [1]. In agricultural applications such as the wireless sensor systems in durian orchard in Thailand, it is employed to predict the maturity stage of durian. The sensor nodes will send the detected information (electrical properties of durian) to the server system via RF signal. Thus, knowing RF propagation channel characteristics is indispensable. The behavior of the communication channel (in forest) is important for planning the networks. One parameter that is used to setup networks is the path loss information or signal strength versus the distance. The path loss along the propagation path is dependent on the characteristic of the channel and its variation [2-3].

The experimental models of the forest environment are convenience to setup the WSN network. This paper focuses on WSN at the frequency of 2.4 GHz. The experimental data of signal strength versus distance in the durian orchard is used to construct the propagation model. We carried out our experiments in the durian orchard located at the Chantaburi province, Thailand. The experiments on point-to-point radio links between a fixed transmitter and a movable receiver (portable spectrum analyzer) were performed at various transmitting antenna heights. The empirical models such as the single slope and dual slope model are used to represent the path loss [4]. The comparison between single slope and dual slope models are presented. This paper is organized as follows. Section II describes the method of measurement. The measurement results such as single slope and dual slope regression are presented in Section III. The comparison between measurement results and the path loss modeling are discussed. Finally, Section IV is the conclusion.

2. Measurement Setup

![Figure 1: Propagation measurement in durian orchard](image)

(a) Model of durian orchard   (b) Photograph of durian orchard

Fig. 1 Propagation measurement in durian orchard

The scenario of durian orchard is shown in Fig. 1 (a). The photograph of the measurement setup and location of measurement is shown in Fig. 1 (b). The distance between durian trees is about 8m. The average height of durian tree is higher than 10 m. The direction of measurement is illustrated in Fig. 1 (b). The measuring equipments consist of a 2.4 GHz transmitter, a portable spectrum analyzer...
and transmission lines. The dipole antennas are employed as the transmitting and receiving antennas. The transmitter is used to generate continuous wave with transmitting power of 10 dBm. The transmission line loss is about 2 dB. At the measurement points, the portable spectrum analyzer is employed to receive the signal strength and the signal is collected every 8m (at the bole of the trees). The measurements can be classified into two cases. The first case, the heights of transmitting and receiving antennas are 50 cm, while the heights of transmitting and receiving antennas are 150 cm for the second cases.

3. Measurement Results

![Fig. 2 Received power level (dBm)](image)

(a) Tx and Rx antenna heights are 50 cm  
(b) Tx and Rx antenna heights 150 cm

The received signal strength of both antennas heights are shown in Fig. 2. For the first cases as shown in Fig. 2 (a), the heights of the transmitting and receiving antennas are 50 cm. The received power from the half-wave dipole antenna is connected to the spectrum analyzer. The signal strength is collected along the propagation path of row 1 by averaging values with 20 samples. The attenuation of the signal along the propagation path of 128 m is relative to maximum of 40 dB.

The second cases as shown in Fig. 2 (b), the heights of transmitting and receiving antennas are 150 cm. In this case, the attenuation along the propagation paths is higher than the case of 50 cm high of transmitting and receiving antennas due to the obstruction of durian leaves.

4. Path Loss Modelling

4.1 Single slope regression model

The Line of Sight (LOS) path loss is a function of distance to the power $n$ as shown below

$$L_{LOS}(d) = L_{d_0} + 10\log_{10}\left(\frac{d}{d_0}\right)^n$$

where $L_{LOS}$ is the path loss at the distance $d$ from the transmitter, and $L_{d_0}$ is the path loss at the reference distance $d_0$ from the transmitter. $n$ is the path loss exponent.

![Fig. 3: Single slope regression model](image)

(a) Tx and Rx antenna heights are 50 cm  
(b) Tx and Rx antenna heights 150 cm
Fig. 3 shows the received signal power versus log-scale of the distance. The attenuation slope can be modeled by single straight lines to represent the path loss along the propagation distance. The path loss exponent $n$ is a slope parameter determined by straight line fitting (least square error) the experimental data. In the case of transmitting and receiving antennas heights of 50 and 150cm, the path loss exponent $n$ is equal to 3.5345 and 3.0179, respectively. In this work, to confirm the agreement between the experimental data and fitting data, the correlation factor between the experimental data and fitting data are employed. The correlation factor is less than 0.93.

### 4.2 Dual slope regression model

Generally, when the observation point is moving away from the transmitter, the received signal strength are decreased by factor of the path loss exponent $n$. At far-regions, the path loss exponent $n$ may change due to the line-of-sight component is slightly affected. The propagation loss as a function of distance of two regions as follows

$$L_{LOS}(d) = \begin{cases} L_{Rb.1} + 10\log_{10}\left(\frac{d}{R_b}\right)^{n_1} & \text{for } d<R_b \\ L_{Rb.2} + 10\log_{10}\left(\frac{d}{R_b}\right)^{n_2} & \text{for } d>R_b \end{cases}$$

(2)

The parameter $R_b$ is the break point distance that is measured from the transmitting antenna. The $L_{Rb.1}$ and $L_{Rb.2}$ are the initial field strengths. The $n_1$ and $n_2$ are the path loss exponents on the first region and the second region, respectively.

![Fig. 4 Correlation factor versus distance](image_url)

(a) Tx and Rx antenna heights are 50cm   
(b) Tx and Rx antenna heights 150cm

![Fig. 5 Dual slope regression models](image_url)

(a) Tx and Rx antenna heights are 50cm   
(b) Tx and Rx antenna heights 150cm

Fig. 5 shows the received signal power versus log-scale of the distance. The attenuation slope can be modeled by two straight lines, one representing the slope between the base site and the break point of the two straight lines, and the other between the break point and final point of the propagation path (128m). The optimum break point is determined by varying the break point distance and then the correlation factors between the first straight line and measurement data of the first and second straight lines are considered, respectively. For the optimum break point, we choose the break point at the cross point of the correlation factor of two lines as shown in Fig. 4. For the transmitting and receiving antennas heights of 50 and 150cm, the optimum break points is about 32 m.

For the attenuation line of the starting point to the break point (first attenuation line) in the cases of transmitting and receiving antennas heights of 50 and 150cm, the path loss exponent is equal to...
3.2921 and 3.1129, respectively. These cases show the larger attenuation rate than the free-space attenuation (equals 2).

For the distance from the transmitter of greater than the break point (second attenuation line) in the cases of transmitting and receiving antennas heights of 50 and 150cm, the path loss exponent is equal to 2.9361 and 2.6174, respectively. These cases show the lower attenuation rate than in the area closer to the transmitter (first attenuation line). The propagation effects such as the diffraction and the reflection of the durian tree at the distance beyond the break point are strong. The correlation factors of the dual slope models for the cases the transmitting and receiving antennas heights of 50 and 150cm are better than 0.98 and are higher than single slope regression model.

5. Conclusion

This work presents the study of radio-wave propagation phenomena at 2.4GHz in the durian orchard scenario. The path loss models are constructed by using the experimental data. It is found that the attenuation rates of the durian orchard are higher than the free-space attenuation. For the optimum propagation models, it is found that the dual slope regression is suitable due to the correlation factor is higher than the single slope regression model. It can be used to predict the signal strength at the desired distance calculated from the path loss exponent \( n_1 \) and \( n_2 \). The measured results and propagation model in this paper is essential to set up the wireless network in durian orchard.

Acknowledgments

This work was supported by the TRF through the Senior Research Scholar Program under Grant no. RTA5180002.

References


