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Thesis Outline

Radio Propagation Channel Analysis and Modeling in Outdoor Agricultural Environments for Wireless Sensor Networks at 2.4 GHz Band

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In precision agriculture, the wireless sensor network is used in gathering the variability in the fields for intelligent management to improve the yield. Understanding the characteristics of the radio propagation in such environment is useful in deploying the wireless sensor networks. This thesis aims to model and predict such propagation characteristics in two common types of outdoor agriculture environments - the tall food grass field and the fruit orchard - at 2.45 GHz band.

This thesis proposed the multitone-overlapping frequency stepping technique (MOFS) and applies the over-the-air timing synchronization by power detection to develop the wide-band channel sounder for the radio propagation measurement in the outdoor agriculture environments by utilizing the limited bandwidth SDR system. The proposed technique can be applied in any radio system to enable the wider bandwidth measurement than its original specification.

This work conducted the measurements at 2.4 GHz band in two common agriculture environments; sugarcane field representing the tall food grass field and jackfruit orchard representing the fruit orchard.

In the sugarcane field, the results reveal that the number of ridges existing along the line-of-sight (LOS) of the transmitter (Tx) and receiver (Rx) is the

dominant cause of the angular variation. Therefore, the vegetation obstruction model is proposed to better represent the angular variation. Utilizing the proposed model, the procedure of predicting the path loss at any point in the sugarcane field by using a few measurement results can be formulated. This procedure can reduce much of the effort in practical WSN planning and deployment. Although further experimental validation is needed, the same procedure is expected to be applicable to other food grass agriculture fields under the conditions described in this work. Third, the small-scale fading in terms of the Rician K-factor is investigated for a range of vegetation depth that is more suitable for precision agriculture than the existing works. It reveals the possibility of predicting the Ricain K-factor at any point in the field if the path loss information is available. Finally, due to the lack of wideband channel parameters in the tall food grass scenario, the root-mean-square (RMS) delay spread is investigated in this work.

In the jackfruit orchard, the influence of the angular direction and the number of trees existing along the LOS, n, on the path loss is clarified through measurement result. Observing that n can be counted as 1 only when the LOS of the Tx and Rx is passing through the center of a tree, the concept of the equivalent number of trees along the LOS, n_{t}, is introduced to represent n in any angular direction. Second, the results reveal that n_{t} is the significant cause of the angular path loss variation. The equivalent vegetation obstruction model is proposed as the semi-empirical function of n_{t} to better represent such an angular variation. This leads to the procedure of the path loss prediction approach at any point in the jackfruit orchard by using a few measurement efforts. Although further experimental validation is needed, the same procedure is expected to be applicable to other fruit orchards under the conditions described in this work.

Finally, this work introduces the Monte Carlo simulation using the numerical electromagnetic scattering computation called hybrid T-matrix method to evaluate the relative angular vegetation loss of a single tree that is used as the input to determine n_{t}. The evaluation results suggest that it can further reduce the measurement workload required for the proposed path loss prediction procedure.

The provided results and the proposed approaches in this thesis will be useful for designing and deploying the wireless sensor networks for precision management in the agriculture field.