Vegetation Effect in Paddy Field for A Wireless Sensor Network

Daisuke Kuramoto, Tatsuki Tokunou ,and Toshihiko Hamasaki
Hiroshima Institute of Technology
Graduate School of Science and Technology
Hiroshima, Japan
t.hamasaki.rs@it-hiroshima.ac.jp

Abstract—In this paper, we report the influence of vegetation in paddy fields with antenna height as a parameter for 2.4GHz (3mW) and 920MHz (20mW) propagation. From the viewpoint of practicality, a commercially available wireless communication module equipped with a small pattern antenna was used for the experimental apparatus. In order to consider the worst case of communication loss, detailed measurements were made assuming the height of rice grown 105 cm, and the antenna height was 55cm, 105cm, 155cm. Based on the measurement results, fitting was performed on the Exponential Decay (EXD) model, and the propagation characteristics in paddy fields were verified. As a result, at 2.4GHz, even under line-of-sight conditions, there was attenuation due to the influence of scattering of reflected waves due to plant arrangement, and it was found that the same degree of remarkable attenuation due to vegetation occurred regardless of the height under rice top. On the other hand, at 920MHz, which is said to have strong diffraction, it was revealed that the loss characteristic of vegetation is proportional to the height.

Keywords—WSN, radio wave propagation model, paddy field, path-loss, pattern antenna, rice, exponential decay model.

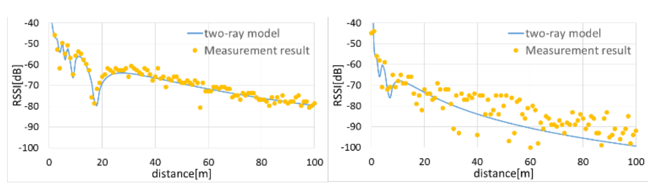
I. Introduction

Improvement of productivity of rice cultivation is an urgent issue in Japan's domestic agricultural policy and promotion of IT conversion of environmental monitoring is considered to be an effective means. The wireless technology according to the IEEE 802.15.4 standard is supposed to be low power consumption short range communication and is attracting attention as a means for constructing a sensor network at low cost. For its widespread use, general farmers are required to be able to guarantee robust communication. However, concerns at many application stages are losses due to the influence of vegetation of propagation between compact wireless modules installed at a relatively low altitude in the farm. Li and Gao modeled the propagation loss in Cornfield (about 1m height) for the transmission distance of 70 m for 2.4 GHz and found that the matured dense plants act as the plane surface f or the Fresnel zone [1]. Balachanders *et al.* tried various Exponential Decay (EXD) models of path-loss [2-4] for expressing the several kinds plant fields [5]. Gay-Fernandez and Cuinas tried another concept model for expressing antenna height dependence in vegetated environments [6]. In this report, we measured the propagation characteristics of radio waves 2.4 GHz and 920 MHz in typical paddy fields in Japan where the height of the grown plants was almost constant and the stem was equally spaced. We employed the Wireless Sensor Module equipped with a small pattern antenna which has already been introduced as a mass-market product as the experimental apparatus. And, we carried out detailed measurements of propagation at various altitudes in paddy fields, and based on the EXD model for propagation loss, we verified the characteristic effect of rice plants vegetation.

II. Experimental Field and Condition

The equipment used is the NEC ZB24TM-E2036 (2.4 GHz) and TYSS 92-E 2730 (920 MHz) modules with built-in pattern antenna (20mm × 5 mm) designed for low power consumption WSN. The polarization characteristics of the antenna in these modules are measured by the anechoic chamber equipment in the campus, and it is first confirmed that it is omnidirectional in the horizontal direction. Subsequently, in order to confirm the reliability of the installation and measurement method of the apparatus, measurements were carried out at 1 m intervals in a flat soil in Campus Field in the range of 0 m to 100 m. It is confirmed that the measurement curve agrees well with the two-ray model as shown in Figure 1.

Especially at 2.4 GHz, weak diffraction, notch position and attenuation intensity are nearly perfectly matched, variance σ 2.5dB. Even at 920 MHz with high diffraction, it is 7.1dB. The RSSI is the averaged value of 100 times of communication. After that, measurements were carried out under the same conditions in the paddy fields as shown in Figure 2. Paddy field position is 34.54 N, 133.35 E, measurement day September 1st, (weather - fine, temperature at 29 degrees Celsius, humidity 50%) and rice plant height is about 105cm. Here, the antenna height is 55cm, 105cm, and 155cm for both transmitter and receiver. RSSI measurement was carried out with a distance between transceivers 0 - 57m.



(a) (b)

Fig. 1. RSSI measurement result on a flat soil in the campus for frequency 2.4GHz (a) and 920MHz (b). The antenna height is 105cm. Solid line indicates two-ray model.

Fig. 2. Measurement Environment. Sub-urban paddy field on September 1st , Fukuyama city, Hiroshima Prefecture.

III. VEGETATION WITH A DIFFERENT ANTENNA HEIGHT EFFECT IN PADDY

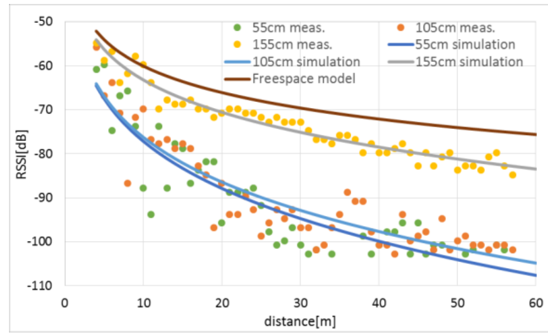
The measurement results in paddy fields are shown in Figures. 3(a) and (b) for 2.4GHz and 920MHz, respectively. The attenuation characteristic by vegetation was fitted by the equation (1). Here, the parameter coefficients obtained by using the algorithm for minimizing the RMS error are summarized in Table I.

$$\boldsymbol{G}[\mathbf{dB}] = \boldsymbol{G}_{path\ gain} - \boldsymbol{A} \times \boldsymbol{f}^{\boldsymbol{B}} \boldsymbol{d}^{\boldsymbol{C}} \qquad (1)$$

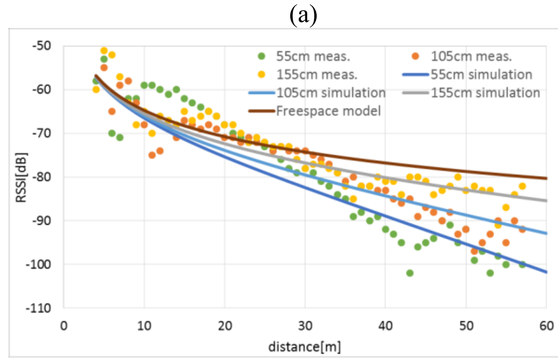
f is the frequency, *d* is the distance between the transmitter and receiver, and A, B and C are fitting constants. We applied Weissberger model concept for B considering the similarity of experimental condition[5]. From Figure 3(a), there is no significant difference in the measurement results of the antenna height 55cm and 105cm at 2.4GHz, and there is almost no difference in the fitting constants in Table 1. This is considered to be due to the fact that the diffraction at 2.4GHz is weak and the dominant pass attributes to the first Fresnel zone propagation. Thus, top of the dense matured plants act as the plane surface for 155cm height, which deteriorate the propagation compared with free space. On the other hand, vegetation loss becomes significant below 105cm. It is interesting to note that the loss rate is almost equal for 55cm deep inside of plants and for 105cm near top of the matured plants. In the case of 920 MHz, Figure 3 (b), it seems there is no significant difference the distance up to around 25m. However, it can be confirmed that the propagation loss increases with decreasing antenna height. It can be cofirmed by the value change of parameter C in Table 1. Thus, diffrafction over the plants influenced by vegetation as well as direct propagation for 920MHz.

TABLE I. VEGETATION MODEL PARAMETERS AND RMS ERROR

	***Antenna Height*[cm]**	***A***	***B***	**C**	***RMS error*[dB]**
2.4GHz	**155**	**0.14**	**0.284**	**0.51**	**1.82**
	105	**1.09**	**0.284**	**0.33**	**4.56**
	55	**1.10**	**0.284**	**0.35**	**5.29**
920MHz	**155**	**0.01**	**0.284**	**1.05**	**3.30**
	105	**0.01**	**0.284**	**1.27**	**3.99**
	55	**0.01**	**0.284**	**1.4**	**5.53**



(a)



(b)

Fig. 3. Propagation of each antenna height in paddy field : frequency (a) 2.4GHz (b) 920MHz. Solid lines are fitting curves using equation (1).

IV. CONCLUSION

In this paper, detailed measurements are carried out in paddy fields and the characteristics of vegetation are verified based on the EXD model. In spite of the fact, that the antenna height is 155cm at 2.4GHz, degradation occurs due to the influence of reflected waves by top plane of matured rice plants, although the line of sight is taken. There was no significant difference between the antenna height of 55cm and 105cm, and it was confirmed that the vegetation increased as the distance became longer. On the other hand, at 920MHz, path-loss was hardly observed up to the point of 10m, but the influence of vegetation increased as the distance became longer depending on the antenna height.

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