Australian Journal of Basic and Applied Sciences, 7(5): 55-60, 2013
ISSN 1991-8178

Antenna Positioning Impact on Wireless Sensor Networks Deployment in Agriculture

[1]A. Harun, [1]M.F. Ramli, [2]D.L. Ndzi, [3]L.M. Kamarudin, [1]A.Y.M. Shakaff, [4]M.N. Jaafar, [1]A. Zakaria

[1]School of Mechatronic Engineering, University Malaysia Perlis (UNIMAP), Perlis, Malaysia
[2]School of Engineering, University of Portsmouth, Portsmouth, UK
[3]School of Computer and Communication Engineering, University Malaysia Perlis (UNIMAP), Perlis, Malaysia
[4]School of Bioprocess Engineering, University Malaysia Perlis (UNIMAP), Perlis, Malaysia

Abstract: quality data and network continuity are two important considerations in determining the success of wireless sensor network (WSN) motes deployment in agriculture. Nevertheless, these two factors are closely related to the behavior of antenna position and orientation during deployment which has often been ignored. Although extensive research has been done on antenna heights and characteristics, very few looked into potential antenna misplaced during deployment. This paper presents a study on effect of antenna heights and orientation to wireless sensor network signal power variation. The results showed that although the antenna height affects the signal strength significantly, as long as the transmitter and receiver are higher than the far field distance of the antenna, the power loss is insignificant. On the other hand, misplaced antenna radiating towards receiver in the absence of front lobe, may cause critical data loss and network continuity. The study also showed that Log-distance model is a better fit to signal loss profile in agricultural field compared to Free Space Loss model.

Key words: WSN, RSSI, received signal strength indicator, antenna radiation, orientation

INTRODUCTION

Wireless Sensor Network (WSN) devices are now becoming commonplace in various applications requiring instantaneous or delayed data acquisition and decision making. One of the leading applications utilizing these devices is modern precision farming. In this unique application, WSN devices or nodes are normally used for crop health and yield monitoring. As their usage becomes more widespread, especially in time critical applications, so too is the need to ensure that they are reliable and can meet quality of service requirements. To provide reliable and adequate network coverage whilst minimizing cost, detailed knowledge of wireless signal propagation within the specific environment is required (Harun *et al*., 2012). In addition to that, another important factor to consider in such deployment is the network continuity which largely dependent upon the position of the nodes in the deployment map.

A wireless sensor network consists of numerous nodes equipped with sensor(s) and a radio transmission unit for wireless communication. This radio unit is normally equipped with quality indicators such as received signal strength indicator (RSSI) and link quality indicator (LQI). RSSI is calculated within the radio unit and provides a useful indication of the wireless link quality. LQI is based on signal-to-noise ratio within the frequency band and provides average correlation value for each received packet (Lee *et al*., 2010). Many researchers have discussed the important of link quality to determine correct and accurate data acquisition in wireless sensor networks (Lee *et al*., 2010),(Thelen *et al*., 2005),(Liu, 2006), (Liu *et al*., 2009) however only some discussed antenna positioning as important factor in correlating the link quality between transmitting nodes to the sink or gateway (Gay-Fernández *et al*., n.d.),(Wang *et al*., 2012) to the signal quality and network continuity.

For specific WSN deployment, such as in modern precision farming, although link quality between the nodes is very important to ensure data continuity, the position of the nodes i.e. the antenna are more critical since dropped or misplaced antenna nodes are certain to sever the linkage from the farm to gateway and database. In order to fully understand the effect of various antennas positioning in the farm area to the link quality, a specific signal propagation profiling is required as a reference for further antenna positioning comprehension. This paper reports on the signal propagation study for three antenna heights and two antenna orientations in a typical tropical climate precision farm.

Background And Literature Review:

Application of WSN in agriculture is envisaged to be one of the major uses that will have a profound impact on world communities. Until recently most studies in WSN have focused on the devices (Liu *et al*., 2007), protocols (Wu and Dai, 2005),(Heinzelman *et al*., 2000) and the network architecture (Holderness and Sheehan, 1988). Little interest has been paid to the signal propagation. Studies using simulation platforms often use simple

Corresponding Author: A. Harun, School of Mechatronic Engineering, University Malaysia Perlis (UNIMAP), Perlis, Malaysia

channel models such as the free space loss (FSL) given by (1), or the two ray channel model (Meng *et al*., 2010) which we will not be dealing with in this paper.

$$L_{FSL} = -27.56 + 20\log_{10}(d) + 20\log_{10}(f) \quad (1)$$

The parameter f is the frequency in MHz, d is the distance between the isotropic transmitting and receiving antennas in meters.

Gay-Fernandez *et al*. (Gay-Fernandez *et al*., 2010) have shown that WSN channel can be modeled using a log-distance model. The log-distance model is described by (2).

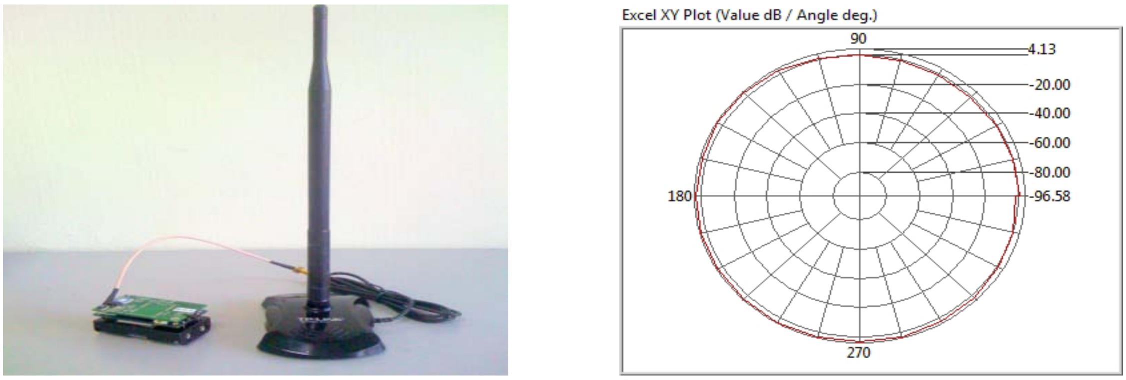
$$P_r(d) = P_{r_0} - 10\alpha log_{10}(d) + X_\sigma \quad (2)$$

Where $P_r(d)$ is the received power (in dBm) at a distance d (in meters) from the transmitter, P_{r_0} is the signal strength at 1 m antenna separation, α is the path loss exponent and X_σ represents a Gaussian random variable with zero mean and standard deviation of $\sigma\ dB$.

The study reported in this paper uses RSSI value for path loss comparison measurement purposes. The maximum range is defined as the transmitting and receiving mote separation beyond which the motes can no longer establish the connection. However, there are also conditions when the transmission is being stopped as the experiment ran out of field.

Equipments And Measurements:

This study has been performed using MEMSIC's IRIS XM2110 mote equipped with Atmel RF230 radio chip. The mote transmits in the 2.4 GHz – 2.5 GHz ISM band and of ZIGBEE/IEEE802.15.4 compliant (www.memsic.com). The motes are connected to external antenna as depicted in Fig. 1 (a) and (b).



(a) (b)

Fig. 1: (a) MEMSIC wireless sensor mote which has an integrated temperature and humidity sensor (b) measured antenna radiation pattern

Antenna height and orientation signal measurements experimentation were conducted in a large open grass field similar to the one shown in Fig. 1. For this measurement, the objective was to compare the signal propagation strength at various antenna heights and orientations.

Fig. 2: Open field for measurement

During the study, the receiving nodes remained at a fixed position whilst the transmitting nodes were placed at specific distances from the receiver in a straight line. The experiments were carried out with antenna heights of 0.5 m, 1 m and 2.3 m. As for the antenna orientation measurement, the height of the antenna was set at 1 m. This measurement looked at transmitting antenna in pointing orientation (towards the receiving antenna) and perpendicular orientation (against the receiving antenna). The diagram illustrating the measurement setup is as in Fig. 3.

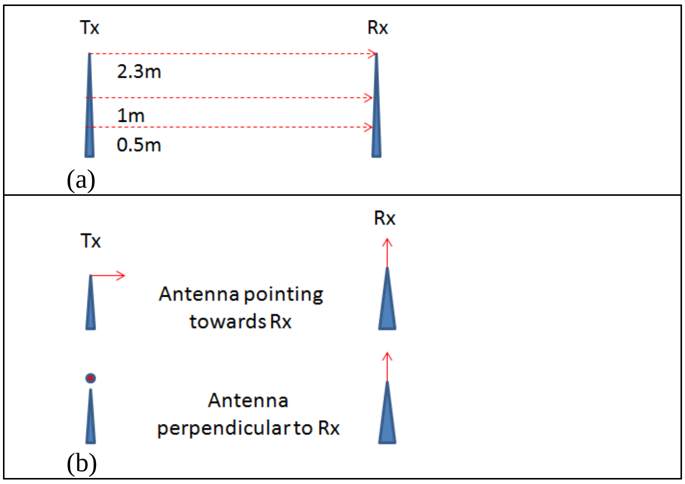


Fig. 3: Diagram illustrating the measurement (a) three antenna heights measurements and (b) antenna orientation at pointing and perpendicular to Tx antenna RSSI values were collected during each of the transmissions and analyzed.

RESULTS AND DISCUSSIONS

This section discusses the results obtained both from antenna heights measurement and transmitter antenna orientations. The results are presented based on the average RSSI values at various transmitting to receiving mote distances.

Fig. 4(a) compares the performances of the three antenna heights 0.5 m, 1.0 m and 2.3 m. All the three signals showed almost similar variation throughout the length of the field as a result of uniform scattering from the grass field producing multipath signal components which arrived at the receiver in their own amplitudes and delays. Signal profile for 1 m antenna height seemed to exhibit higher power compared to 0.5 m antenna height signal where at certain distances measured about 8 dB margins although at some other distances 0.5 m signal recorded higher signal strength than that of 1 m signal. On the other hand, 2.3 m signal did not seem to obey logarithmic pattern which could be attributed to interference from local access point or other foreign signals operating in the same frequency band. Nevertheless, signal profile at 2.3 m recorded on average the highest signal strength in comparison to the other two signals. As we ran out of the field length, all the signals did not go to the noise level which showed quite a long range of operation for this mote in line of sight (LOS) condition.

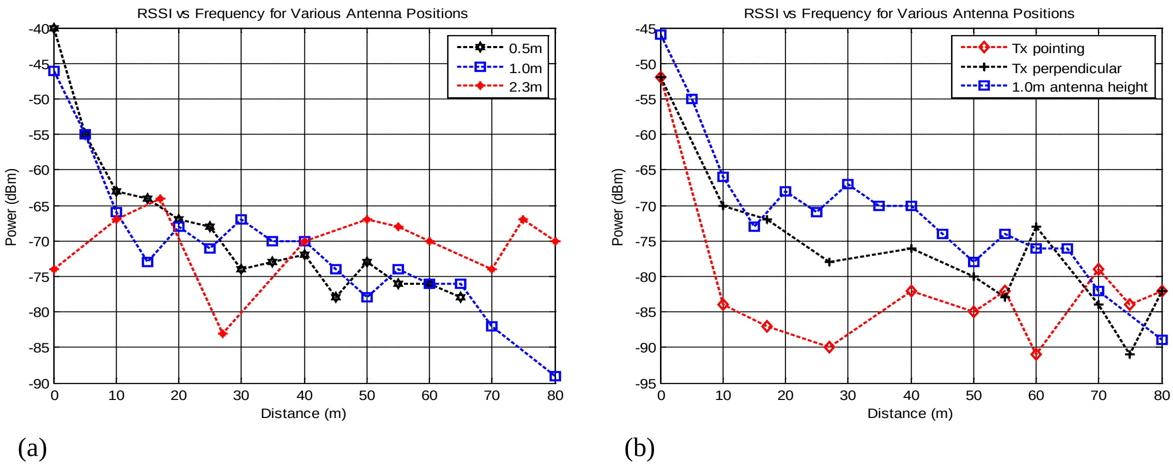
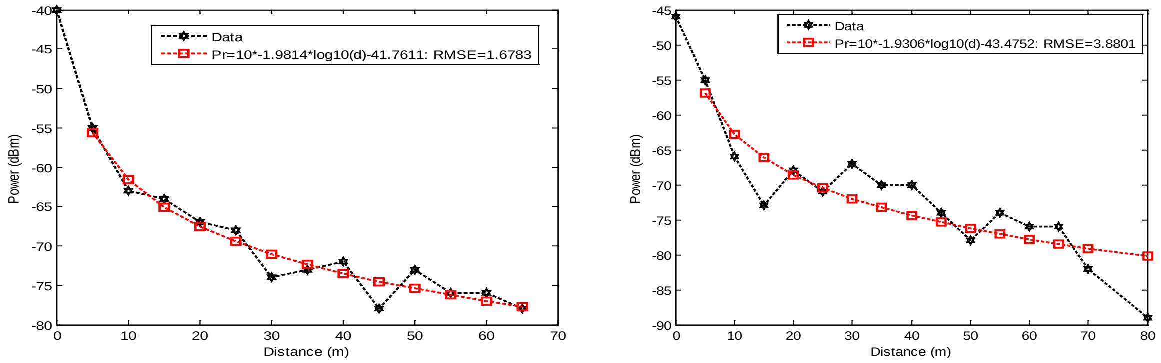


Fig. 4: (a) RSSI versus range for all three antenna heights and (b) RSSI versus distance for antenna pointing and perpendicular towards Rx

Fig. 4(b) showed the signal strength for transmitter antenna pointing and perpendicular towards receiver over various distances at 1.0 m antenna height. The figure also shows the reference signal which is the 1.0 m antenna height (normal straight up antenna orientation) for comparison. Signal strength variation seemed to be insignificant up to 50 m distance for both antenna orientations. Nevertheless, after 50 m onwards, intense fluctuation in signal strength observed for both and ground reflection over various Fresnel zones in addition to scattering by grass surface attributed to this variation. Reflection happened in odd number Fresnel zones supplemented direct signal path and produced signal spike while reflection in even number Fresnel zone cancelled some of the direct path components and caused the abrupt signal drop.

It is apparent that the transmitter antenna in pointing orientation showed reduced signal strength where at some instances having very poor signals to noise ratio. The margin between these signals to reference signal is almost 20 dB at the highest and 4 dB at the lowest. Most signal components are only radiated by side lobe for this orientation accounting for the sharp reduction in the signal strength as the antenna is Omni-directional radiation in design. Transmitter antenna in perpendicular orientation on the other hand showed insignificant signal power drop in comparison to the reference signal where at most instances are about 10 dB the highest and 3 dB the lowest. Most of the signal components are originated from front lobe radiation and absence of side lobe radiation accounted for the slight drop in the signal strength. An important conclusion from this study is the radiation pattern of the antenna played significant impact to the misplaced antenna in any deployment application.

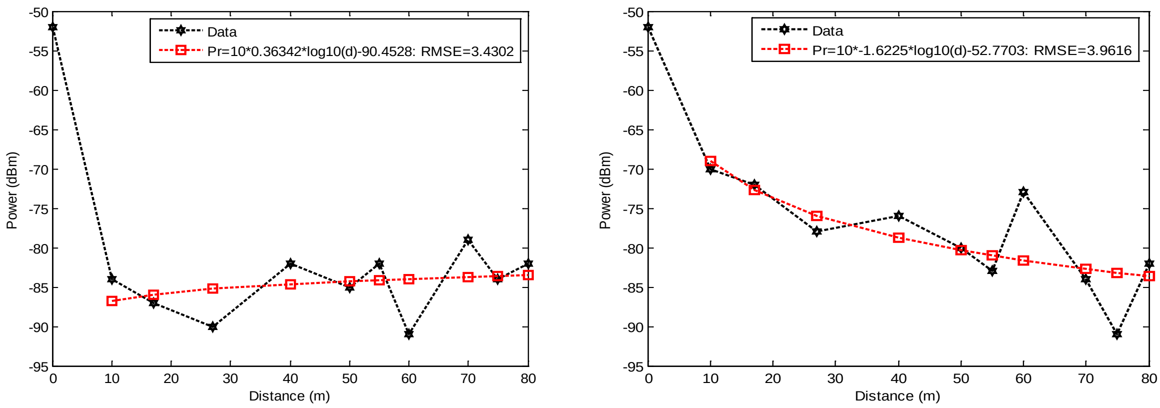
To model signal power variation with distance, the log-distance model was fitted to the data. Fig. 5(a) shows the fitting to the mote RSSI data for measurements at 0.5 m antenna height. The equation that describes the fitted model is given in the figure with a root mean square error of 1.68 dBm. Fig. 5(b) also shows the fitting to the data for 1.0 m antenna height. Because of large variations in the signal power with distance, the root mean square is slightly higher.



(a) (b)

Fig. 5: (a) IRIS mote antenna height at 0.5 m and Log-distance model fitting and (b) IRIS data at 1 m antenna height fitted with Log-distance model

Compared to results from 1 m antenna height measurements, the signal decay with distance exhibited smoother variations at 0.5 m. This resulted in better fittings to the model as shown in Fig. 5(a).



(a) (b)

Fig. 6: (a) Tx antenna pointing to Rx fitted with Log-distance model and (b) Tx antenna perpendicular to Rx fitted with Log-distance model

Fig. 6(a) and Fig. 6(b) show the signal power decay with distance for measurements at antenna orientation (pointing and perpendicular respectively) at 1 m antenna heights. The different in radiating pattern of the antennas showed significant signal variations from one antenna orientation to another. Nevertheless, although signal for pointing antenna showed significant reduction in strength, the variation is less compared to signal for perpendicular antenna as indicated by the RMSE for both of them. This is mainly attributed to the scattering produced by the grass field where the experiment is conducted affecting the higher radiation power which is the front lobe in the perpendicular antenna orientation. As the propagation of the signal in pointing orientation mainly contributed by the side lobe of the radiated antenna, less effect observed due to the scattering. In addition, the rate of signal power decay with distance is much higher with value of α (from Log-distance model) that are greater than 1.5 in perpendicular antenna orientation compared to pointing antenna orientation where the value is less than 0.5.

For comparison, the data were also fitted with free space loss model and result is tabulated in table 1. The result showed that FSL actually under estimated the scattering by grass field for a short distance path loss modeling. Log-distance on the other hand, took into consideration the effect in short distance path loss thus fit better to the graph.

Table 1: Result for log-distance and free space loss modeling

Antenna position	Log-distance model		FSL model RMSE
	α	RMSE	
0.5m height	1.9814	1.6787	5.2397
1.0m height	1.9306	3.8801	7.1661
Antenna Pointing	0.3634	3.4302	14.054
Antenna Perpendicular	1.6225	3.9616	7.7390

Conclusions:

This paper presented a study on antenna positioning and orientation in open grass field for references to WSN motes deployment in tropical agricultural farm. This would be very important in assessing the impact of misplaced antenna in WSN motes deployment as this would mean losing critical crop data or not. The results showed that antenna at 1 m height suffer less signal power loss over distance compared to antenna at 0.5 m height. Nevertheless differences in the power levels were not significant which measured about 8 dB margin between them thus both antenna heights could be utilized in the deployment, whichever fits into the requirement.

On the other hand, antenna orientation contributed significantly to the link quality between transmitter and receiver for WSN motes. Transmitter antenna at pointing direction towards receiver suffered significant power loss while transmitter antenna at perpendicular to receiver showed slight drops in signal strength. The absence of front lobe radiation towards receiver in pointing antenna brought the power loss to almost at the noise floor level.

Analysis showed that the Log-distance model is the best fit to all of the measured data when compared to FSL model. It is also observed that signal power decay over distance for antenna in perpendicular to receiver is higher than that pointing to receiver which could be explained by the stronger front lobe radiation compared to side lobe. In short, in order to ensure high quality data transmission and continuity in WSN deployment, antenna orientations have to be checked and monitored to ensure optimal positioning.

REFERENCES

Gay-Fernández, J.A., I. Cuinas, P. Gómez, n.d. A Comparison on the Radioelectric Propagation along Grasslands and Scrublands at Wireless Frequency Bands. Session 3P7 RF and Wireless Communication, Multipath 854.

Gay-Fernandez, J.A., M. Garcia Sánchez, I. Cuinas, A.V. Alejos, J.G. Sanchez, J.L. Miranda-Sierra, 2010. Propagation analysis and deployment of a wireless sensor network in a forest. Progress In Electromagnetics Research, 106: 121-145.

Harun, A., M.F. Ramli, L.M. Kamarudin, D.L. Ndzi, A.Y.M. Shakaff, A. Zakaria, M.N. Jaafar, 2012. Comparative Performance Analysis of Wireless RSSI in Wireless Sensor Networks Motes in Tropical Mixed-crop Precision Farm, in: Intelligent Systems, Modelling and Simulation (ISMS), 2012 Third International Conference On. pp: 606-610.

Heinzelman, W.R., A. Chandrakasan, H. Balakrishnan, 2000. Energy-efficient communication protocol for wireless microsensor networks, in: System Sciences, 2000. Proceedings of the 33rd Annual Hawaii International Conference On. p: 10.

Holderness, C.G., D.P. Sheehan, 1988. The role of majority shareholders in publicly held corporations: An exploratory analysis. Journal of financial economics., 20: 317-346.

Lee, Y.-D., D.-U. Jeong, H.-J. Lee, 2010. Performance analysis of wireless link quality in wireless sensor networks, in: Computer Sciences and Convergence Information Technology (ICCIT), 2010 5th International Conference On. pp: 1006-1010.

Liu, H., Z. Meng, S. Cui, 2007. A wireless sensor network prototype for environmental monitoring in greenhouses, in: Wireless Communications, Networking and Mobile Computing, 2007. WiCom 2007. International Conference On. pp: 2344-2347.

Liu, H., Z. Meng, M. Wang, 2009. A wireless sensor network for cropland environmental monitoring, in: Networks Security, Wireless Communications and Trusted Computing, 2009. NSWCTC'09. International Conference On. pp: 65-68.

Liu, X., 2006. Coverage with connectivity in wireless sensor networks, in: Broadband Communications, Networks and Systems, 2006. BROADNETS 2006. 3rd International Conference On. pp: 1-8.

www.memsic.com.

Meng, Y.S., Y.H. Lee, B.C. Ng, 2010. Path loss modeling for near-ground vhf radio-wave propagation through forests with tree-canopy reflection effect. Progress In Electromagnetics Research, M 12: 131-141.

Thelen, J., D. Goense, K. Langendoen, 2005. Radio wave propagation in potato fields, in: First Workshop on Wireless Network Measurements (co-located with WiOpt 2005), Riva Del Garda, Italy.

Wang, D., L. Song, X. Kong, Z. Zhang, 2012. Near-Ground Path Loss Measurements and Modeling for Wireless Sensor Networks at 2.4 GHz. International Journal of Distributed Sensor Networks 2012.

Wu, J., F. Dai, 2005. Efficient broadcasting with guaranteed coverage in mobile ad hoc networks. Mobile Computing, IEEE Transactions on 4: 259-270.