Tidal Level Estimation Using a 5GHz Band Wireless Access System

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***Abstract*—Recently, ICT has been introduced to various fields of fishery and marine work. For example, wireless access systems are used for realizing a broadband environment in coastal areas and on isolated islands. The authors also realized a marine broadband environment for small fishing vessels to manage aquatic resources. In order to establish stable use of wireless access systems, it is necessary to evaluate the characteristics of wireless access systems in severe conditions, such as anomalous tide levels caused by a typhoon or a tsunami. In this study, the authors evaluated the long-term characteristics of a wireless access system by constructing a 5 GHz band wireless access system that has propagation paths including the surface of the sea. As a result, we could obtain RSSI data when a typhoon approached, and we confirmed that the system could maintain communication quality. The authors also considered the possibility of the detection of anomalous tidal levels from RSSI of the wireless access system.**

I. Introduction

Recently, Information and Communication Technology (ICT) has been introduced to various fields such as fishery and marine work. For example, Japan consists of 6,852 islands. In order to realize a broadband Internet environment in coastal areas and on isolated islands, the use of wireless access systems has been investigated. The authors also constructed a marine broadband environment to manage aquatic resources in the coastal areas of Rumoi, a city in northwest Hokkaido, Japan[1]. In overseas countries, there is various research into establishing a broadband environment[2].

On the other hand, wireless access systems have also been considered for use in achieving maritime safety. The Japan Coast Guard cites “the safety measures of marine traffic when large-scale disaster occurs” as a problem which needs to be solved. To solve the problem, it is necessary to construct a system to provide information inside and outside the harbor. Wireless access systems are widely expected to act as a channel backup system when disasters occur. The City of Hakodate Fire Headquarters is considering the system’s use as backup communication lines among headquarters and branches. However, they have a serious concern about fluctuation of communication quality, because the propagation path includes the surface of the sea. In order to use wireless access systems as a backup, the systems should be able to communicate stably in not only normal meteorological and hydrographic conditions but also abnormal conditions such as anomalous tide levels caused by a typhoon or a tsunami.

In general, it is common knowledge that sea-surface radio wave propagation is influenced by sea level variation. Conversely, there is a possibility that tidal level can be estimated from Received Signal Strength Identifier (RSSI). In this study, the authors constructed a wireless access system in Hakodate bay to observe the relationship between RSSI and tidal level. The authors also investigated the possibility of the detection of anomalous tidal level from the RSSI of the wireless access system.

II. Principles and measurement environment

Figure 1 shows the principle of radio wave propagation including the sea surface. In this case, the propagation can be explained in terms of two waves, a direct wave and a reflected wave. A direct wave travels directly from a transmitting antenna to a receiving antenna. A reflected wave is reflected by the sea surface and reaches a receiving antenna. At a receiving antenna, RSSI is calculated from the synthetic wave of direct and reflected waves[3]. Path length of direct wave λ_d, Path length of reflected wave λ_r, and the phase difference between direct and reflected waves $\Delta\phi$ are determined by the following equations.

$$l_d = \sqrt{(h_t - h_r)^2 + d^2} \quad (1)$$

$$l_r = \sqrt{(h_t + h_r)^2 + d^2} \quad (2)$$

$$\Delta\phi = \frac{2\pi(l_r - ld)}{\lambda} = \frac{4\pi h_t h_r}{\lambda d}. \quad (3)$$

Here, h_t is the height of the transmitting antenna, h_r is the height of the receiving antenna, d is the distance between both antennas, and λ is the wavelength of the radio waves. The sea surface moves up and down according to sea level variation, so h_t, h_r and l_r vary with time. Therefore, the antenna which measures maximum/minimum RSSI differs depending on time. In this study, the authors tried to estimate the tidal level from the combination of the RSSI of plural antennas.

In this study, the authors measured RSSI by constructing 5 GHz band wireless access systems between Future University Hakodate (FUN) and Hakodate Research Center for Fisheries and Oceans (HRCFO). Figure 2 shows the principle of our study. The authors set up a transmitting station at FUN, and installed a receiving station at HRCFO to study the relationship between RSSI and tidal level. The authors used OWS 2400

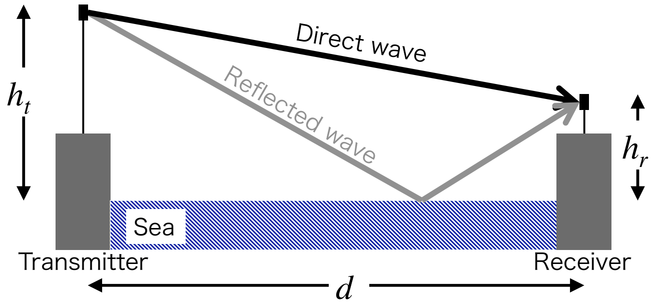

Fig. 1. The principle of radio wave propagation including sea-surface propagation

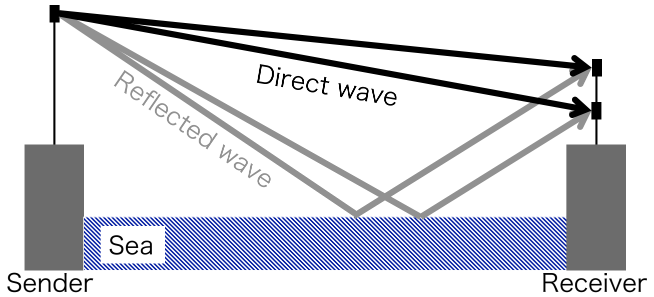

Fig. 2. The principle of our study

TABLE I. SPECIFICATIONS AND SETTINGS OF OWS 2400

Wireless standards	IEEE802.11j
Modulation method	OFDM
Frequency	4.92GHz (Fixed)
Data rates	54 Mbps (Max.)
Transmission Power P_t	125 mW
External Dimensions	310 × 254 × 152 mm
Weight	about 7.5 kg

(Strix System Inc.) as a wireless access system. This system supports IEEE 802.11j standard, which is designed for utilizing 5GHz band within Japan, and it has been introduced successfully in Japan. Table I shows the specifications and setting parameters of OWS 2400. OWS 2400 has an automatic channel selection function. However, automatic channel selection may disturb the observations on the relationship between RSSI and tidal level. So, in this study, the frequency band was fixed at 4.92 GHz. The authors also used a patch-type flat antenna AT719. This antenna is used for OWS2400, and its gain is 9.5 dBi. At the transmitting station, the authors introduced a wireless communication module and an antenna, and set two modules and two antennas at the receiving station. At the receiving station, the two antennas were arranged vertically. The spacing between these antennas was 0.75 m. Figure 3 and 4 are photographs of antenna arrangement at FUN and HRCFO. In order to measure the distance between FUN and HRCFO, the authors used A100 (Hemisphere Inc.) GPS antenna, which supports Satellite-Based Augmentation System (SBAS). The result showed the distance to be 8,464.7 m. We also calculated the antenna height from the design drawing of FUN and HRCFO. The antenna height is 146.7 m at FUN, and 17.55 m and 18.30 m at HRCFO. RSSI is measured by the command which is prepared in advance by the manufacturer of the wireless access system. No other equipment was used for measuring RSSI.

Fig. 3. Installation of antenna at Future University Hakodate (FUN).

Fig. 4. Installation of antenna at Hakodate Research Center for Fisheries and Oceans (HRCFO).

III. MEASUREMENT RESULTS

In this section, the authors describe the measurement results of RSSI using the wireless access systems. The measurement was carried out from Jul. 19, 2014 to Dec. 31, 2014. RSSI was measured 5 times per minute at each antenna of the receiving station, and the median value of these five results was regarded as the RSSI at that time. The authors obtained the tidal-level data from the Hydrographic and Oceanographic Department, 1st Regional Coast Guard Headquarters. The department has been updating the tidal level in Hakodate bay at 5 minute intervals.

Figure 5 and 6 show the temporal changes of RSSI of the wireless access system and tidal level in Hakodate bay. In these figures, the horizontal axis represents Japan Standard Time (JST), green dots stand for the RSSI of the lower antenna, pink dots show the RSSI of the upper antenna, and the blue line is the tidal level in Hakodate bay. Generally, it is clear that the tidal level is relevant to RSSI. For example, RSSI of the upper antenna tended to be higher than that of the lower antenna, when the tidal level was within a range of 30-60 cm. The lower antenna recorded higher RSSI than that of the upper antenna, when the tidal level was within a range of 60-90 cm.

Figure 7 and 8 show the relationship between the tidal level and RSSI of antennas at the receiving station. In these figures, red circles stand for RSSI measurement values on Aug. 11, blue circles are the values on Dec. 23, and the black line is the median value of RSSI. In the measurement period, the highest tidal level was recorded on Aug. 11 (138 cm), and the lowest tidal level was recorded on Dec. 23 (-15 cm). On August 11, it was tempestuous due to a typhoon at dawn, and weather warnings about heavy rain, floods, and storms were given by the Japan Meteorological Agency (JMC). On December 23, it was snowing and windy. From these figures, it is clear that there is a relationship between RSSI and tidal level. It is also obvious that the fluctuations of RSSI and the existence of null point differ depending on the installation height of antennas. Specifically, there are null points when the tidal level is about 10cm in Fig. 7 and 100cm in Fig. 8, and there are peaks of RSSI value when tidal level is about 100 cm (Fig. 7) and 30 cm (Fig. 8). In such an environment, it is difficult to maintain communication quality using a single antenna. Therefore, space diversity by using several antennas is a valid method to maintain stable communication (Naturally, this is a well-known measure for researchers).

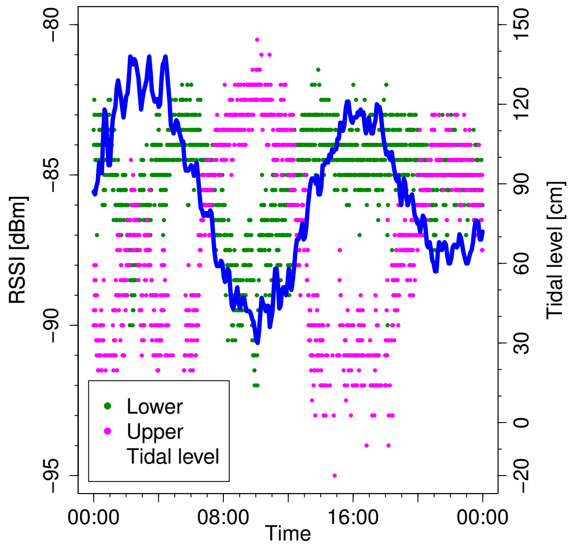

Fig. 5. Temporal changes of RSSI of both antennas and tidal levels (Aug.11, 2014).

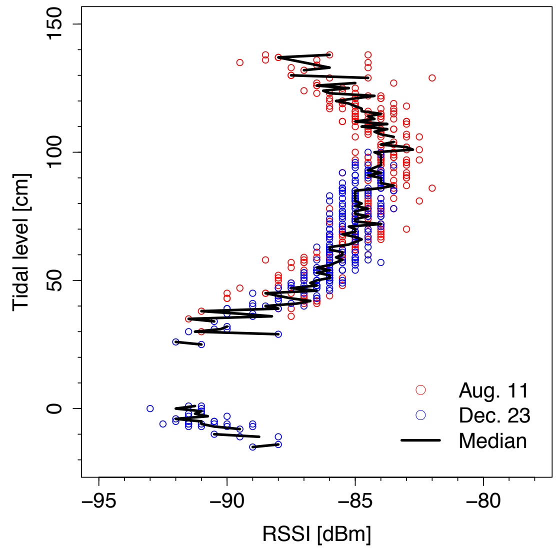

Fig. 7. The relationship between median of tidal level and RSSI of the lower antenna (antenna height is 17.55 m).

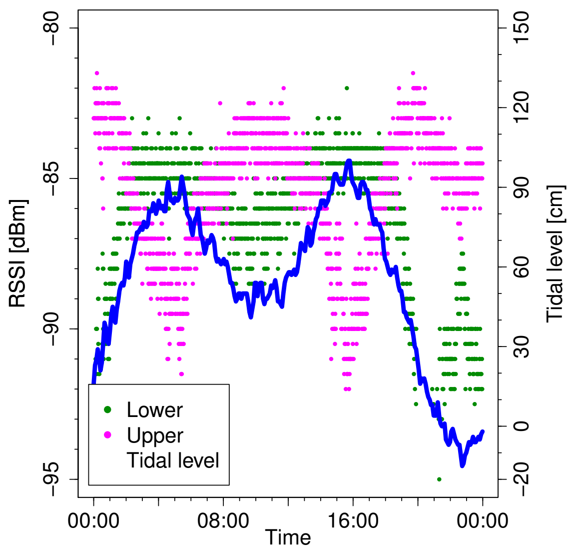

Fig. 6. Temporal changes of RSSI of both antennas and tidal levels (Dec. 23, 2014).

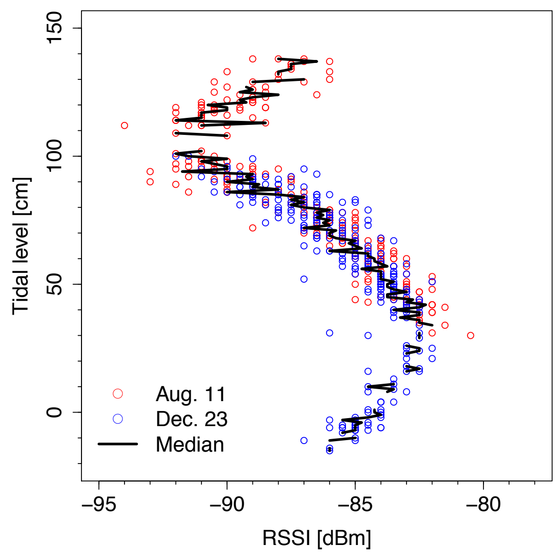

Fig. 8. The relationship between median of tidal level and RSSI of the upper antenna (antenna height is 18.30 m).

Figure 9 shows the colormap which illustrates the relationship between tidal level and RSSI of both antennas on Aug. 11 and Dec. 23, and Figure 10 shows the colormap during the measurement period. The colors represent the median values of tidal level corresponding to the RSSI of both antennas. There are dispersions in parts of the colormap, because there are few data that correspond to both the RSSI figures. Figure 11 shows the distribution of tidal level when the measured RSSI of the lower antenna is -85 dBm, and that of the upper antenna is -84 dBm From the figure it can be seen that almost all data is contained within the range from 50 cm to 100 cm. Therefore, we can roughly estimate the tidal level of Hakodate bay from the RSSI of antennas.

The estimation accuracy is high enough to detect anomalous tidal levels in Hakodate bay. For example, in the case of the Great East Japan Earthquake which occurred on March 11, 2011. The earthquake generated a huge tsunami, and the tsunami caused severe damage to the Tohoku area. The tsunami was also observed in Hakodate bay. The observed height was over 2m, and one person was killed by the tsunami. In many cases, a tsunami first causes abnormal backwash, and triggers a leading wave after that. Consequently, the tidal level fluctuates in a short period of time. We may detect abnormal tidal levels by monitoring the RSSIs of wireless access systems.

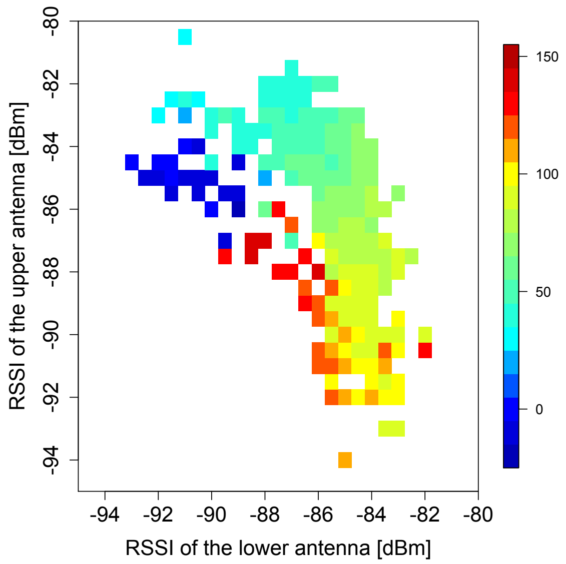

Fig. 9. The colormap which illustrates the relationship between tidal level and RSSI of both antennas on Aug. 11 and Dec.23.

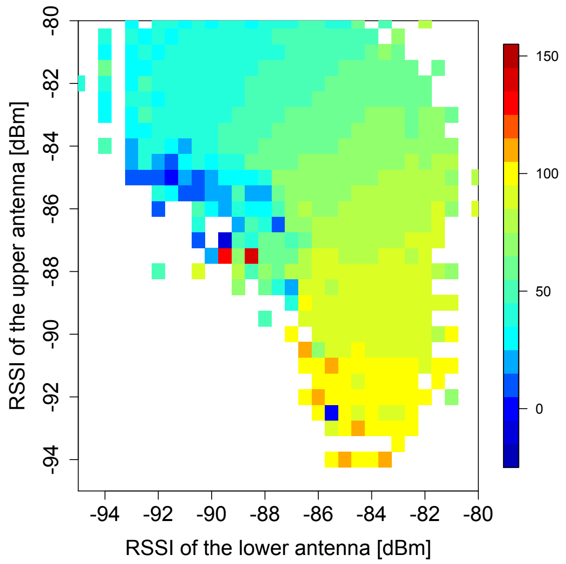

Fig. 10. The colormap which illustrates the relationship between tidal level and RSSI of both antennas during the measurement period (Jul.19 - Dec.31, 2014).

IV. Conclusion

In this paper, the authors described the possibility of the detection of anomalous tidal levels using the RSSI of the wireless access system. To consider the possibility, the authors constructed a 5 GHz band wireless access system using plural antennas. The result of long-term measurements shows, as is well known, that there is a relationship between the tidal level and the RSSIs of antennas. The authors think we can detect disasters, such as tsunamis, with wireless communication, by monitoring the RSSI of several antennas continuously.

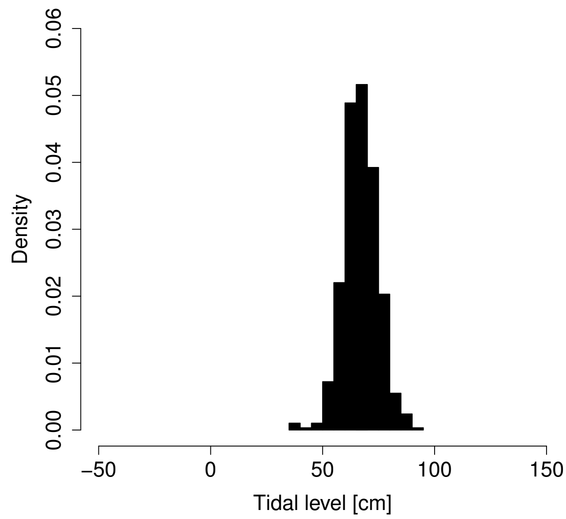

Fig. 11. Distribution of tidal level when RSSI of lower antenna = -85 dBm and RSSI of upper antenna = -84 dBm

In this analysis, the authors only considered the tidal level in Hakodate bay. However, RSSIs is affected by various factors, such as the temperature of the sea surface, and wave height, among others. In our future research, we will measure the conditions of the sea surface besides tidal level, and analyze the relationship between the conditions and RSSIs.

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