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An Adjusted Propagation Model for Wireless Sensor Networks in Corn Fields

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Abstract

In this paper, we propose some adjustment parameters for three popular propagation models typically used in vegetated environments. We validate the adjustments proposed with measurements in a small corn field typically found in Colombian farms. The proposed adjustments seem to work properly for wireless sensor networks typically used in the Internet of things for automated assisted farming in small crops.

1 Introduction

Wireless Sensor Networks (WSNs) are emerging as a significant technology for applications in agriculture farm [1]. Besides, some agriculture related parameters could be included to be monitored and then controlled by WSNs [2]. For this reason, propagation models have been used for WSN planning and deployment in agriculture fields. However, propagation models such as the Early ITU vegetation and Free Space Loss show very poor prediction accuracy [3].

In this work, we propose a correction factor for diffractions complementing Free Space Loss, Early ITU Vegetation and Two-Ray models, using the measured RSSI (Received Signal Strength Indication). The measurements of RSSI were made in a small cornfield in order to evaluate the propagation through vegetation for NLOS (non-line-of-sight) and LOS (line-of-sight).

This paper is organized as follows: Section two described the propagation Models used; Section Three described the environment and measurement conditions; the results are shown and analyzed in the Section Four; and Finally in the Section five, the conclusions.

2 The Propagation Models

Free Space Loss model

Free Space Loss (FSL) model [4] is represented for radio wave propagation as:

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

where f is the frequency in MHz and d the distance in meters. And, in all wireless environments [5], the RSSI power may be expressed as:

$$P_r = P_t + G_t + G_r - PL \quad (2)$$

where P_r is the received power in dBm, P_t the transmitted power in dBm, and G_t and G_r are transmitter and receiver antenna gains respectively in dBi. PL is the path loss in dB.

ITU Vegetation model

Early ITU Vegetation model [6] was developed from measurements carried out mainly at ultra-high frequency, and was proposed for cases where either transmit or the receive antenna is near to a small groove of trees so that the majority of the signal propagates through the trees.

$$ITU_L(dB) = 0.2 * f^{0.3} * d^{0.6}, d < 400\ m \quad (3)$$

where f is the frequency in MHz and d the depth of the foliage in meters.

Two-Ray model

The 2-ray ground reflection model [5] is a useful propagation model that is based on geometric optics, and considers both the direct path and a ground reflected propagation path between transmitter and receiver. The total received E-field, E_{TOT}, is then a result of the direct line-of-sight component, E_{LOS}, and the ground reflected component, E_g.

To assess the wider application of models, Root Mean Square Error (RMSE) between the models and the observed data were calculated [3]. The RMSE is a frequently used measure of the difference between values predicted by a model and the values actually observed from the environment. RMSE is a good measure of accuracy of the models. Generally, RMSE is given by equation (4), where X_{obs} is observed values, $x_{mod\,el}$ the modeled values, and n the number of samples.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(X_{obs,i} - X_{mod\,el,i})^2}{n}} \quad (4)$$

The Adjusted Models

The received powers to FSL and Two-Ray models are then adjusted with a correction factor for diffractions using the measured RSSI in the receiver:

$$P_{r(Adj)} = P_r - 7.125 * f^{0.3} - 10^{-h_C/h_r} - 10^{-h_C/h_t} \quad (5)$$

where P_r is the theoretical received power in dBm, f is the frequency in MHz, h_C is the average height of the corn plant in meters, h_r is the height of the receiver in meters and h_t is the height of the transmitter in meters.

The received power to ITU model is then too adjusted with:

$$P_{r(Adjusted)} = P_r - 62.23 - 10^{-h_C/h_r} - 10^{-h_C/h_t} \quad (6)$$

3 Environment and Measurements Conditions

RF propagation measurements were made at 2.4 GHz using Digi's XBee-Pro ZB S2C transceiver modules at transmitted power of 17 dBm (50 mW) with external antennas (Tx, Rx) of gain 3.8 dBi and the cable and connector loss is 4 dB.

In order to obtain RSSI values, experiments were carried out in a small cornfield, the ground conductivity is 0.0012 S/m and $\varepsilon_r = 15$, we performed peer-to-peer propagations measurements to investigate the vegetation loss values obtained from XBee- Pro ZB S2C transceiver modules.

The measurements were carried out in a small cornfield of agricultural experiment station San Pablo, Chinacota Village, North Santander department, Colombia. The average height of the corn trees is 0.5m.; The plant stem average diameter is 2.5 cm. Corns are regularly planted in rows. The row with is about 1 m, and within one row, the corn plants are usually planted 15 cm to 20 cm: [GPS coordinates: 7°34'11.514"N, 72°37'28.88"W]. Figure 1 (right) represents the Tx and Rx positions in the small corn fields.

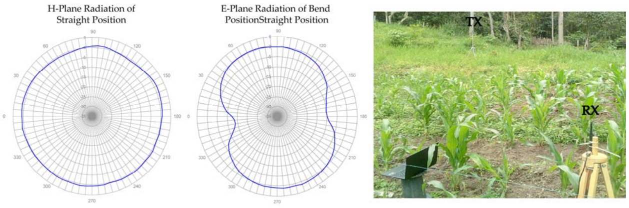

Figure 1. Pattern antenna (left). Photograph of small corn field (right).

A transmitter TX position was fixed at 5 meters from the sidewalk and 6.25 meters from the corner of the small cornfield, while a receiver RX was moved step-by-step in three routes from the cornfield border to 35 meters. Figure 2 provides the measurement locations for Route 1 (R1 in blue), Route 2 (R2 in red) and Route 3 (R3 in green). R1 and R3 are symmetrical about the distance of the transmitter position.

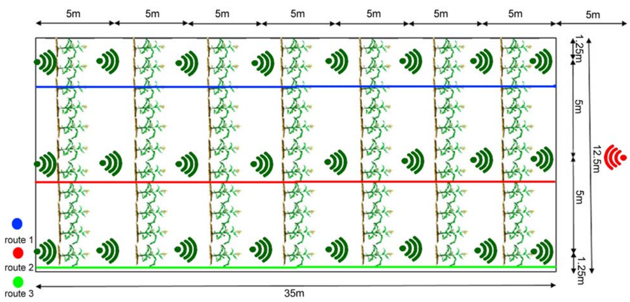

Figure 2. Measurements locations.

4 Measurements and Results

Root Mean Square Error (RMSE) values were deduced from the measured RSSI from all positions in this environment. In figures 3 to 5, we present a comparison of RSSI behavior between measurements, simulated and adjusted models. Note that, almost similar pattern is observed for RSSI values simulated of FSL and Two-Ray models. These figures are plotted in order to observe whether RSSI values behavior change with different routes of measurement and different height of receivers. These figures shows that applying a correction factor for diffractions could reduce the overall RMSE significantly if compared with non-adjusted. We also present a table with all measurement, simulated and adjusted recorded data in order to show how effective this correction factor would be.

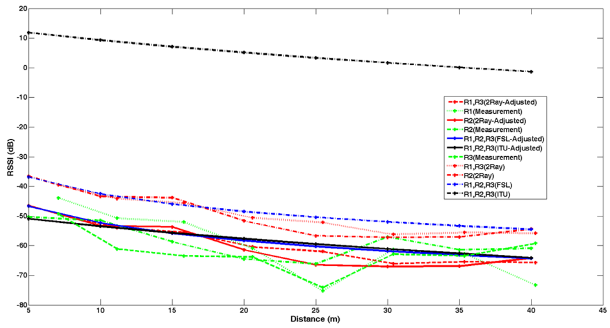

Figure 3. Results of RSSI measurements, simulated and ajusted models for receivers placed at a height of 0.5m.

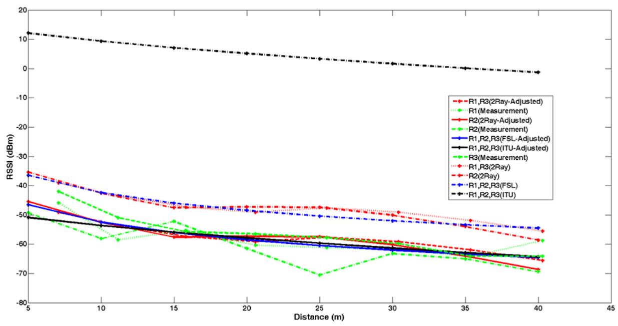

Figure 4. Results of RSSI measurements, simulated and ajusted models for receivers placed at a height of 1.0m.

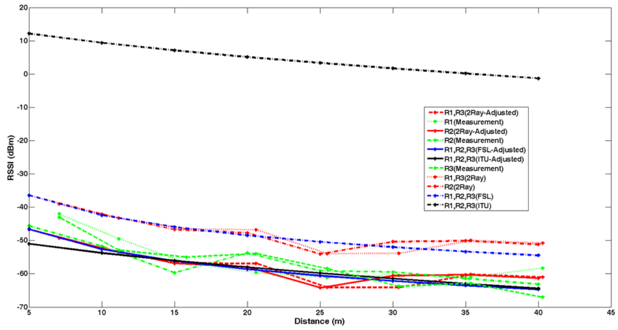

Figure 5. Results of RSSI measurements, simulated and ajusted models for receivers placed at a height of 1.5m.

Table 1. Statistical Summary of RMSE (dB)

Route	Models					
	ITU		FSL		Two-Ray	
	Init	Adj.	Init	Adj.	Init.	Adj.
	Receivers placed at a height of 0.5m					
R1	64.3	1.5	11.4	1.5	10.1	0.2
R2	63.5	0.7	10.8	1.0	8.7	1.1
R3	66.5	3.7	13.6	3.7	12.2	2.3
	Receivers placed at a height of 1.0m					
R1	62.6	0.4	9.7	0.4	10.4	0.3
R2	65.9	2.8	13.2	3.1	13.3	3.2
R3	60.7	2.3	7.78	2.3	8.5	1.5
	Receivers placed at a height of 1.5m					
R1	60.5	2.7	7.5	2.7	8.1	2.1
R2	61.5	1.7	8.8	1.4	9.4	0.8
R3	61.5	1.7	8.5	1.7	9.1	1.1

5 Conclusion

In this paper, we compare different propagation models to analyze the behavior in corn plants.

We proposed a correction factor to include the canopy reflection and diffraction by tree trunks effects. The correction factor improves the results, at least for the test scenario, and we expect similar behavior in other corn fields.

6 References

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