Jurnal Teknologi

Full paper

Measurement and Modeling of RFID Propagation Channel in Palm Oil Trees

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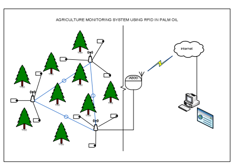
Article history

Received: 8 March 2012
Received in revised form: 10 April 2012
Accepted: 18 July 2012

Graphical abstract



Abstract

This paper presents the information about the vegetation effect at palm oil trees to the terrestrial propagation of wireless communication at 433MHz. By using the well-established technology which is Radio Frequency Identification (RFID), a measurement is conducted at both Open Space and Palm Oil farm. Based on RFID Air Interface Standards ISO/IEC 18000-7, it supports standard air interface implementations for wireless and non-contact information system equipment. The characteristic of palm oil trees will be studied as it will be the main obstruction to the communication. The data will be analyzed and the average excess path loss due to Palm Oil trees can be determined. Furthermore, the performance of signal from the measurement will be compared with the result from existing model of propagation.

Keywords: RFID; vegetation; path loss; propagation; wireless

■1.0 INTRODUCTION

Technology development in various fields of industry leads to the growing of economy in the country. This give benefits to human such as the farmers out there in ways on monitoring the plant daily. The farmers are continuously searching for ways on maximizing their return. Thus, plants need to be monitored daily in order to let it grow healthily and can give maximum profits. However, farmers are still facing problems monitoring the plants in terms of temperature, water level and humidity.

Recent advances in sensors and RFID technologies and all their integration with the Internet offer a platform for development and application of sensor system for agriculture. The main goal is to create a regional and on-farm sensor networks that provide remote, real-time monitoring and control for the farming operations.

Figure 1 shows the overall framework of the project which is to design an agriculture monitoring system in palm oil farm using RFID system at 433 MHz. It consists of RFID active tags, RIFD reader and a monitoring database server. The establishment of the system is highly demanded but the main constraint is to deal with excess path loss due to obstruction that exists. Foliage or vegetation is the significant feature to the degradation signal.

It is well known that for signal below 5 GHz [22], it will not affected by the environmental effect such as rain and wind speed. But then, other factors like tree trunks, branches and leaves will play the main role to degrade the quality of signal. It might contain water and with various orientations and configurations, it will result in strong absorption and scattering. The trees as the main component contribute to the attenuation loss and they seem unavoidable. The optimum network has to be proposed, where all the information from each tags can be send to the reader without less damage or corrupted data. Hence, the attenuation loss that relative to the distance of RFID tags and reader needs to be investigated.

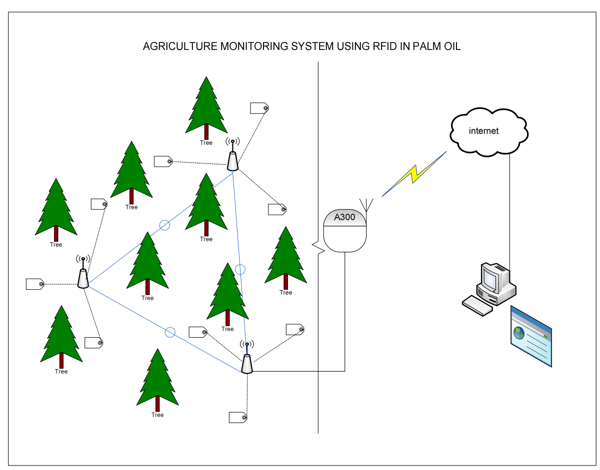


Figure 1 Overall framework of the project

2.0 RELATED WORKS

Previous research had been performed for various cases regarding on the propagation through trees. They are dealing with measurement setup for series of trees at the roadside, single tree, foliage distribution, physical of trees, and distance of trees to receiver and so forth [2]. The normalized path loss data has been compared to existing model of propagation, like MED model [16] and to the Vogel and Goldhirsh model [19]. The conventional model for predicting the increase in loss due to propagation through trees is the exponential decay (EXD).

$$L_v = 0.26 f^{0.77} D_v \quad (1)$$

Where

D_v = depth of foliage along the LOS path (meters)
f = frequency (GHz)

EXD considers two parameters which are operating frequency, f and the distance through vegetation, D_v from incoming wave to the receiver. For frequency range between 230 MHz to 95GHz, a better prediction is obtained called the modified exponential decay (MED) also called Weissberger's model from the Centre of Communication Interface Research (CCIR), Edinburgh, UK equation is given as [24]

$$L_v = \begin{cases} 1.33 f^{0.284} {D_v}^{0.588} & 14 < D_v < 400 \\ 0.45 f^{0.284} D_v & 0 < D_v < 14 \end{cases} \quad (2)$$

Where

D_v = depth of foliage along the LOS path (meters)
f = frequency (GHz)

For the Vogel and Goldhirsh model, it takes into consideration the foliage density and the elevation angle, θ and can be used for a single tree.

$$\text{Full foliage: } L = -0.48\theta + 26.2 \quad (3)$$
$$\text{Bare Tree: } L = -0.35\theta + 19.2$$

It is showed that the MED model seems to fit the measurements and the Vogel and Goldhirsh model is giving values closer to the deep fades produced by the tree. Meanwhile Bullington's model [14] is the derivation from the Knife-Edge Diffraction model (refer to Figure 2).

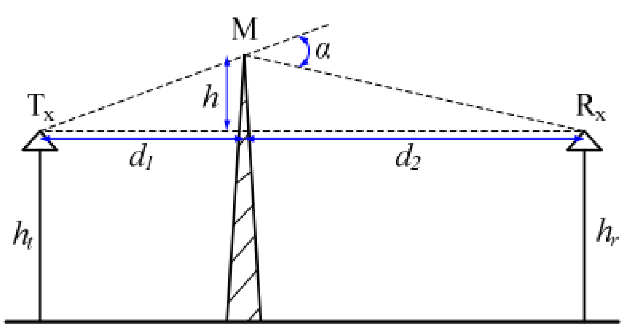


Figure 2 Geometry of the knife-edge diffraction model

For case where shield objects (two or more), between the transmitter and receiver, the Bullington's method represents the single equivalent shield obstacle (refer to Figure 3).[12]

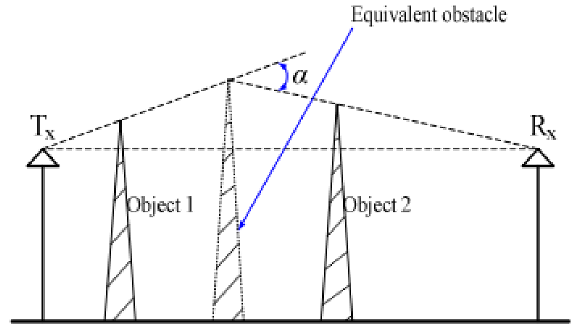


Figure 3 Bullington's method

$$\frac{E_d}{E_o} = F(v) = \frac{(1+j)}{2}\int_v^{\infty} \exp\frac{(-j\pi t^2)}{2}\, dt \quad (4)$$

$$v(d_1, d_2, h) = h\sqrt{\frac{2(d1+d2)}{\lambda d1 d2}} \quad (5)$$

Where

d_1 = distance between Tx and the M
d_2 = distance between Rx and the M
h = effective distance from the top of M to the link between Tx and Rx.
α = diffraction angle

The values of E_d and E_0 are the electric field and free space field strength respectively. *F(v)* is the complex Fresnal integral expression and *v* is the Frisnal-Kirchoff diffraction parameter. α is the diffraction angle. The diffraction is said to be as

$$L_d(dB) = 20\log|F(v)| \quad (6)$$

Besides, the information on the propagation effects of changing physical local environment at frequencies in excess 1.5GHz is scarce [4]. Vegetation or foliage is said to be the major source of attenuation at both UHF and 1.5GHz and its increases at higher frequencies. Not forgotten, modeling of propagation through trees is very complicated. Parameters like height, foliage density, type of trees and seasonal variations combining together create a function that contributes to the attenuation that later influence the propagation phenomena in this environment.

In this case the chosen site is palm oil farm. Palm oil trees or Elaeis guineensis is a perennial tree, of late and long yield, and it can grow up to 30 meters. The stem of the palm tree is straight and the plant forms the shape of an inverted cone. Young palms have rough, jagged stems. Later older palms have smoother stems but have scars left behind as some 40 leaves wither and fall off, giving the stems a layered and segmented texture.

Wireless propagation at frequency of 433MHz in the palm oil will be studied to ensure the efficiency of the project. Signal will be attenuated by absorption of the tree, scattering, diffraction and depolarization. From open literature, there is minimal research work done on the path loss in a foliage channel for weather induced effect. A detailed statistical characterization and modeling of the combined effects of several typical weather phenomena was performed over the VHF (240 MHz) and UHF (700 MHz) bands for near ground communications (2.15m) [22]. As for result, in general, at higher frequency (700 MHz), the wavelength is smaller and thus comparable with the size of physical elements of the forested channel. Therefore it more potentially gets affected by the variation in weather condition.

3.0 MEASUREMENT SETUP

In this section, it provides information on the measurement setup of the research. It includes hardware and software development, testing, field measurement and manual data measurements.

3.1 RFID Tag and Reader

This RFID tag also called as HAC-AID is a realized sensor, identification and other transmission device in one whole. The features of HAC-AID are a non-contact automatic identification method, it can identify object automatically and obtain some correlative information using RF signal at frequency of 433MHz. It works in active transmission mode. The interval for transmitting can be adjusted depends on user’s need, commonly its average is 10s.

(a)Front

(b)Back

Figure 4 (a) Front side of RFID tag (b) Back side of RFID tag

As for RFID reader, it was developed at the Wireless Communication Centre, UTM lab as displayed in Figure 5 and Figure 6. It consists of RFID module, main circuit board, and 433MHz monopole antenna. With 12V of power supply, output of this reader is from DB9 serial port to PC or laptop through RS232 cable. Since it is an active RFID, the transmission of signal can go up to 100m Line of Sight (LOS). Two types of reader are developed; wired and wireless connection. Wired connection mean from the RFID reader to laptop or PC using RS232 cable while wireless mean no physical connection between them. It used Wi-Fi module that operates at frequency 2.4GHz.

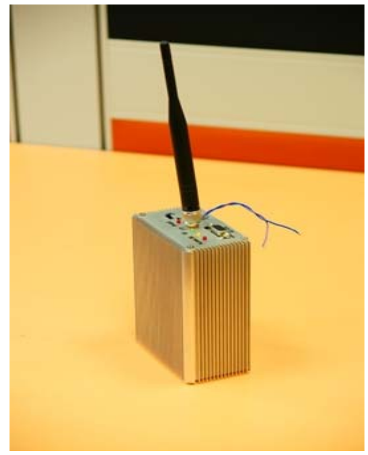


Figure 5 RFID Reader

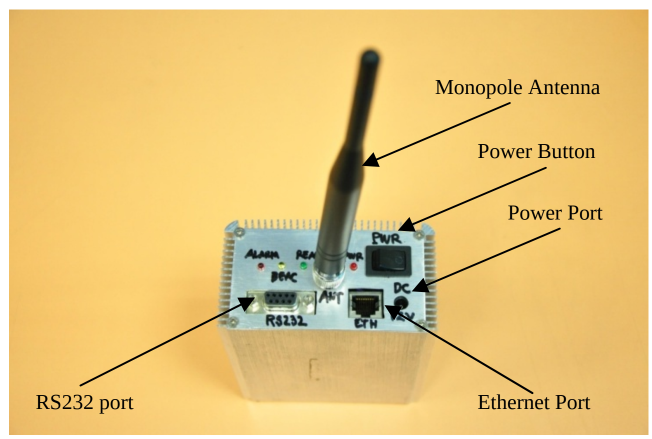


Figure 6 RFID Reader

3.2 Schematic Diagram

Details of measurement setup are shown in Figure 6. The main objective of this research is to predict the attenuation caused by the Palm Oil tree. For each measurement setup, the data will be collected for time and distance varying. Both reader and tag are placed 1m from the ground. The reader connected directly to the laptop using RS232 cable.

In order to see the effect of the distance to the signal received, the reader remained at the same place but the tags position will be varying to create a separation distance between the reader and tags. During the time varying measurements, the RFID reader and tags remained at the stationary positions at 40m. The receiver was placed in-line with the direct path from the transmitter. Thus, at Palm Oil farm, the signal will pass through series of tree. These scenarios were intended to allow the recording of the temporal variations of the received signals due to the movement of the vegetation structure [13].The location where the outdoor measurement is performed is at Padang Kawad as in Figure 7, represented the open space and at

Palm Oil farm behind Kompleks Sukan UTM to see the vegetation effects as in Figure 8.

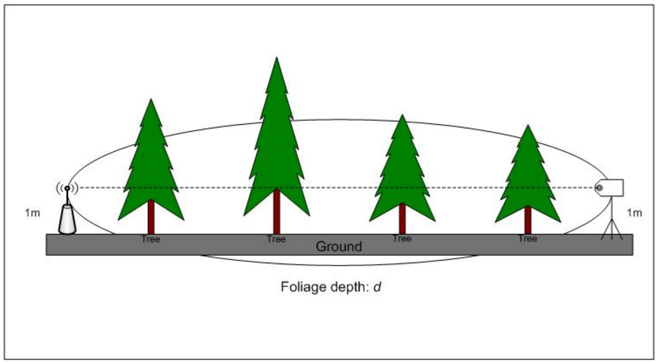


Figure 6 Schematic diagram of the measurement setup

Figure 7 Measurement setup at Padang Kawad (Open Space)

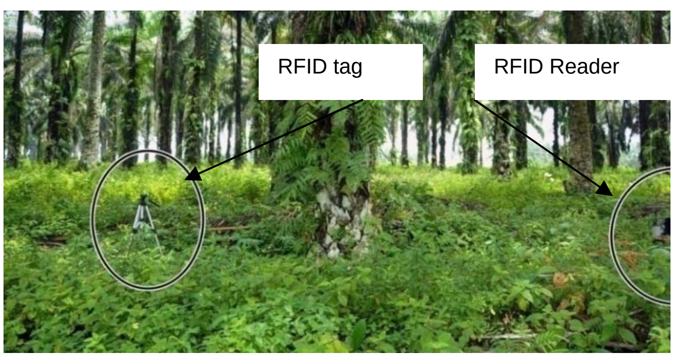
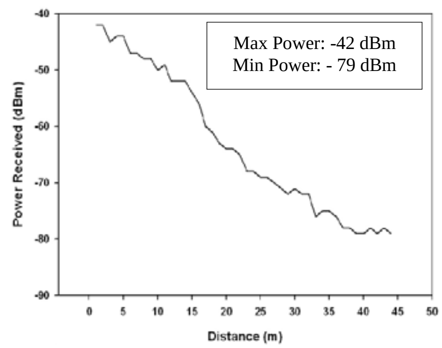


Figure 8 Measurement setup at Palm Oil farm

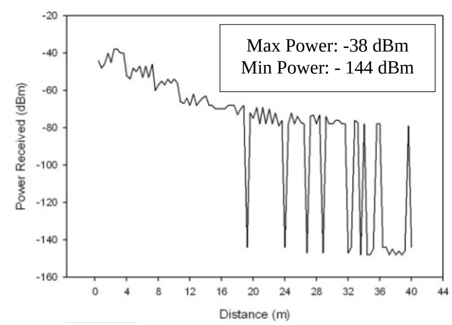
4.0 RESULTS AND ANALYSIS

Figure 9(a) shows the signal is decrease smoothly due to no obstructions along the path from the transmitter and the receiver (refers to RFID tag and the reader respectively). With a dominant direct ray component, power received signal is only affected by free space loss which explains its significant signal variability with arbitrary signal decrement. In comparison with Figure 9(b), it is observed that the significant signal decrease with a bit ripple and then become unstable signal when the distance is greater than 20m. Obstruction in between the link contribute to the rapidly signal drops. Contrary with the LOS link at Open Space, the multipath components propagating attenuate by the vegetation includes tree trunk, bushes and leaves.

The average received signal varies from -42 to -79 dBm and from -38 to -144 dBm for Padang Kawad and Palm Oil farm respectively, as the separation distance between transmitter and receiver increases. In addition, the degradation signal is more noticeable because of the obstruction over the effect of distance. Meaning, the effect of the palm oil tree itself contribute to the attenuation of signal over the condition of environments like wind or rain effects on this tropical foliage channel. Although it is well known, that environment factors like wind and rain affects the propagation only at higher frequencies of above 5 or 7 GHz, but there are research proven that it also affected even at low frequencies of VHF and UHF band within the forest environment.



(a)



(b)

Figure 9 Power Received vs Distance at (a) Padang Kawad (Open Space) (b) Palm Oil farm

For the fix distance, observation was done to study the behavior of RFID signal at a certain period of time. Both figures (Figure 10 (a) and (b)) show almost consistent signal variation but with different ripple performance. Figure 10 (b) shows a big ripple due to attenuation of the palm oil trees itself, bushes, trunk and leaves. There is a significant amount of multipath components propagating through the vegetation channel. [11]. It can be due to reflection, scattering, diffraction or a combination from the broad leaves, the branches and the tree trunks. Upon inspection, the maximum and minimum powers received are considerably large difference which is -75 dBm and -118 dBm.

It is given that the power transmitted from the tag is -15.59dB, the gain is 1 dBi while the reader's antenna gain is 3dBi. From the link budget equation, the path loss equation can be computed.

By taking average Power Received, $P_r = -76.63\ dBm$,

$$P_r = P_t + G_t + G_r - L_t$$
$$-76.63 = -15.59 + 1 + 3 - L_t$$
$$L_t = 65.14\ dB$$

Free Space Path Loss, FSPL $= 32.45 + 20\ \log d\ (km) + 20\ \log f\,(MHz)$

$$= 32.45 + 20\ \log(0.040) + 20\ \log(433)$$
$$= 57.22\ dB$$

Thus, the path loss, $L_o = 65.14 - 57.22$
$= 7.92\ dB$

For calculation of excess path loss at the Palm Oil farm, L_p is given below.

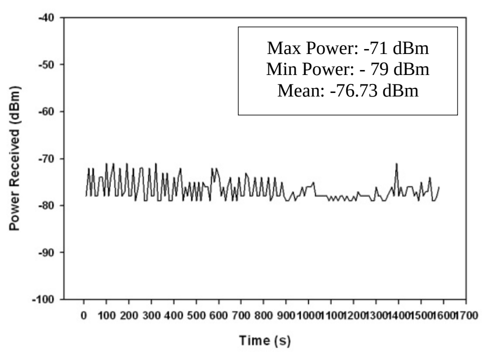
By taking average Power Received, $P_r = -91.642\ dBm$,

$$P_r = P_t + G_t + G_r - L_t$$
$$-91.642 = -15.59 + 1 + 3 - L_t$$
$$L_t = 80.052\ dB$$

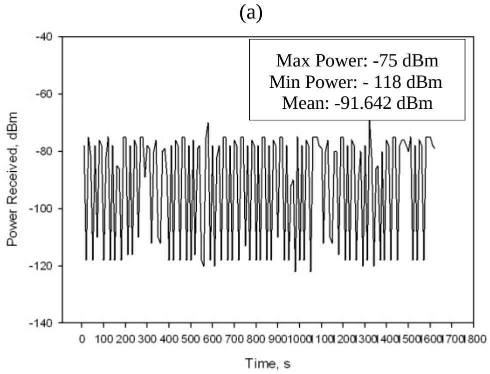
Total loss at Padang Kawad (Open Space) is 65.14 dB. Thus, the path loss, L_o

$$L_p = 80.052 - 65.14$$
$$= 14.912\ dB$$

It is found that the excess path loss at Palm Oil farm at 40m separation distance is 14.912 dB. Since there are six trees between the transmitter and receiver, the attenuation of Palm Oil tree can be considered as 2.49 dB/ tree.



(a)



(b)

Figure 10 Power Received vs Time at 40m separation distance between the tag and reader for (a) Padang Kawad (Open Space) (b) Palm Oil farm

There are many studies regarding the effects of vegetation within several of frequencies. Based on foliage studies, the models reviewed and summarized into another combination models like Weissberger's modified exponential decay model [24], Bullington's model [12], COST235 [13] and ITU-Recommendation [14]. The reason to choose the Weissberger's Model is because the operating frequency 433MHz in between the range and the Bullington's model regarding the shield obstacles that referring to Palm Oil trees. The comparison of both propagation models to the measurement result shown in Figure 11.

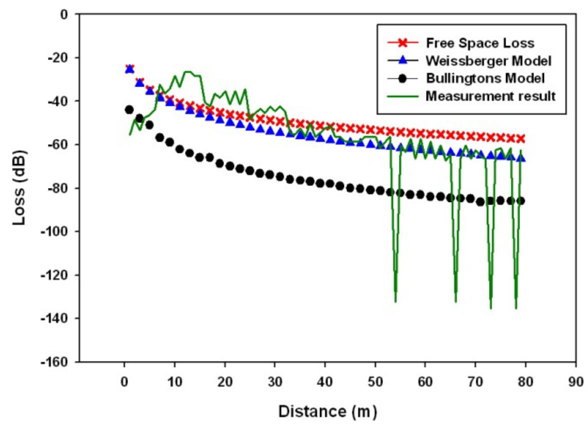


Figure 11 Comparison with propagation models

From Figure 11, the result of Weissberger's Model is slightly showing the same pattern with the measurement result. This model is also near to the result of the free space loss because this model only predict the loss due to foliage, thus the path loss must be calculated with the inclusion of free space path loss. As compared to the Bullingtons Model, the loss predicted is quite high and not suitable to be applied at this situation. However, from the result it indicates that the attenuation rate is significantly reduced with a great distance and the excess transmission loss is becomes practically not relevant.

Signal strength is very crucial as it shows the efficiency of the link performance. Be it high or low, the main important thing is when the power received nearly same with the power transmitted. The good signal strength meaning that that location has a good performance of WLAN design.

5.0 CONCLUSION

For the Line of Sight link, the signal will experienced no obstruction but the signal strength drops slowly as the distance increased. The measurement at Padang Kawad (Open Space) shows a minimum power received of -79 dBm at 40m separation distance. At the Palm Oil farm, without doubt, the signal is also drops with a big ripple performance. This is called NLOS link and the signal distortion attributed to vegetation that exists in the between the link is depends and varying with the condition of trees. For a row of trees with medium density of foliage, it is showed that the average mean power received at 40m separation distance is -91 dBm. The average attenuation at 433 MHz using RFID signal is 14.912 dB, where it is represents the excess path loss due to the Palm Oil trees. Since the measurement includes of six trees in a row at 40m separation distance, thus the specific attenuation caused by palm oil tree is 2.49 dB/ tree.

Comparison also made between the measurement result, Weissbergers and Bullingtons model. It is found that Weissberger's exponential decay model shows almost the same performance of propagation loss with the measurement. Thus, it can represent the calculation of path loss for RFID signal at 433 MHz at the palm oil farm. Although a significant research done to predict the best propagation loss modeling, it is still a big challenge to characterize the radio wave behavior in the vegetation environment.

Acknowledgements

This research work is supported by the Wireless Communication Centre, Faculty of Electrical Engineering, Universiti Teknologi Malaysia, and 81310 UTM Johor Bahru.

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