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A research on the radio signal propagation characteristics in corn field

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ABSTRACT

Wireless sensor networks arranged in farmland give the farmland manager real time environment parameter data. The radio signal propagation environment changes a lot throughout the crop growth stage because of the changes of crop height, density and some other farmland environment parameters. This paper collected and analyzed radio signal propagation data of a complete growth period and established corn field path loss model for radio signal propagation to provide support to sensor node deployment and energy planning. The result shows that the radio signal propagation path loss exponent increases with the growth of corn; at the same corn growth stage, the radio signal propagation path loss exponent reduces according to the antenna height variation. This paper uses Log-normal distribution model to predict the radio signal propagation in corn field and the correlation coefficients between computational values and measurement values were between 0.906 and 0.998.

KEYWORDS

Wireless sensor networks;
Radio signal;
Propagation; Corn field;
Path loss exponent.

INTRODUCTION

China's agriculture is in the transition from traditional to modern agriculture at present. The development and application of information technology accelerate the pace of development of modern agriculture. In the information collection field, large scale sensor nodes arrangement in farmland and data transmission by wireless sensor networks give the farmland manager real time environment parameter data. These data provide a reliable basis for agricultural production.

Radio signal propagation environment has a great impact on the signal transmission distance, transmission quality. In the farmland environment, the radio signal propagation impact not only by the farmland facilities, the farmland terrain and the weather but also by the farmland crops. The crops have strong impact on the radio signal propagation in farmland environment because of plants absorption. The crops germinate, grow and fruit in the whole growth stage and the radio signal propagation environment changes a lot throughout the crop growth stages because of the changes of crop height, density.

Wireless sensor network nodes in farmland are always arranged vast, decentralized and far from power facilities. The environment monitoring lasts long time, sometimes even years in farmland because of the crops' long growth cycle. These factors require people to consider the nodes coverage and the relationship between signal transmission and energy in the process of sensor nodes arrangement. The study on the radio signal propagation characteristics of the gradually variation farmland environment provides support to sensor node deployment and energy planning.

Wireless sensor networks deployed in different environments based on different applications and different wireless channels have different propagation characteristics. In the recent years, the research on wireless sensor network channel propagation characteristics and model has begun to attract more and more attention. The research mainly focuses on underwater wireless sensor networks, underground wireless sensor networks, body sensor networks and so on. The research on wireless sensor networks in agriculture and animal husbandry has just started and few relevant studies have been reported. Guo Xiuming[1], etc.analyzed 2.4GHz wireless channel propagation characteristics on the apple orchard with different transceiver node heights; Li Siyu[2], etc. do field measurements of power attenuation and packet loss rate of different growth stages in wheat fields and calculated out the transmission range and the path loss; Wen Tao[3], etc. studied radio frequency (RF) signal strength attenuation and the corresponding influential factors in citrus orchards, and a distributive chart of the best antenna height indicating the combination of different plant depths, antenna heights and communication distance variations was obtained, possibly providing good guidance for WSN system configuration and node deployment in citrus orchards.

Based on the wireless sensor networks transmission experiments in china northern summer corn farmland, this paper studied the impact of the corn plant height, plant density and the transceiver node distance on the signal propagation. Through experimental data analysis this paper established a corn field environments radio signal transmission path loss model. This model provides support to sensor node deployment, power control and energy planning.

DESIGN OF EXPERIMENT

Experimental environment and objects

The experiment is carried out in the corn field in Beijing Academy of Agriculture and Forestry Sciences. It is a flat open farmland with an area of 100m×50m. There is no other obstacle to block the signal in addition to corn plants in the field.

Study objects are three typical corn growth stages: seedling, heading, grain filling stage. The Corn seedling stage lasts long, but the corn plant height and leaf area changed little, so in this stage plants have short height and sparse leaves; corn plants grows rapid in the heading stage. The stem length, the leaf area and volume grow exponentially. The plant height is generally up to 1.5 ~ 2m. In the grain filling stage, the corn leaf growth reached a lifetime maximum and the plant height is generally 2m. The experiment monitors the radio signal in different height in the three different corn growth stages and realizes data fitting.

Experimental equipment

We used wireless sensor nodes with a transmission frequency of 2.4GHz produced by WEBEE as experimental equipment. The receiving sensitivity of the nodes is -101dBm and the outdoor transmission distance is 300m.

Experimental scheme

We need to study radio signal transmission characteristics in corn field to provide support to sensor node deployment and energy planning. In the experiment we need measure the RSSI (Received Signal Strength Indication) in different corn growth stage and different receivers and transmitters height.

There are many factors affect radio signal transmission in agricultural environment. This paper studies the affects of the plants height and density to the radio

TABLE 1 : Signal quality indicator and the factors that affect the signal propagation

Affect factors	the height of planting corn plants the height of receiving and transmission nodes the distance of receiving and transmission nodes
Signal quality indicator	RSSI (Received Signal Strength Indication)

signal transmission. The main factors are: plant heights, plant foliage density, transmit and receive nodes height.

Experimental study transceiver nodes need an antenna are located within the corn wireless carrier signal propagation characteristics were measured at different growth transceiver nodes at different heights of the received signal strength and packet loss rate, which according to the height of the antenna and transmit power to calculate the node signal coverage for the power control and network deployment study basis.

Figure 1 shows the transmitter and receiver distance setting schematic diagram. The receiver node is fixed on the edge of the corn field. The transmitter is placed in the field with a distance of 10m, 20 m, 40 m, 60 m, 80m, 100m to the receiver in turn.

Figure 2 shows the transmitter and receiver height setting schematic diagram. The transmitter and receiver

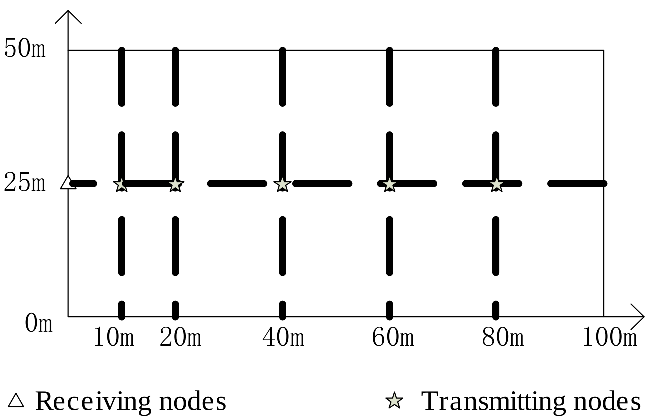


Figure 1 : transmitter and receiver distance setting schematic diagram

antenna height were set to 0cm, 40cm, 80cm, 120cm, 160cm and 200cm according to the corn plant height.

In this experiment, we use the omnidirectional antenna and the antenna gain is 3 dB. The transmitter and receiver are at the same height. We measure the RSSI data of receiver with different transmitter and receiver distances and different heights.

The transmitting node transmits a sequential number for marking the serial number of the transmitted data. After the receiving node has received the signal packets it extracts received signal strength RSSI and the serial number and records the RSSI via the USB interface to a laptop computer. The computer calculates the average RSSI of each test point through self-written software. The transmitting node sends a signal every 1 second. For each test point, the transmitter sends 100 signals and the receiver records all the signal strength RSSI. Finally, we analyze the measurement data to get the radio signal propagation characteristics of corn fields.

EXPERIMENTAL DATA AND ANALYSIS

Corn growth information

TABLE 2 shows the growth information of the corn plants in different growth stage.

RSSI variation

The figure shows the radio signal attenuation in seedling, heading, grain filling stage of corn plants. As can

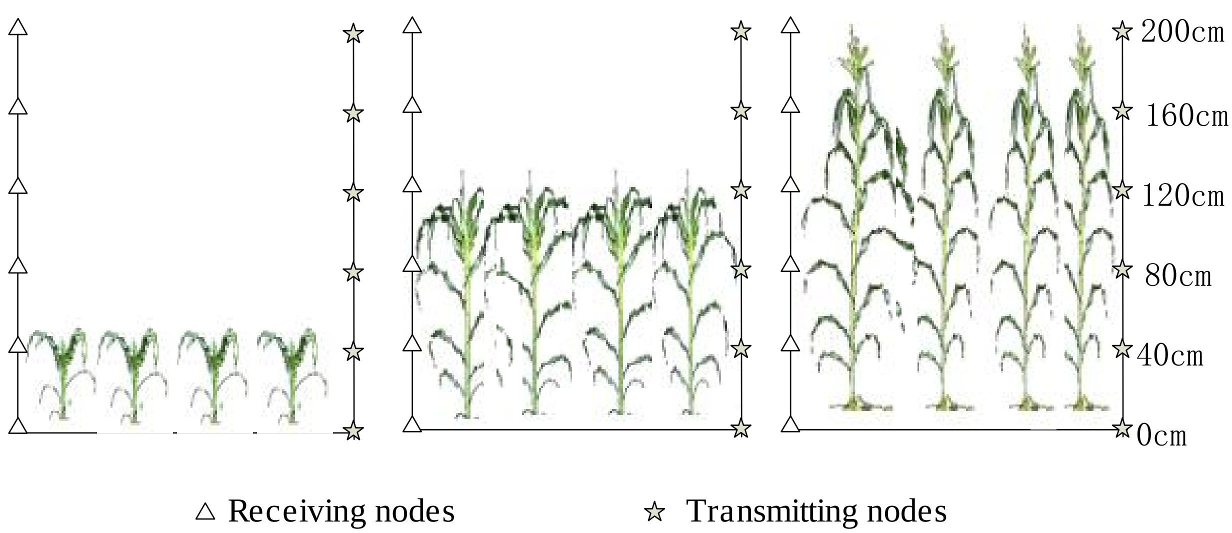


Figure 2 : transmitter and receiver height setting schematic diagram

TABLE 2 : Corn growth information

Crop growth period	Average row spacing (cm)	Average plant spacing (cm)	Average plant heights (cm)	The average number of leaves per plant
seedling	60	40	40	6
heading	60	40	120	10
grain filling	60	40	200	15

be seen from the Figure 3, as the transmission distance increases, the receiving node receives the signal gradually becomes weaker.

Model

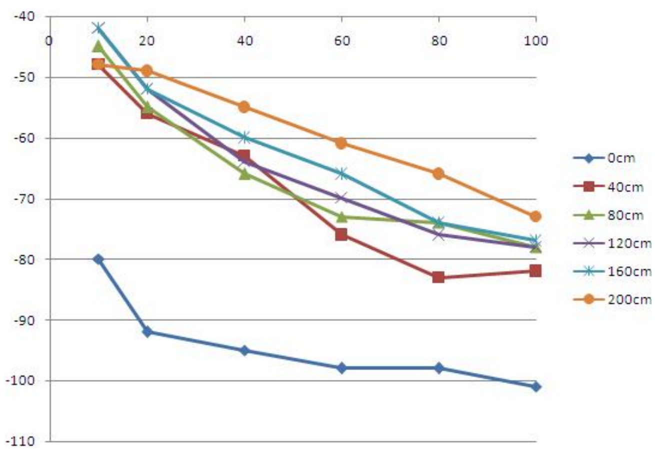
There are three commonly used wireless sensor network signal propagation path loss model: logarithmic-normal distribution model; free-space propagation model; log-distance path loss model. Logarithmic-normal distribution model considering the path reflection, diffraction, obstructions and other factors, so it often use log-normal distribution model to calculate the signal propagation distance. The mathematical statistical model is as follows [4]:

$$P_r(d) = A - 10\eta \lg(d) + X \qquad (1)$$

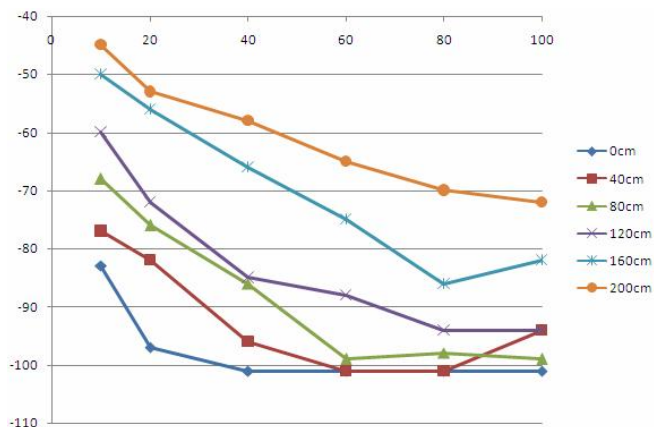
Where A is the model parameter, dBm; d is the distance between the receiver and the transmitter, m; Pr(d) is the received power on the distance d, dBm; η is the path loss exponent; X is a log-normal random variable, reflect the received signal power change when the distance is constant, dBm.

This paper simplified the calculation formula (1) by ignore random variable X, the key to fix the model is to fix the value of the parameter η.

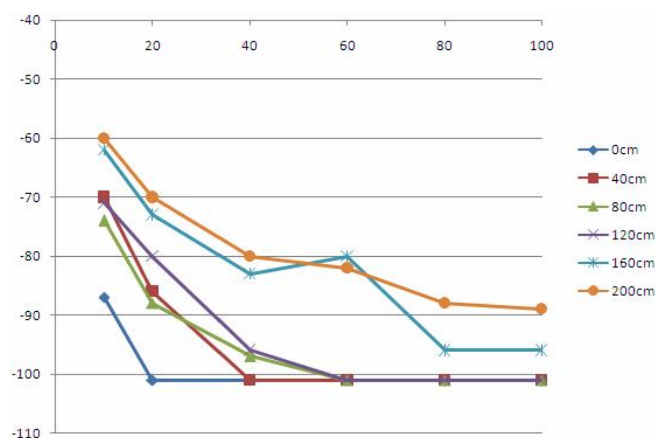
This paper fitted data according to the wireless sensor networks path loss model to get the variation law of η.



(a) seedling stage



(b) heading stage



(c) grain filling stage

Figure 3 : The radio signal attenuation in different corn growth stage

Regression analysis and curve fitting

TABLE 3 shows the experimental data regression parameter. As can be seen from the table, the correlation coefficients are more than 0.9, the highest correlation is 0.998 and the lowest correlation is 0.906.

TABLE 3 : data regression parameter

Crop growth period	plants height(cm)	Nodes height(cm)	A	η	R^2
Seedling	40cm	0	-64.08	1.87	0.911
		40	-8.831	3.70	0.954
		80	-12.1	3.32	0.992
		120	-4.63	3.70	0.997
		160	-6.623	3.46	0.985
		200	-8.442	3.06	0.968
heading	120cm	0	-54.76	2.99	0.906
		40	-42.81	3.25	0.964
		80	-33.24	3.41	0.956
		120	-26.14	3.51	0.983
		160	-10.96	3.64	0.942
		200	-17.3	2.7	0.982
grain filling	200cm	0	-40.49	4.65	0.998
		40	-18.67	5.15	0.998
		80	-40.88	3.46	0.978
		120	-29.67	4.04	0.985
		160	-28.98	3.3	0.908
		200	-31.65	2.91	0.988

The table also shows that the average path loss exponent η increases with the growth of the corn plant. The average path loss exponent η is 3.19 in seedling stage, 3.25 in heading stage, and 3.92in grain filling stage.

CONCLUSION AND DISCUSSION

This paper studied on the 2.4G radio signal propagation characteristics in corn field. This paper uses Log-normal distribution model to predict the radio signal propagation in corn field and the correlation coefficients between computational values and measurement values were between 0.906 and 0.998.

The experimental results also show that in the corn planting environment, the growth of crops causes changes of radio signal propagation environment. The radio signal propagation environments vary greatly in different corn plant growth stages; in the same corn growth stage, the radio signal propagation has different characteristics because of different receiving and transmission nodes height.

The research on radio signal transmission path loss analysis in corn field environment provides support to sensor node deployment, power control and energy planning.

In this paper, we considered the height of planting corn plants, the height of receiving and transmission nodes, the distance of receiving and transmission nodes as major factors affect to signal propagation. In the process of research we find that the corn growth foliage and fruit density are two important environment factors. It is necessary to join the crop density and other environmental factors to carry out a more detailed study in the future research.

ACKNOWLEDGEMENT

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