International Journal of Computer (IJC)

ISSN 2307-4523 (Print & Online)

http://ijcjournal.org/

Measurement of LoRa-based Received Signal Strength Indication (RSSI) Using Point-to-Point Topology in a Seaside Area

Jiratip Ratnikorn[a], Wasana Boonsong[b], Chinda Samakee[c], Tanakorn Inthasuth[d*]

[a,c,d]*Department of Electrical Engineering, Faculty of Engineering, Rajamagala University of Technology Srivijaya, Songkhla 90000, Thailand*

[b]*Department of Electrical Education, Faculty of Industrial Education and Technology, Rajamagala University of Technology Srivijaya, Songkhla 90000, Thailand*

[a]*Email: jiratip.mork.2012@gmail.com*

[b]*Email: wasana.b@rmutsv.ac.th*

[c]*Email: chinda.s@rmutsv.ac.th*

[d]*Email: tanakorn.i@rmutsv.ac.th*

Abstract

A data monitoring system's performance analysis is fundamental to proving quality and networking efficiency. This paper presents the received signal strength indication (RSSI) measurements of wireless communication with point-to-point LoRa technology for use in the 433 MHz frequency band. The test was performed in the area of Chalathat beach, Songkhla province, Thailand, which has a barrier environment of trees along the shore and is opposite the Rajamangala University of Technology Srivijaya (RUTS). This demonstration was conducted in the actual location to observe the loss from coastal environment conditions from waves and sea breeze. In addition, the study aimed to determine the effect of signal performance by RSSI measurements. The test consisted of a transmitter (Tx) and a receiver (Rx) with a transmit power of 17 dBm and an antenna gain of 3 dBi on both Tx and Rx. The testing starts with RSSI measurements from a distance of 10 meters and increases the number of measures by 10 meters until data loss begins. The test results showed that communication distances could be connected up to 500 meters without packet loss, with RSSI as low as -107 dBm, and a correlation graph in the form of a logarithmic function with a reduced tendency. However, the RSSI value decreases as the distance increases. At the same time, the test results can indicate its effectiveness as a guide for further application of monitoring systems at the beach area.

Keywords: Signal effect; point-to-point communication; RSSI; LoRa.

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* Corresponding author.

1. Introduction

Long Range (LoRa) Wide Area Network (WAN) is one of the leading Low Power Wide Area Network (LPWAN) solutions that work in an unlicensed band. LPWAN is a group of wireless technology that is developed to meet the requirements for wide-range, low power, and low-cost connectivity [1]. The typical applications are small data.volumes transmitted over long distances with infrequent data transfer from varying environments [2]. LoRaWAN has an advantage in technology's long-range capability. It has a substantial link budget and processing gain and enables decoding signal powers below the noise floor, making it invulnerable to multipath padding, Doppler Shift, and narrowband interference [3]. A single gateway of LoRaWAN can cover entire cities; thus, with minimal infrastructure, entire broad towns or areas can be included [4].

Many applications use LoRa technology in cities, farms, or other places with different limitations. Therefore, most of the research on and simulated LoRa communication networks is in the simulation stage. However, in actual application, LoRa's extreme communication distance is measured, and the space is updated. In addition, these experiments find and explore environments with minimal interference from the altitude and location of two communicating devices. Therefore, although LoRa network projects and technologies with actual implementations are presented, they do not provide details about the existing environment. Instead, these studies suggested the real climate of LoRa's RSSI [5, 6].

Songkhla province in the south of Thailand is the center of economic prosperity, tourism, and sports. The strength of Songkhla province, the primary source of essential resources, is Chalatat beach, which receives tourists all year round. However, while the problem of coastal erosion has occurred every year [7], by solving the problem, sand was added to carry out repairs in the beach area to slow coastal erosion [8]. Unfortunately, no data is collected from problems from monsoons, wind speeds, or erosion rates in real-time to collect statistical information for troubleshooting purposes, and there is no monitoring station to do this detailed report.

In developing coastal monitoring systems, foreign research papers have already been studied using various wireless communication technologies, including SigFox, LoRa, NB-IoT, and LTE, which are supported via the Internet of Things platform. (IoT) [9, 10]. Radio transmission with the technology mentioned earlier has a long communication distance and low power consumption [11]. In wireless communication systems, the signal performance must assess by measuring the received signal strength indicator (RSSI) [12]. In this paper, the LoRa wireless communication system, which the authors have previously tested, has a maximum transmission distance of about 500 meters between buildings, with some obstacles such as trees and structures [13].

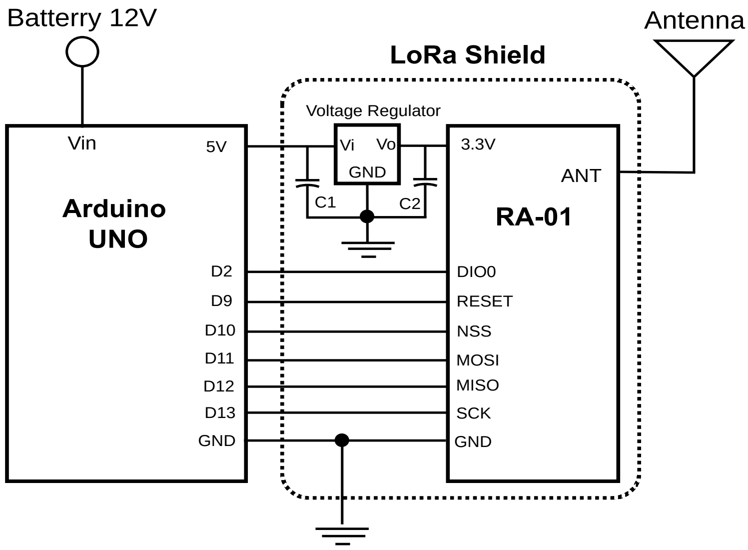
However, previous research has not found reports of coastal RSSI measurements. Therefore, this paper presents a test of RSSI of a wireless system with a point-to-point topology of LoRa technology, which has the same testing methods and communication devices in the research [14] to estimate the distance that can communicate the furthest. First, the authors compared the measurement results between the relation of the Friis transmission formula as a guideline for estimating the distance to the RSSI. Next, the RSSI measurements were carried out on the beach to study the effect. There are obstacles to pine trees along the coast.

2. The communication system of the LoRa network

This section describes a system's design for transmitting data through radio waves through the LoRa network. The test system is divided into two parts: hardware and firmware. More information is detailed in the following sections.

2.1. Hardware

This section is to present the block diagram of LoRa's hardware components. It can be set as a transmitter or receiver. Therefore, the LoRa module hardware is designed inside the receiver, and the transmitter has the same components, such as a microcontroller board for data processing, Arduino, RA-01 module, 3 dBi antenna, and 12 volts battery. The circuit connection and hardware are shown in Figure 1.



(a) Schematic

(b) Hardware

Figure 1: LoRa transceiver base on 433 MHz frequency band

Wireless communication with LoRa, for this research, the RA-01 module was used by the manufacturer from Anxinke Technology with integrated circuit SX1268 by connecting Arduino and RA-01 to communicate in SPI format [15]. Therefore, the authors built a LoRa circuit board for easy connection.

2.2. Firmware

In the section firmware part, the firmware in Figure 2 was programmed into the hardware mainboard for both functions to be transmitter and receiver [16]. After that, the planning test was performed to test the packet transmission, including reading RSSI values by the transmitter and receiver firmware, as shown in Figures 2(a) and 2(b), respectively.

```
#include <SPI.h>
#include <LoRa.h>

// LoRa connect config
#define NSS_PIN    10
#define NRESET_PIN 9
#define DIO0_PIN   2

String text = "Hello LoRa";

void setup() {
  Serial.begin(9600);
  while (!Serial);

  Serial.println("LoRa - TX");

  LoRa.setPins(NSS_PIN, NRESET_PIN, DIO0_PIN);
  if (!LoRa.begin(433E6)) {
    Serial.println("Starting LoRa failed!");
    while(1);
  }
}

void loop() {
  LoRa.beginPacket();
  LoRa.print(text);
  LoRa.endPacket();
  Serial.print("Send '");
  Serial.print(text);
  Serial.println("'");
delay(1000);
}
```

(a) Transmitter firmware

```
#include <SPI.h>
#include <LoRa.h>

// LoRa connect config
#define NSS_PIN    10
#define NRESET_PIN 9
#define DIO0_PIN   2

void setup() {
  Serial.begin(9600);
  while (!Serial);

  Serial.println("LoRa - RX");

  LoRa.setPins(NSS_PIN, NRESET_PIN, DIO0_PIN);
  if (!LoRa.begin(433E6)) {
    Serial.println("Starting LoRa failed!");
    while(1);
  }
  LoRa.setTimeout(100);
}

void loop() {
  if (LoRa.parsePacket() > 0) {
    String text = LoRa.readString();
    Serial.print("Receiver '");
    Serial.print(text);
    Serial.print("' RSSI is ");
    Serial.println(LoRa.packetRssi());
  }
  delay(1);
}
```

(b) Receiver firmware

Figure 2: Firmware of testing system

Figures 2(a) and 2(b) firmware of the transmitter and receiver, which have the same default operation, with the Serial and LoRa connection settings, which are inside the “Setup” function. In the transmitter (Tx), when operating into the "Loop" function, the Arduino starts sending the packet sending every 1,000 milliseconds that the variable has been declared (text = “Hello LoRa”) to the receiver (Rx). While in the Rx, using the LoRa.parsePacket() function reads the packets of data transmitted by Tx and performs the LoRa.packetRssi() function for reading RSSI to get of communication efficiency status.

3. LoRa RSSI measurement test at the coast environment

An experiment of Tx transmits the packet to Rx in a straight line at Chalatat beach. The testing aimed to study the signaling effect between different distances on the received power of the Rx. The measurement result compares with the Friis transmission formula of free space loss for guidelines.

3.1. Configure test system parameters

This testbed of RSSI measurements uses point-to-point communication. It consists of a Tx and an Rx. It uses Arduino IDE software in the serial monitor function to collect the RSSI data from the Arduino microcontroller board via USB cable. The test system shows the components as shown in Figure 3.

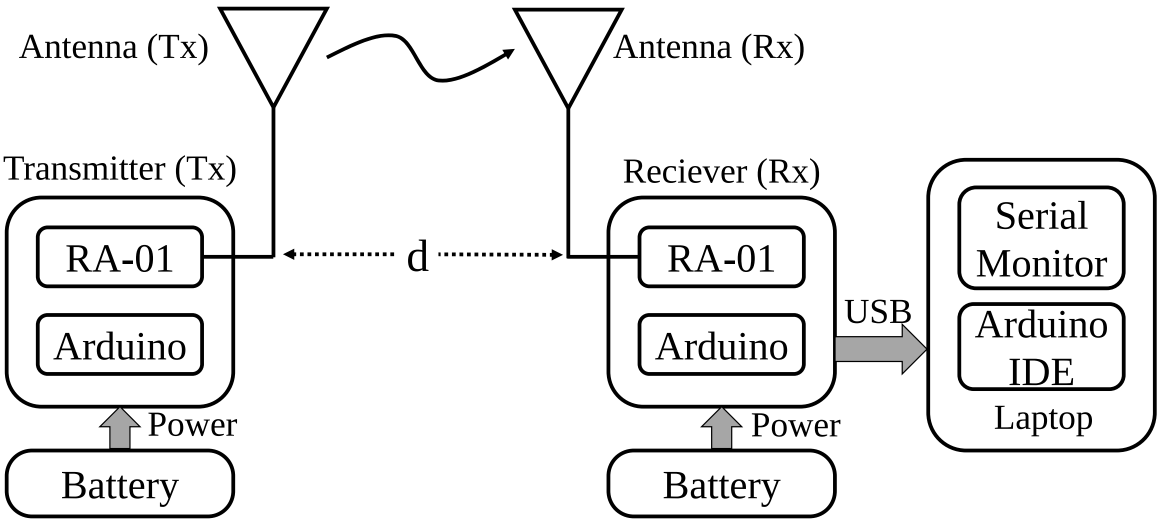


Figure 3: Configuration of a testing system

The RSSI guideline used the Friis transmission equation shown in equation (1) [17] with the testing parameters in the representation shown in Table 1.

$$RSSI\ [dBm] = P_t + G_t + G_r + 20log\left(\frac{c/f}{4\pi d}\right) \quad (1)$$

Table 1: Parameters of RSSI measurements

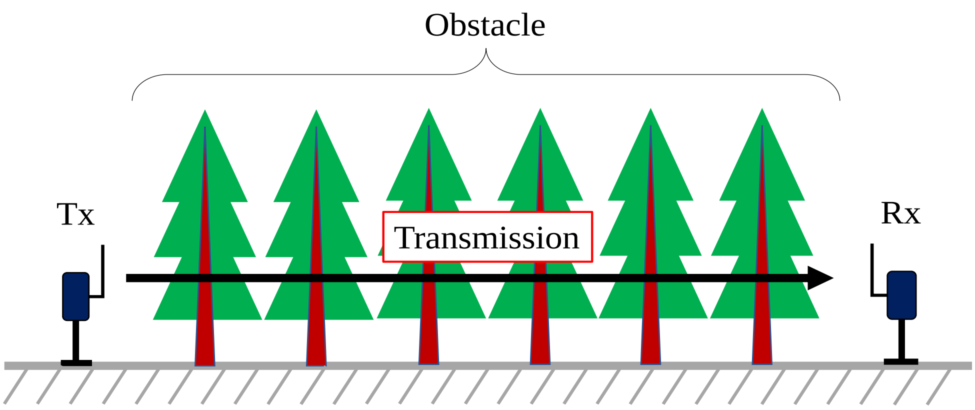
Testing Parameters	**Symbol**	**Testing values**
Power transmitter	P_t	17 dBm
Antenna gain	G_t, G_r	3 dBi
Frequency	f	433 MHz
Speed of light	c	$3x10^8$
distance	d	10,20,30, … and, 500 m

3.2. Transmission limitation in the beach area

The effect of RSSI studies the experimental by the Tx and the Rx signals around Chalatat beach in opposite to the Rajamangala University of Technology Srivijaya, Songkhla province, Thailand. This test area has pine trees along the coast, showing the test environment as shown in Figure 4.

(a) The Google map

(b) The photograph



(c) Packet transmission between Tx and Rx in a beach area

Figure 4: RSSI measurement test area

Figure 4 shows the RSSI measurement test in the area of the Chalatat coastal environment. The Tx transmits the packet to Rx in a straight line on the beach, transmitted via the tree obstacle area. This experiment aims to study the signaling effect between different distances on the received power of the Rx.

4. Results and discussions

RSSI measurements of LoRa using 433 MHz radio frequency in Chalathat beach area with pine trees along the test line throughout the experiment. The measured RSSI value is graphed along with the estimated logarithmic function by recording data at a distance of 10 meters until the measurement result has no connection of 500 meters. The raw data of measurement results are shown in Table 2, which shows the RSSI measurement results at the beach area with a distance between Tx and Rx at d = 10, 20, 30, …, and 500 meters. Each test point was measured five times, then calculate the mean. The results showed that the RSSI value ranged from -52 dBm to -107 dBm. The authors divided the signal level into six levels, from level 0 to level 5. The RSSI statistical data can be summarized as shown in Table 3.

Table 2: Raw data of RSSI measurement in the Chalatat beach area

Distance	**RSSI [dBm]**						**Distance**	**RSSI [dBm]**					
(d)	**1**	**2**	**3**	**4**	**5**	**Average**	**(d)**	**1**	**2**	**3**	**4**	**5**	**Average**
10	-53	-52	-52	-54	-54	-53.0	260	-99	-99	-100	-100	-99	-99.4
20	-58	-57	-57	-56	-57	-57.0	270	-101	-102	-104	-101	-101	-101.8
30	-61	-61	-61	-60	-60	-60.6	280	-98	-98	-98	-100	-100	-98.8
40	-67	-68	-66	-66	-67	-68.8	290	-100	-101	-101	-101	-101	-100.8
50	-69	-67	-68	-69	-72	-69.0	300	-100	-101	-100	-102	-100	-100.6
60	-73	-75	-78	-75	-74	-75.0	310	-103	-103	-100	-102	-100	-100.6
70	-76	-75	-74	-75	-77	-75.4	320	-98	-97	-98	-99	-98	-98.0
80	-75	-76	-76	-76	-77	-76.0	330	-97	-98	-97	-97	-97	-97.2
90	-75	-75	-75	-75	-75	-75.0	340	-98	-99	-100	-101	-98	-99.2
100	-81	-82	-82	-82	-81	-81.6	350	-104	-103	-104	-104	-104	-104.0
110	-85	-85	-86	-84	-85	-85.0	360	-105	-106	-105	-106	-106	-105.6
120	-82	-83	-83	-81	-82	-82.2	370	-101	-101	-100	-101	-101	-100.8
130	-80	-80	-80	-79	-80	-79.8	380	-103	-101	-103	-102	-103	-102.4
140	-88	-89	-90	-91	-88	-89.2	390	-105	-106	-107	-106	-106	-106.0
150	-85	-85	-82	-86	-85	-84.6	400	-102	-102	-102	-104	-102	-102.4
160	-91	-88	-91	-90	-91	-90.2	410	-104	-104	-103	-103	-104	-103.6
170	-94	-90	-91	-93	-90	-91.6	420	-105	-106	-105	-102	-104	-104.4
180	-90	-91	-91	-90	-90	-90.4	430	-	-	-	-	-	-104.6

								106	106	104	100	107	
190	-95	-96	-94	-94	-95	-94.8	440	-107	-106	-103	-106	-105	-105.4
200	-101	-95	-95	-95	-94	-96	450	-101	-100	-101	-101	-101	-101.0
210	-96	-97	-96	-96	-96	-96.2	460	-101	-100	-101	-102	-102	-101.2
220	-92	-94	-93	-92	-92	-92.6	470	-107	-106	-106	-105	-102	-106.0
230	-92	-92	-94	-93	-93	-92.8	480	-103	-106	-106	-106	-103	-104.8
240	-92	-92	-92	-92	-92	-92	490	-105	-105	-105	-104	-105	-104.8
250	-92	-94	-93	-93	-94	-93.2	500	-102	-102	-102	-101	-102	-101.8

Table 3: RSSI statistical data in each level

RSSI level	**RSSI range [dBm]**	**Distance in RSSI at each level**	**Statistical data of RSSI [dBm]**						
			Mean	**Mode**	**Standard deviation**	**Variance**	**Range**	**Maximum**	**Minimum**
5	[-50, -60]	10 – 20	-55.83	-57	2.82	7.97	8	-52	-60
4	[-61, -70]	30 – 50	-65.83	-61	3.07	9.42	8	-61	-69
3	[-71, -80]	50 – 130	-76.08	-75	1.53	4.87	8	-72	-80
2	[-81, -90]	100 – 160	-85.48	-90	3.29	10.79	9	-81	-90
1	[-91, -100]	140 – 340	-95.75	-100	3.17	10.06	9	-91	-100
0	[-101, -110]	200 – 500	-103.41	-101	1.97	3.87	6	-101	-107

As a result of measurements, RSSI of levels 5 and 4 are the narrowest in the range of distance data. Nevertheless, at levels 3, 2, 1, and 0, the range of data began to widen accordingly. It results from the relationship of reductions by the logarithm function similar to the Friis function. The measurement result RSSI summarizes the relationship between distance and RSSI axis based on the RSSI measurement data and regressive estimation according to equation (2) with the R-Square (R^2) of 0.96 and plotted the Friis formula, as shown in Figure 5.

$$RSSI\ [dBm] = -12.4 - 15.1\ \ln(d) \tag{2}$$

The primary focus of this research is on beach-based RSSI measurements to guide the future deployment of wireless communications equipment. However, in a previous study, the RSSI was only tested indoors or outdoors with other types of obstacles, but on the beach, in most cases, trees were the specific obstacle of the test area. Therefore, in this article, the relationship between distance and RSSI values. RSSI data was measured at all test points, comparing the Friis transmission function formula guidelines. Although this formula is free space loss, the trend in the experimental results showed a similar trend, but due to the obstacles in the test site environment. As a result, the measuring data is less than -40 dBm over all distances. In addition, the measurement results in this article are compared with the previous works for outdoor comparisons.

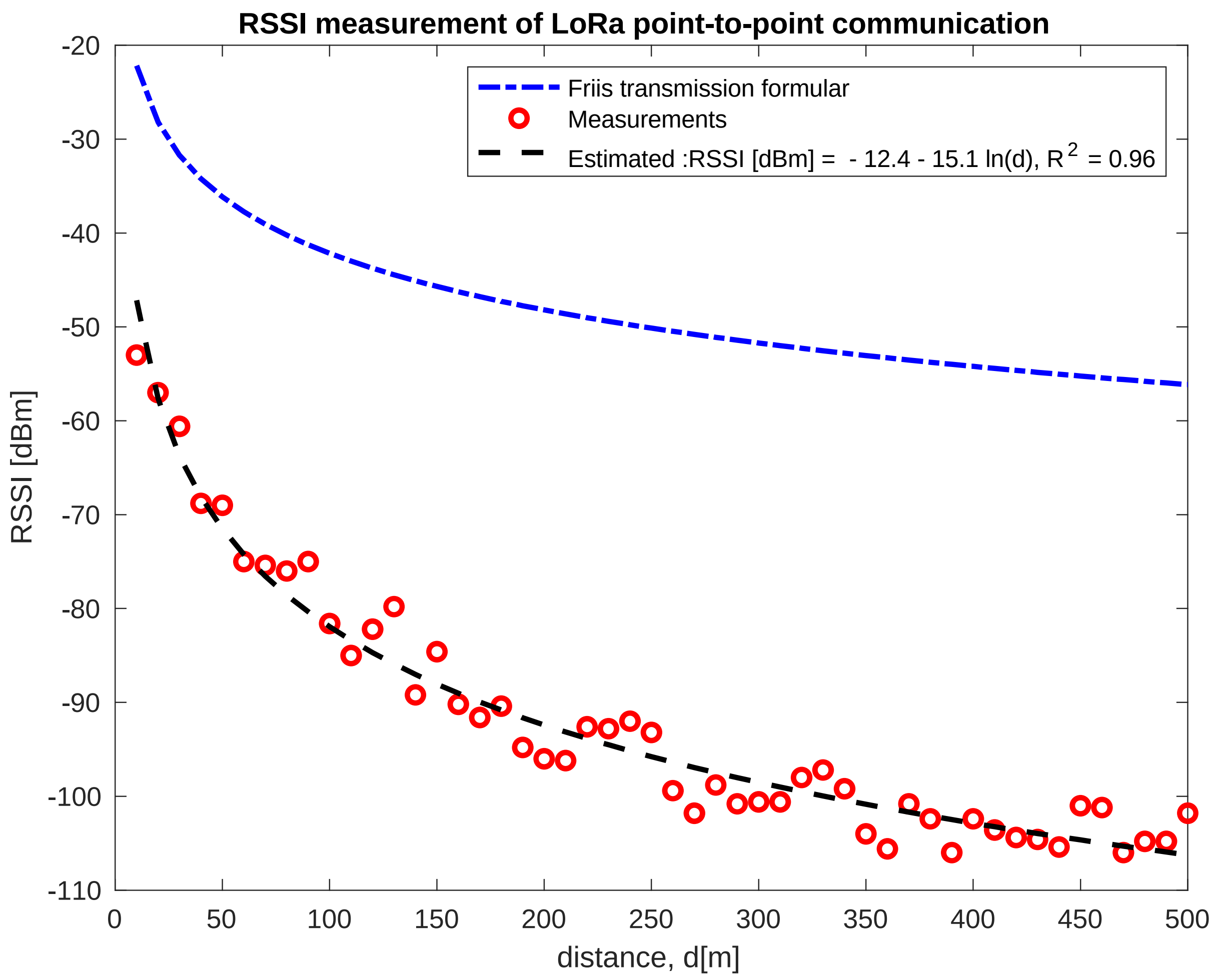


Figure 5: Comparison of RSSI values between the Friis transmission formula and measurement results

For example, in [13], the results showed the sensitivity was similar to that during the previous study, with the farthest being about 570 m in line of sight (LOS) environmental conditions. Still, in the tests of this study, it was communicated up to 500 meters, which is a slight difference, which is a little different. In [17], the RSSI was higher than 9.2 dBm due to also LOS environment. Moreover, in [18], the RA-01 module was also used, but the antenna gains of 2.5 dBi were lower and had a denser forested environment. with a lower average RSSI of about 4.8 dBm. Overall, as discussed in the comparison of outdoor communications between this article and previous research, it was found that the main variables were transmitting power, antenna gain, and environmental conditions. The results, as expected, are helpful for the further development of the system, which is more parameters studied on loss factors and other fading.

5. Conclusion

This article selected a radio transmitter and receiver with LoRa technology based on the RA-01 module, a cheap, low-power radio transceiver. Along with supporting the connection of the Arduino board for processing to extract the RSSI value. By testing the RSSI measurement test results in the beach area obstructed by pine trees along the beach, which is expected to have a limited impact on data transmission. However, the test results showed that the RSSI value was close to the previous research, despite the different environments [13, 17, 18]. Therefore, this experiment found that it can still use the case of installing a LoRa wireless communication device with the RA-01 module. Furthermore, it performs well compared to the previous research in different environments.

Acknowledgments

The authors would like to thank the student team of the Telecommunication Engineering Program at the Rajamangala University of Technology Srivijaya for testing and data collecting.

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