ANFIS for Vegetation Effects Prediction in Paddy Field for Wireless Sensor Network

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Abstract—**Currently, the establishment of a dedicated wireless sensor network distributed in agricultural areas. Monitor and record the physical conditions of the environment and forward the collected data to a control center. The wireless sensor network (WSN) measures the environmental conditions such as temperature, humidity and rainfall. But the height of plants, the height of the transmitting antenna, the distance and the frequency of the WSN system have the effect on the transmission of radio waves. In this experiment, the measurement data set includes the height of rice grown 105 cm, antenna height 55 cm, 105 cm and 155 cm were used to find the vegetation effect for wireless sensor network using adaptive neuro-fuzzy inference system (ANFIS). The frequency of 2400 MHz and 930 MHz were used at different distances from 5 m to 55 m. The results from the ANFIS model were more accurate compared to the Weissberger model. Furthermore, the antenna heights at 55 cm. and 105 cm. Furthermore, the antenna heights of 55 cm and 105 cm, radio signal transmission was attenuation due to rice plants significantly.**

Keywords—ANFIS, Vegetation Effects prediction, paddy field, Weissberger model, WSN

I. INTRODUCTION

Application of WSN in large farms to control irrigation, fertilizer, pest control, etc. get more attention. It is positioning the sensors in another location appropriately. In setting up the WSN system, the vegetation effect must be taken into consider. The radio attenuation of each plant growing affects the positioning of the sensor. WSN conditions must be received the signals with minimal power consumption. Several researches study the WSN in the plant fields in the following. Li, S. and Gao, H. [1] studied and analyzed the propagation mechanisms and the impact factors on the propagation characteristics of wireless channel in cropland. The nodes should be placed in an open area such as a wide corridor, it is possible in order to minimize propagation loss and increase the node's coverage effectively. The antenna height of 1.4m to 1.6m is a good condition, which will be more economic and feasible. Ozuomba, S. and et. al. [2] studies the propagation loss models of 1800 GHz at Gliricidia sepium Arboretum. The propagation loss models were tuned using foliage depth tuning constant with the training dataset. The study found that the un-tuned Weissberger model had a root mean square error (RMSE) of 21.098 dB while the tuned Weissberger model had a RMSE of 3.375 dB. Pal, P. and et. al. [3] studied a WSN monitoring infrastructure for a vegetative environment. A path loss model bases on the effects of vegetation height and density on signal strength between two sensor nodes communicating under the IEEE802.15.4 Wireless standard. The path loss coefficients have been analyzed for 2.4 GHz RF signals at various development stages of Rice and Millet crop. Kuramoto, D. and et. al. [4] studied the vegetation effects in paddy field for a WSN using the Weissberger model. The study found that the attenuation signal depends on the distance and the height of antenna. However, the measurement data signal has certainty and vague uncertainty as a fuzzy. Then, it can be used fuzzy logic to create prediction models. Fuzzy methods are linguistically based on the input and output variables. Ojo, S. and Etta, V.O. [5] studied a fuzzy-logic based path loss prediction model. A signal loss propagation model developed at 2.6GHz using fuzzy-logic to represent all measure of uncertainties and uncertain data thereby producing accurate results. The signal loss prediction model compared with the experimental data and with each of the theoretical empirical models. In addition, machine learning of neural networks can be used to learn the signal loss propagation information. Hakim, G.P.N. and et. al. [6] proposed the hybrid neural network with fuzzy logic called ANFIS. This study analyzes the propagation at near ground. The ANFIS model gives the less than RMSE where compares with the Okumura-Hata model for all environments at 433 MHz and 868 MHz.

From the researches mentioned above, this research proposes the vegetation effect model in paddy field for WSN using ANFIS. In this study, the vegetation effects between the Weissberger model and the ANFIS model will be compared in the detail of next section.

II. MODELS AND METHODS

A. Weissberger model

Weissberger model is a wave propagation model which estimates the path loss due to the presence of one or more trees in a transmit node to a received node. This model can be applied to determine the vegetation effect in a paddy fields to find the attenuation of wave propagation. The measured received signal strength (RSSI) values in dBm were converted to the measured path loss using ($PL_{m(dB)}$) in equation (1) –(6) [2]

$$PL_{m(dB)} = P_{BTS} + G_{BTS} + G_{MS} - RSSI(dBm) \tag{1}$$

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where P_{BTS} is the transmitter power (dBm),

G_{BTS} is the transmitter antenna gain (dBi) and

G_{MS} is the receiver antenna gain (dBi).

A wireless signal propagates through the vegetation area, the total propagation loss $Pl_{Tl}(dB)$ can be determined as in equation (2)

$$Pl_{Tl}(dB) = Pl_{FSP}(dB) + Pl_{Foilage}(dB) \quad (2)$$

where Pl_{FSP} is the free space propagation loss and

$Pl_{Foilage}$ is the propagation loss due to the foliage.

The Pl_{FSP} can be computed as the equation (3)

$$Pl_{FSP}(dB) = 32.5 + 20 + \log(f) + 20 + \log(d) \quad (3)$$

where f is the frequency in MHz and

d is the distance point to pint communication link in Km.

The foliage propagation loss in dB based on the Weissberger model is

$$Pl_{weis}(dB) = \begin{cases} 0.45f^{0284}(dB) & for\ 0 \le d_f \le 14\ m. \\ 1.33f^{0.84}(d_f)^{0588} & for\ 14 \le d_f \le 400\ m\ . \end{cases} \quad (4)$$

where d_f is the depth of foliage along the LOS path in meters and f is the frequency in GHz. Then,

$$Pl_{Tl}(dB) = 32.5 + 20 + \log(f) + 20 + \log(d) + \begin{cases} 0.45f^{0.284}(d_f)\ for\ 0 \le d_f \le 14\ m. \\ 1.33f^{0.84}(d_f)^{0588} \quad for\ 14 \le d_f \le 400\ m \end{cases} \quad (5)$$

This application model was tuned using foliage depth tuning constant $K_{df}tuned(d_f)$ as shown in equation (6)

$$Pl_{Tl}tuned(dB) = 32.5 + 20 + \log(f) + 20 + \log(d) + \begin{cases} 0.45f^{0.284}(K_{df}(d_f))\ for\ 0 \le d_f \le 14\ m. \\ 1.33f^{0.84}(K_{df}(d_f))^{0588} \quad for\ 14 \le d_f \le 400\ m \end{cases} \quad (6)$$

B. *Adaptive Neuro Fuzzy Inference System Method*

The fuzzy system is a linguistic processing system based on fuzzy inference engine which consists of fuzzy rules in a knowledge base. The fuzzy rules in the knowledge base are obtained from the experts. But in the applications, the fuzzy rules should be adapted to obtain the appropriate output. Therefore, the input-output pair must be learned to optimize the output. A neuron network is used to learn the input-output relations to adjust the fuzzy set to find an appropriate output. The hybrid architecture called Adaptive Neuro Fuzzy Inference System (ANFIS). The Jang's ANFIS architecture research consists of 5 layers as following [5].

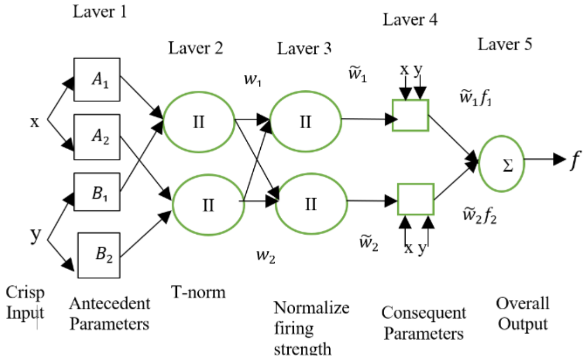


Fig. 1 ANFIS architecture structure.

Figure 1 is the ANFIS architecture, 2 inputs, an output. Each input is divided into 2 fuzz sets. Each set contains A1, A2 and B1, B2 and parameters of output as pj, qj, and rj, with the number of rules n as follows:

Rule 1: If x_1 is A_2 and x_2 is B_2 THEN $f_1 = p_1x_1+q_1x_2+r_1$

Rule 2: If x_1 is A_2 and x_2 is B_2 THEN $f_2 = p_2x_1+q_2x_2+r_2$

|

Rule n: If x_1 is A_n and x_2 is B_n THEN $f_n = p_nx_1+q_nx_2+r_n$

The structure consists of 5 layers as following.

Layer 1: Antecedent Parameters is a fuzzy determination from the Crip input x to membership value μ_{A_i} or μ_{B_i} using the membership function as in equation (7)

$$O_i^1 = \mu_{A_i}(x) \quad (7)$$

where O_i^1 is the membership of Ai derives from x input. The membership function may be a triangular, inverted bell or any other shape.

Layer 2: T-norm Operator or fuzzy rule layer (fuzzy rule base) is a layer to associate fuzzy values from each dimension and sends the product of fuzzy as an output signal as in equation (8).

$$w_j = \mu_{j1}(x_1)\mu_{j2}(x_2) \quad (8)$$

where w_j is the firing strength from each rule and $\mu_{ji}(x_i)$ is the fuzzy value from the i^th^ dimension of rule j.

Layer 3: Normalize firing strength or weighted layer to be the fuzzy sums all the terms from all rules into a single value as in equation (9).

$$\tilde{w}_j = \frac{w_j}{w_1 + w_2 + \cdots + w_n}, j = 1, 2, \ldots, n \quad (9)$$

Layer 4: Consequent parameter is the parameter output layer which can be obtained from equation (10)

$$\tilde{w}_j f_j = \tilde{w}_j (p_jx_1+q_jx_2+r_j) \quad (10)$$

Layer 5: Overall Output is the output layer of the network which combine every incoming signals and defuzzification as in equation (11).

$$\tilde{w}^T f = \sum_{j=1}^{n} \tilde{w}_j f_j \quad (11)$$

where $\tilde{w}^T = [\tilde{w}_1\ \tilde{w}_2 \ldots \tilde{w}_n]$ is the value of fuzzy that normalize from the rule 1-n and $f^T = [f_1\ f_2 \ldots f_n]$ is the output of rules 1… n.

III. MODELING AND RESULTS

In this study, the RMS error (dB) was used to evaluate the performance of the ANFIS model and Weissberger model. The data set from the graph in the vegetation effect in paddy field for WSN [4] at 0.92 GHz and 2.4 GHz were used in the performance comparisons. A comparison for vegetation effect model using two different frequency band. Divide the data into 2 data sets for training and testing. Training sets consist of the input output data pairs such as the height of antenna (m), distance (m) and RSSI measurement (dB) at each distance. In training, fuzzy member input set 5, 5, number of epochs 500 are used.

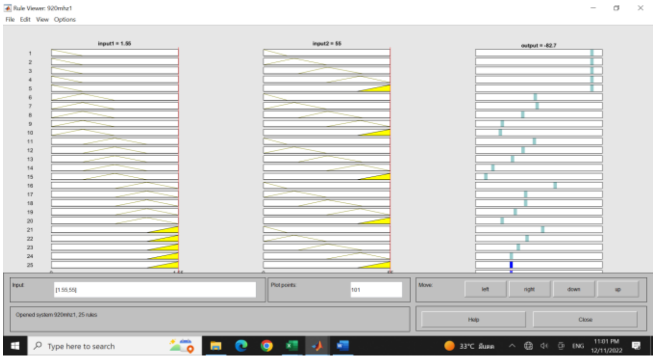
For the Weissberger model, the parameter coefficients obtained using the algorithm for minimizing the RMSE. The model was tuned the parameter A, B and C in the equation (12) [4].

$$G(dB) = G_{path\ gain} - Af^{B}d^{c} \qquad (12)$$

where f is the frequency and A, B and C are tuning constants.

A. *Modeling Vegetation effect at frequency 0.92 GHz*

The structure of ANFIS uses the first order Sugeno fuzzy model, the inputs are the antenna heights and distances. The output is the vegetation effect to reduce the RSSI. The membership functions are used dsigmf model, a mixed learning process (Hybrid), number of mfs 5, 5 and the number of calculation cycles is 500 epochs. The results are shown in Fig. 2-5.

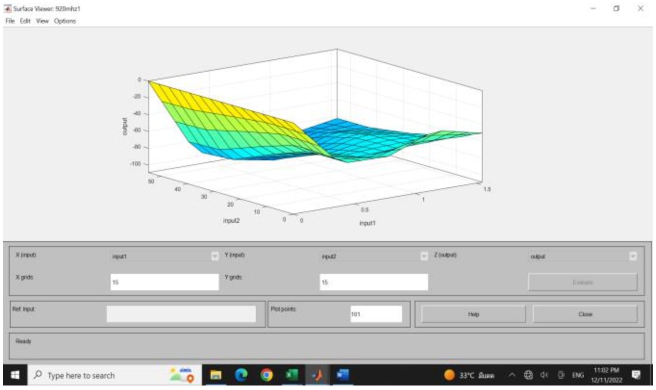


Input: [1.55,55]

Plot points: 101

Opened system 920mhz1, 25 rules

Fig. 2 The fuzzy rules viewer for training of vegetation effect at 0.92 GHz.



X (input): input1

Y (input): input2

Z (output): output

X grids: 15

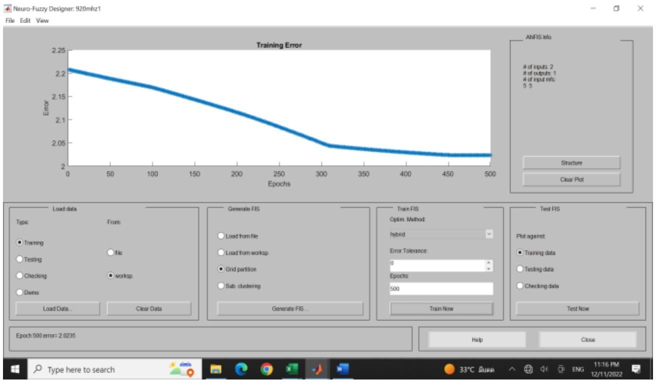
Y grids: 15

Ref. Input:

Plot points: 101

Ready

Fig. 3 The surface viewer at 0.92 GHz.



# of inputs: 2
# of outputs: 1
# of input mfs:
5 5

Type: ● Training ○ Testing ○ Checking ○ Demo

From: ○ file ● worksp.

○ Load from file ○ Load from worksp. ● Grid partition ○ Sub. clustering

Optim. Method: hybrid

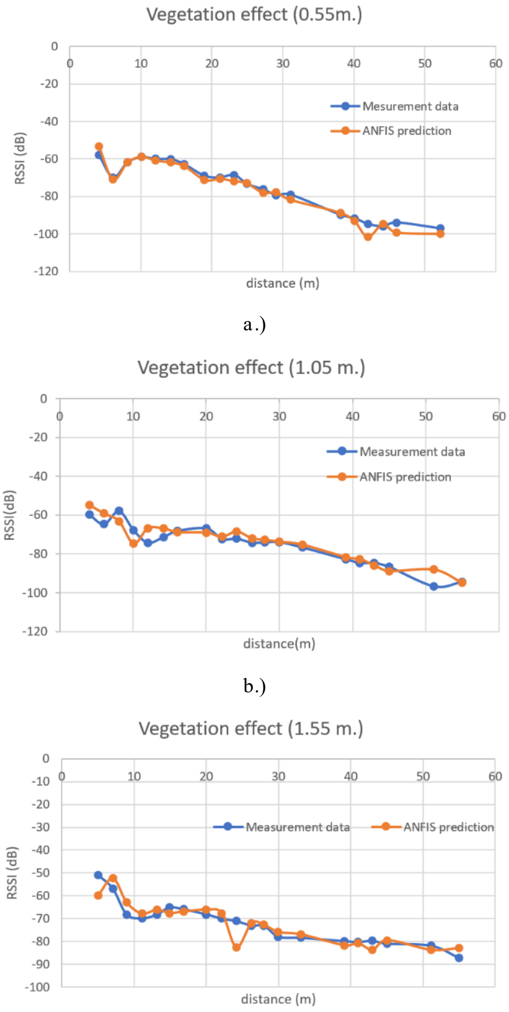
Error Tolerance: 0

Epochs: 500

Plot against: ● Training data ○ Testing data ○ Checking data

Epoch 500 error= 2.0235

Fig. 4 The training neuro fuzzy error.



a.)

b.)

c.)

Fig. 5 Propagation of each antenna height in paddy field compare with the ANFIS prediction at frequency 0.92 GHz: a.) antenna height 0.55 m. b.) antenna height 1.05 m. c.) antenna height 1.55 m.

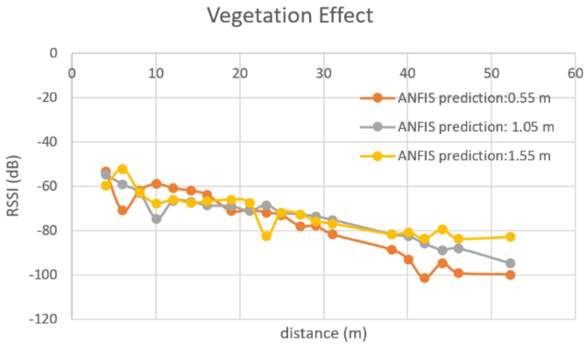
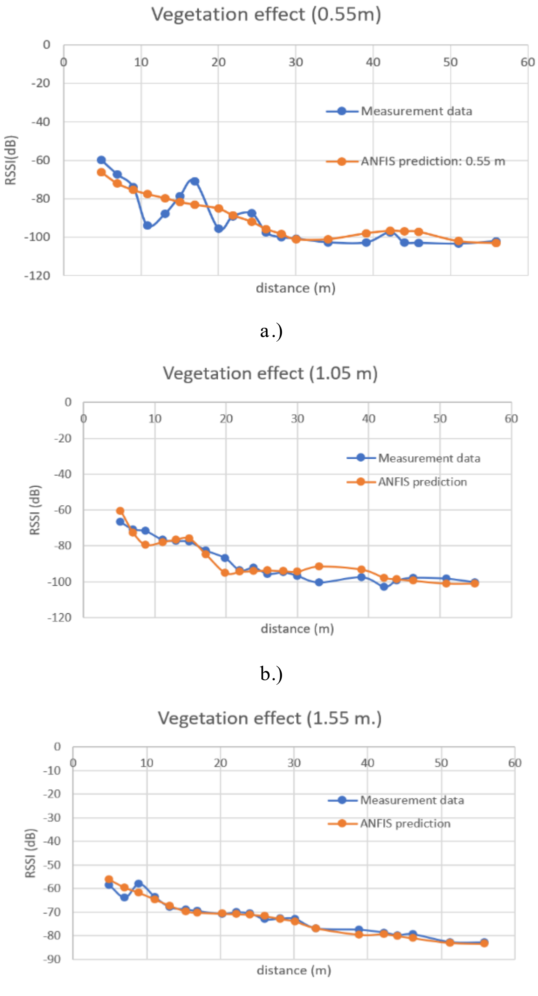


Fig. 6 Comparison the ANFIS prediction at frequency 0.92 GHz for propagation of different antenna height in paddy field.

B. *Modeling Vegetation effect at frequency 2.4 GHz*

The structure of ANFIS is used to train the data that the frequency 2.4 GHz is as same as the case of 0.92 GHz. But changes to number of mfs 10, 10 and the number of calculation cycles is 1,000 epochs. The results of propagation in paddy field are shown in Fig. 7.



a.)

b.)

c.)

Fig. 7 Propagation of each antenna height in paddy field compare with the ANFIS prediction at frequency 2.4 GHz: a.) antenna height 0.55 m. b.) antenna height 1.05 m. c.) antenna height 1.55 m.

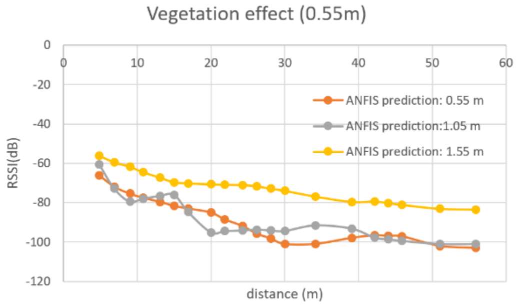


Fig. 8 Comparison the ANFIS prediction at frequency 2.4 GHz for propagation of different antenna height in paddy field.

IV. CONCLUSION

This paper proposes a method for predicting the vegetation effect using ANFIS model to compare the measurement values at the height of the antenna 0.55, 1.05 and 1.55 m., respectively. From the predictions, it was found that ANFIS model predicts the minimum error 1.63 dB, and maximum error 4.06 dB. The comparisons between the prediction values of ANFIS model and the prediction values obtained tuning parameter A, B and C of Weissberger model, it found that the predicted values of ANFIS model were more accurate than Weissberger model as shown in Table 1. From Fig. 6 and 8, there are not significant different between the antenna heights of 0.55 m. and 1.05 m. In addition, the path loss increases at distances more than 10 meters.

TABLE I. THE RMSE ERROR VEGETATION EFFECT PREDICTION BETWEEN THE ANFIS MODEL AND WEISSBEGER MODEL

Frequency (GHz)	Antenna height (m)	RMSE (dB)	
		Weissberger [4]	ANFIS
0.92	1.55	3.30	3.14
	1.05	3.99	2.49
	0.55	5.53	3.56
2.4	1.55	1.82	1.63
	1.05	4.56	4.06
	0.55	5.29	2.46

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