# Research on WSN channel fading model and experimental analysis in orchard environment

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**Abstract:** The wireless sensor networks used in large-scale orchard must be able to run in various environments including different heights and densities of fruit trees. Moreover, as the radio channels have different propagation characteristics in different environments, it is important to study the propagation characteristics of wireless channel in orchards environments. This paper studied the propagation characteristics of wireless channel of 2.4GHz and 433MHz in orchard with different peach tree heights, respectively, and the channel fading and PLR (Packet Loss Rate) were tested. After that, the transmission range and PL (Path Loss) of wireless channel with different antenna heights were analyzed, and the communication channel fading model was also established. It can be observed that antenna height influence on the frequency of 433MHz is slightly larger, but the initial path loss of 2.4GHz wireless channel is greater. And it also can be found that the antenna height of 3.5 meters is better.

**Key Words:** Wireless sensor networks (WSN); channel fading model; precision agriculture; orchard

## 1 INTRODUCTION

Favorable orchard environment is the basis for fruit production. A continuous monitoring on the orchard environment and the growth information of fruit trees was an important technical method to improve agricultural land productivity and resource utilization efficiency, to increase crop production management level and to develop modern agriculture [1-4]. Using WSN technology to solve related issues has become a hot research focus currently [5, 6]. The research on the propagation characteristics of wireless channel provides important guidance for its application in orchard environment [7].

## 2 PRINCIPLES AND METHODS

### 2.1 Path Loss Model

By subtracting received power (in dBm) from transmitted power (in dBm), the path loss in dB is resulted.

Radio signal meet the formula in propagation:

$$PR=PT / dn . \qquad (1)$$

Where d is the distance between the sending and receiving node; n is propagation factor, whose value depends on the propagation environment of wireless signal.

Taking the logarithm on both sides of the formula:

$$10n\lg d=10\lg(PT / PR). \tag{2}$$

Using least-squares fitting the measured power attenuation data in Matlab based on the approximate logarithm distance path loss model, we found the data met Model (3):

$$PL = k+10n\lg d. \tag{3}$$

Where n is the power decay index; K is the model parameters.

Considering that the antenna height h had a greater link with loss index n, Formula (3) could be written as:

$$PL= k+10n（h）*\lg d. \tag{4}$$

Parameter k and n determined the relationship between received signal strength and signal transmission distance.

### 2.2 Experimental Device

The experiments selected CC2430 nodes and 1100SE RF module(CC2430 sends signal of 2.4GHz while RF1100SE sends 433MHz), and DS18B20 Digital Temperature Sensor covered by stainless steel was connected to send real-time temperature information to the receiving node. The transmitting node and receiving node were required to be consistent to ensure that no additional loss occurred to the system. Moreover, the node path loss less demanding, it could be powered by a 3V battery. The following is a brief description of the node.

CC2430 is TI’s new ZigBee wireless RF module. It can work in the 2.4 GHz band, requiring low voltage (2.0-3.6 V) power supply with low power consumption (27mA when receiving data and 25mA when sending). Its sensitivity reaches up to -90dBm, and its maximum output is +0.6dBm at the maximum transfer rate of 250 kbps.

The micro-power wireless transmission module RF1100SE adopts high performance radio chip CC1100. Its maximum transmission rate can be up to 500kbps, and the baud rate can be modified using software. In addition, it can be wake up with wireless. With sensitivity up to-110dBm and high reliability, it is widely used in various short-range wireless communications.

### 2.3 Experimental Methods

Antenna of transmitting and receiving nodes must be consistent, so that the antenna gain would no be generated. The nodes send real-time temperature information by the temperature sensor DS18B20, then sent out with wireless signal through the antenna, monitor the changes of the wireless signal with wirelessmon[6] software on a real-time basis. This software can monitor the received radio signal strength（RSSI）, show receive rate(can easily figure out packet loss rate), draw graphics and record data.

When deploying sensor nodes in the orchard, T – R distance d and the antenna height h (distance between receiving and sending node and the antenna height) are two important factors leading to large-scale channel fading [8]. Through experiments in the orchard, we analyzed the attenuation of energy under different antenna heights, different distances between receiving and sending nodes and different wireless channels, respectively. Given the fact that the peach trees were measured to be about 2.5m high on average, we selected antenna heights (above ground) of

1.5, 2.5, 3.5 and 4.5m, respectively; chose 2.4GHz and 433MHz wireless channels; unified transmit power as 0.6dbm, which was easier for the comparison between two types of nodes. And the receive range was chosen to be 10, 20, 30m…, until the received signal was very weak, which was the case with packet loss rate of 1. The PLR (packet lost rate) was defined as the ratio of the loss of data frame bytes to the number of complete data frame bytes. If the data frame received by receiving node was not complete, then there was packet loss.

## 3 RESULTS AND DISCUSSIONS

### 3.1 Path Loss Model

Table 1 and Table 2 show the path loss parameters in the band of 433MHz and 2.4GHz, respectively. From the table it can be found that path loss index increased as the antenna height decreased, while the model parameter k appeared in two situations: as the antenna height increased, 2.4GHz wireless channel of the path loss index became smaller, but that for 433MHz gradually became larger. This raised the first doubt in the experiment. If one considered the causes such the differences between the nodes in terms of sensitivity and frequency, and discarding the zero, so the initial path loss is not the same.

**Table1. Parameters in** path loss model in 2.4GHz.

| The antenna height(h) | 1.5 | 2.5 | 3.5 | 4.5 |
|---|---|---|---|---|
| n | 2.6667 | 2.2234 | 2.1038 | 2.0857 |
| k | 46.6667 | 43.0711 | 41.7534 | 39.6255 |

**Table2. Parameters in** path loss model in 433MHz.

| The antenna height(h) | 1.5 | 2.5 | 3.5 | 4.5 |
|---|---|---|---|---|
| n | 3.6504 | 3.1299 | 2.1139 | 2.0206 |
| k | 21.6215 | 23.5031 | 25.0325 | 25.3814 |

### 3.2 The effects of different antenna heights on the 2.4GHz band

Fig.1 and Fig.2 show the curve of the 2.4GHz wireless channel with the four different antenna heights, the relation between the transceiver distance and the path loss and the packet loss rate, respectively. It is more clearly seen from Fig.1 that the height of the antenna had a greater impact on path loss, and the different antenna heights in the decreasing order of the amount of path loss were: h = 1.5m> h = 2.5m> h = 3.5m> h = 4.5m. The packet loss rate curve in Fig.2 also confirms that when the packet loss rates at different antenna heights were 100%, the different antenna heights in an increasing order of transceiver distance were: h = 1.5m (60m) <h = 2.5m (140m) <h = 3.5 m (180m) <h = 4.5m (200m), the bracket were the transceiver distance. In addition, one can find that under the condition that the antenna height was 3.5m and 4.5m, the channel fading and loss rates were relatively similar. It could be concluded from the experiment that the antenna

height should be set as 3.5m in 2.4GHz band.

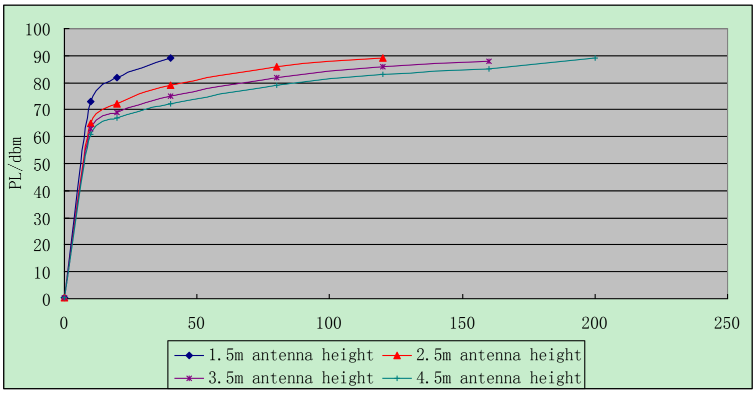

**Fig.1.** Transceiver distance and path loss in different antenna heights curves

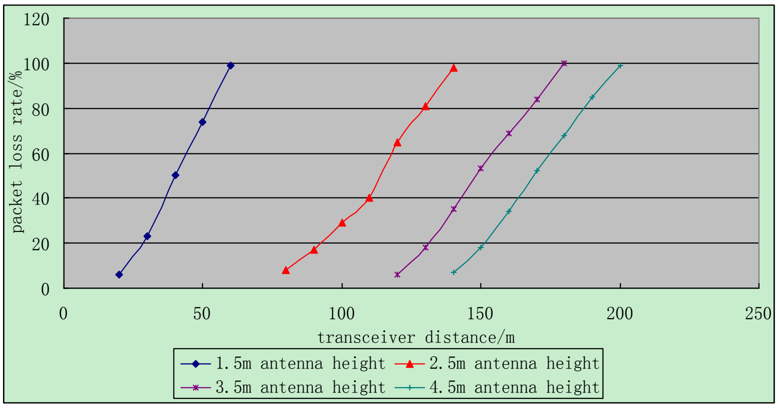

**Fig.2.** Transceiver distance and packet loss rate in different antenna heights curves

### 3.3 The effects of different antenna heights on 433MHz channel

Fig.3 and Fig.4 show the curves of 433MHz wireless channel with the four different antenna heights, respectively, the relation between the transceiver distance and the path loss and the packet loss rate. It is clear from Fig.3 that the height of the antenna had a greater impact on path loss, and the different antenna heights in the decreasing order of amount of path loss are: h = 1.5m> h = 2.5m> h = 3.5m> h = 4.5m. The packet loss rate curves in Fig.4 also confirmed that when the packet loss rated for four different antenna heights were 100%, the four different antenna heights in the increasing order of transceiver distance were: h=1.5m（190m）<h=2.5m（280m）< h=3.5m（360m）< h=4.5m（370m）, the bracket were the transceiver distance. Nodes can be found in the positioning of distance, because the frequency of 433MHz was smaller. At the same time it also had the advantages of less loss of communication channel, and greater penetration. It could be also found that with the antenna height of 3.5m and 4.5m, the situation of the packet loss rate and the path loss were more similar. Thus it could be concluded from the experiment above that the antenna height should be set as 3.5m for 433MHz channel.

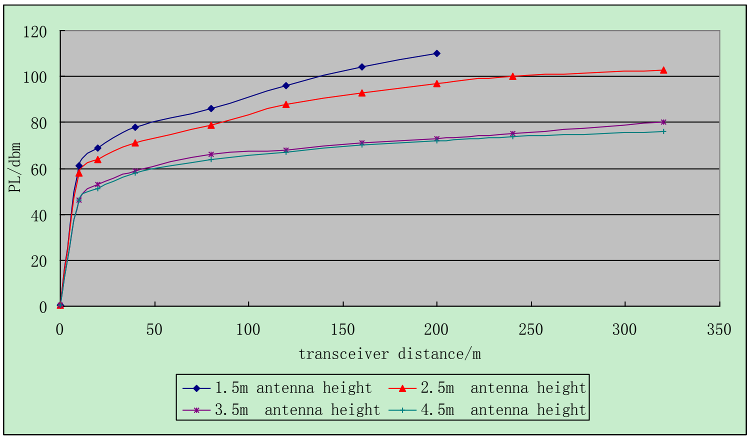

**Fig.3.** Transceiver distance and path loss in different antenna heights curves

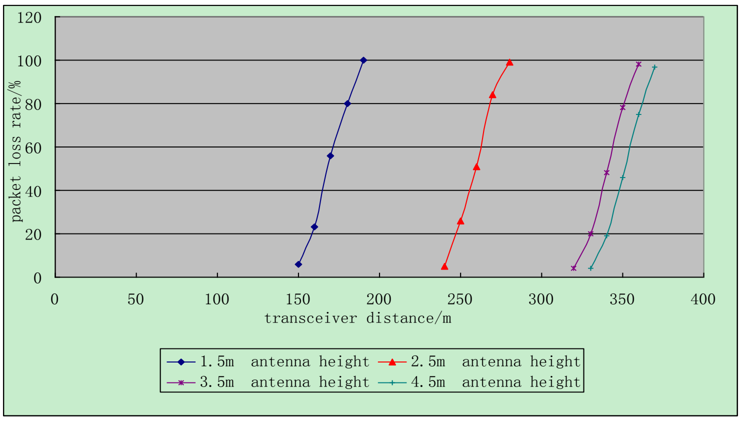

**Fig.4 .** Transceiver distance and packet loss rate in different antenna heights curves

### 3.4 Comparison between different channels

Fig. 5 and Fig.6 are based on the previous two experiments. The curves were plotted at the most suitable antenna height of 3.5m, the path loss and packet loss rate between different frequencies (2.4GHz, 433MHz).

This section described the differences between 2.4GHz and 433MHz namely: the different node receiver sensitivities, -90dbm for 2.4GHz while -110dbm for 433MHz. In Fig.5, the 2.4GHz's energy quickly reached to 63dbm, then gradually slow down the rate of decay, and ultimately rounded up at 90dbm; for 433MHz, reach to 50dbm quickly, began to be more slow rate of decay, and finally tend to 110dbm.

Fig. 6 shows that the 3.5m antenna height could be positioned under the two frequency ranges. For 2.4GHz, the packet loss occurring from the 110m and in the 180m at 100% packet loss rate. For 433MHz, appear to 360m from 320m at the end. And packet loss rate curve was steeper, after pass the receiver sensitivity of the node, the packet loss rate rapidly transition from 0 to 1. It could be known from the above experiment summary, it can give the result that lower path loss has been 433MHz, positioning a wider range, and a more suitable for the complex environment of peach orchards.

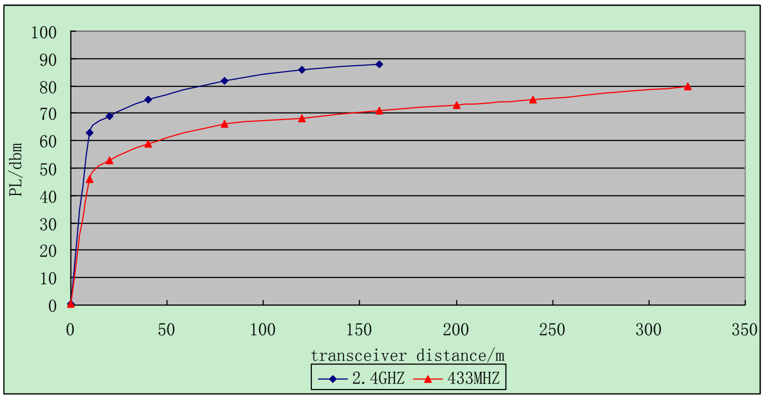

**Fig.5.** Curves of two different frequencies and path loss at antenna height of 3.5m.

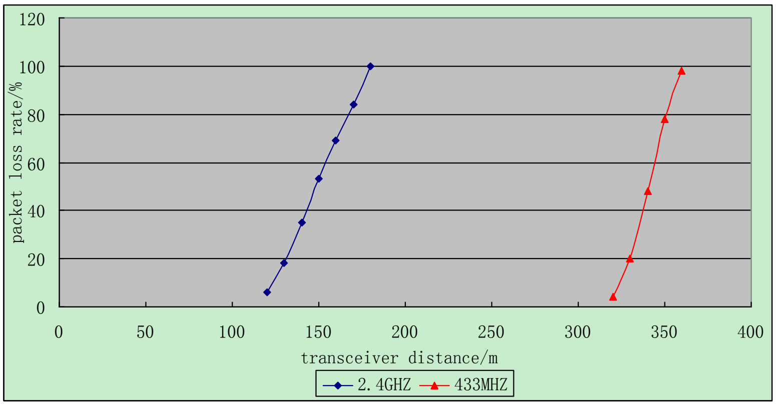

**Fig.6.** Curves of two different frequencies and their packet loss rate at antenna height of 3.5m.

# 4 CONCLUSIONS

## 4.1 The impact of the antenna height

Based on the above experimental results and analysis of Fig.1 and Fig.3, it could be found that influence of antenna height on 433MHz wireless channel was slightly larger, but the initial path loss of 2.4GHz wireless channel was greater.

## 4.2 The suitable antenna height

Through experimental results, it could be found that the antenna height of 3.5 meters was better. While the path loss and the packet loss rate at the height antenna of 4.5m was smaller in the same distance, there was little difference at the antenna height of 3.5m and 4.5m. The higher node height itself would result in the increased costs and higher layout requirements. Therefore, the optimal antenna height was set as 3.5m.

### 4.3 Wireless channel frequency selection

From the comparison between different channels, it could be found that the optimal radio channel frequency was 433 MHz. At the same distance and the same antenna height, the path loss and the packet loss rate of the channel were relatively lower than those of 2.4GHz wireless channel.

### 4.4 Suggestions on wireless node localization

When the antenna height was 3.5m, wireless channel frequency was chosen as 433MHz, and the optimal path loss model of the system was PL=21.139lgd+25.0325. This finding can provide guidance for the determination of the position of wireless nodes in large-scale WSN system.

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