Design of Long-Distance Shrimp Pond Monitoring Using 2.4 GHz IoT Digital Radio Line-of-Sight Transmission

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Abstract

Water quality plays a vital role in shrimp farming, as suboptimal conditions can increase stress levels and disease susceptibility, potentially resulting in mass mortality. Real-time water quality monitoring enabled by Internet of Things (IoT) technology presents a promising solution to this issue. However, implementing IoT systems in shrimp ponds, typically situated in open, low-vegetation, and aquatic environments, poses technical challenges, particularly in maintaining line-of-sight (LOS) conditions between sensor nodes and gateway nodes. This study utilizes a linear path profiling method to evaluate LOS feasibility. A straight-line path is drawn between the transmitter and receiver to determine the minimum required antenna height for unobstructed signal propagation. For a 2.4 GHz WiFi-based transmission over a 1.27 km distance, ensuring 30% Fresnel zone clearance requires the sensor antenna to be elevated 1.5 meters above the water surface, while the gateway antenna must be positioned at a minimum height of 6.5 meters above ground level, assuming a ground elevation of 1.5 meters above mean sea level (AMSL). To achieve a minimum Received Signal Level (RSL) of -80 dBm, simulation results indicate that the system needs a transmit power of at least 12 dBm when using a gateway antenna with 8 dBi gain, or 8 dBm if the gateway antenna has 20 dBi gain, assuming the transmitter antenna gain is 2 dBi. The study also presents a simulation-based relationship between RSL and transmit power across different receiver antenna gains (2 dBi, 8 dBi, and 20 dBi), providing insights for optimizing IoT-based monitoring systems in aquaculture environments.

Keywords: *Water Quality, IoT, Line of Sight, Received Signal Level, Antenna Gain*

I. INTRODUCTION

Internet of Things is a technology that can transform conventional systems into modern systems with the ability to monitor in real time. In its application, sensor modules are equipped with communication capabilities and connected to internet where data exchange occurs. This capability makes it possible to carry out monitoring and for remote data collection. Some examples of the use of IoT in remote monitoring are in land monitoring and early detection of plant problems using drones, weather monitoring and climate prediction in decision-making on harvest scheduling and plant treatment, and controlling irrigation systems to increase the efficiency of water use and reduce agricultural operational costs. [1]

In water quality monitoring, IoT can monitor water quality parameters such as pH, water turbidity, dissolved oxygen (DO) levels and water temperature. The IoT system can provide notification to shrimp pond managers if there is a change in water quality of the shrimp pond [2]. Shrimp cultivation is an aquaculture business typically conducted in brackish water. Maintaining good water quality is important for the growth and health of shrimp, as poor water conditions can lead to stress, hinder growth, and increase the risk of disease. Shrimp need sufficient oxygen levels in the water for respiration. If oxygen levels are low, shrimp can experience stress, which increases susceptibility to disease and reduces growth. The salinity level of the water must be appropriate for the type of shrimp being cultivated, especially in ponds that use brackish water or seawater. Sudden changes in salinity can affect the osmotic balance of shrimp and cause stress. The ideal pH balance for shrimp cultivation ranges from 7.6 - 8.1; a pH that is too acidic or alkaline can disrupt shrimp metabolism and cause health problems [3]. Shrimp require a stable water temperature to support their metabolic processes. Temperatures that are too high or too low can slow growth and reduce the survival rate of shrimp. Waste from food waste and shrimp metabolism produces ammonia, which, if not managed properly, can be toxic to shrimp. Excessively cloudy water can hinder the photosynthesis of microalgae, which serve as a natural source of oxygen in the pond [4].

An IoT system can be developed using low-cost devices like Arduino and Raspberry Pi, which act as the processing units for managing and monitoring shrimp ponds. The sensors are connected to the processing device via wireless communication channels or a wired connection. Data from various water quality sensors, including pH, dissolved oxygen, temperature, salinity, ammonia, and turbidity, can be gathered and sent in real-time to a data collection center linked to the internet. The application of this technology can create an affordable, locally operated monitoring. [5]

The transmit power of the communication module of IoT sensors is an important parameter in ensuring stable connections and efficient use of battery power [6]. Communication modules with high transmit power allow sensors to communicate reliably over longer distances or in environments with many obstacles, such as walls or vegetation. However, while high transmit power enhances connection stability, it can also lead to increased battery sensor power consumption, reducing the device's lifespan. Meanwhile, modules with low transmit power are more power efficient, allowing sensors to operate for a longer time, but are potentially subject to connection problems in adverse environmental conditions. The Communication technologies used in IoT are shown in Table 1. [7] [8]

Tabel 1. Teknologi Komunikasi IoT

Module	Transmit Power (watts)	Effective Transmit Distance
BLE	0.01–0.5	10–100 m
Wi-Fi	0.1–1	≤100 m (low obstacles)
LoRa	0.01–0.1	≤10 km (low obstacles) 1–3 km (medium obstacles)
Sigfox	0.1	≤10 km (low obstacles)
Nb-IoT	0.2	≤10 km

IoT sensor modules integrate a microcontroller, Wi-Fi interface, and GPIO (General Purpose Input Output) into a single chip. The price of IoT modules featuring 2.4 GHz Wi-Fi communication, like ESP8266 and ESP32, is relatively lower compared to other IoT modules that utilize communication technologies such as Zigbee, LoRa, or NB-IoT. [9]

This study investigates the radio transmission system between the sensor module and the gateway operating at a frequency of 2.4 GHz. The analysis includes the transmit power of the sensor communication module, the characteristics of the radio transmission channel between the sensor and gateway nodes, and analysis of antenna installation height and antenna gain at the gateway.

II. METHODS

The communication architecture of the IoT system includes several key components: IoT sensor devices, wireless network technology, IoT servers, and IoT platforms, as shown in Figure 1. In the shrimp pond water quality monitoring application, the IoT sensor module and antenna are placed on the water surface, with some parts of the sensor entering the water. Each sensor is connected to a Wi-Fi network tower, which serves as a communication gateway. These devices collect data from the physical environment and transmit it via a Wi-Fi network to the IoT server on the internet, which serves as a central hub for receiving and processing initial data. Furthermore, the IoT server plays a role in managing and storing data sent by the sensor devices. This data is then forwarded to the IoT platform, which is an application-based infrastructure layer. At this stage, the IoT platform processes the data further or forwards it to the application server for integration into the end-user application.

This architecture shows the interconnection between IoT elements, with data communication flows starting

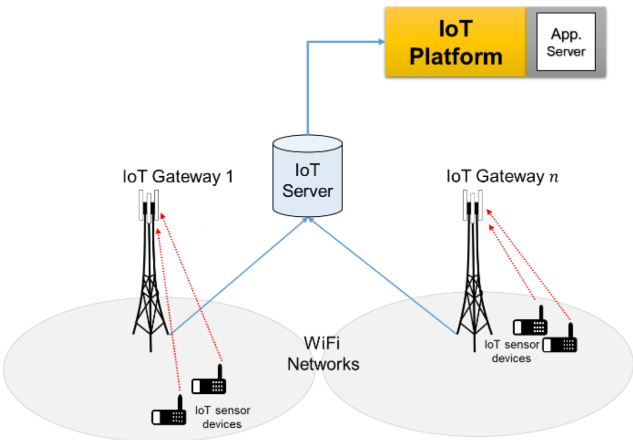


Figure 1. IoT Communciation Architecture

from sensor devices, communication networks, processing servers, to application systems that can be accessed for monitoring, or data-based decision making. The red line in Figure 1 shows the communication path of the sensor device via a wireless channel using a working frequency of 2.4 GHz (Wi-Fi), while the blue line represents the data transfer from the IoT server to the IoT platform which can be done via wired connectivity. The transmit power of the sensor module in the IoT system for water quality monitoring tends to be set low, because some sensor systems are designed to be energy efficient and work at low communication distances. The amount of transmit power is determined by two main factors, namely the communication technology used by the sensor and the power requirements of the sensor itself.

A. Propagation Environment

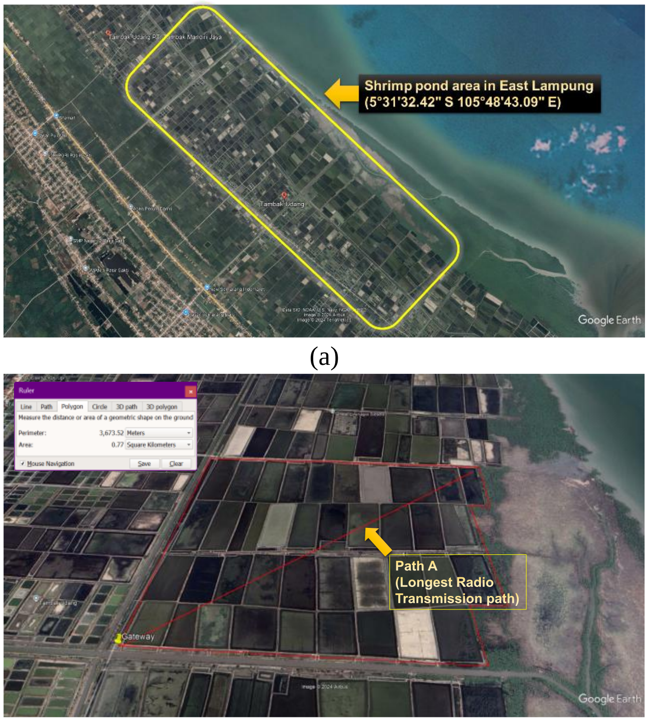
In this study, the radio propagation environment is assumed representing physical obstacles of the shrimp pond area in East Lampung Regency, as illustrated in Figure 2(a). The ponds is vary in size depending on the scale of the aquaculture operation. Small-scale pond range from 500 to 1,000 square meters each, Medium-scale ponds range from 1,000 to 2,500 square meters each, and Large-scale pond cover areas between 3,000 and 5,000 square meters each. The ponds are formed in rectangular to simplify water management and harvesting activities.

The investigation in this works was conducted in a single block of shrimp pond comprising multiple ponds, as illustrated in Figure 2(b). This block cover an area of approximately 0.77 square kilometers with perimeter of 3,673.52 meters. A gateway node is used as a bridge to connect the IoT sensor nodes to the IoT server. This node utilizes a 2.4 GHz wireless connection for network access. The path profile for radio transmission was calculated by selecting one of the farthest sensor-to-gateway communication links. As shown in Figure 2(b), Path A (the longest link at 1.27 km) was analyzed to determine the elevation profile of the terrain along the transmission path. This analysis was used to estimate the minimum required transmit power for reliable signal propagation.

To satisfy Fresnel zone clearance criteria, the effective height of obstacles is adjusted by accounting for Earth's curvature effects using Equation 1, [10]

$$h = \frac{d_1 d_2}{12.75K} \tag{1}$$

Parameter h is the change in vertical distance or earth curvature (in meters), d_1 is the distance in km from one



(a)

(b)

Figure 2. (a). Shrimp pond area in East Lampung Indonesia, (b) Monitoring block.

end of the path to an obstacle, and d_2 is the distance from the other end of the path to the same obstacle.

The earth curvature factor (K-Factor) is a radio wave propagation calculation parameter to adjust the effect of the earth's curvature on the transmission path. Under normal atmospheric conditions, the K-Factor can be as high as 4/3, reflecting the effect of atmospheric refraction on radio waves. However, this value can vary depending on environmental conditions, such as temperature, humidity, and air pressure, which affect the refractive index of the atmosphere. The transmission system must ensure that obstacles have sufficient clearance so as not to cause significant transmission losses due to signal attenuation by an obstacle. The calculation of the required clearance refers to the theory of wave physics, namely the Huygens principle, and the theory developed by Fresnel. To avoid complications of diffraction and scattering in radio transmission paths, a clearance of at least 60% or at least 30% of the first Fresnel zone is required. Where is the radius of the first Fresnel zone or first Fresnel Zone Clearance (F_1) in meters can be calculated using equation 2. [10]

$$F_1 = 17.3 \sqrt{\frac{d_{1(\text{km})} d_{2(\text{km})}}{D_{(\text{km})} f_{(\text{GHz})}}} \tag{2}$$

Where $d_1$and d_2 are the distances from the obstacle in km. Total distance, $D = d_1 + d_2$ in kilometers. In Line of Sight (LOS) microwave transmission lines, the greater the clearance provided, the higher the antenna tower required.

B. Radio Transmission

Line of Sight digital radio transmission can minimize the occurrence of intermodulation noise accumulation, where noise is limited to signal regeneration points only. In IoT systems, bandwidth efficiency need to be considered accurately, especially if there are many sensor nodes operate simultaneously.

The ratio of Energy per bit to Noise Power Spectral Density Ratio (E_b/N_0),, is a performance evaluation parameter in a digital communication system. E_b is the energy received per bit of information sent. N_0 is the noise power density, which quantifies noise in terms of noise power per hertz, with units of W/Hz or dBm/Hz. The N_0 value also represents the thermal noise level which is the basic noise that affects the received signal. The thermal noise level on an ideal receiver with a bandwidth of 1 Hz (bandwidth N_0) can be expressed as in equation 3. [11]

$$N_0\ (\text{dBW}) = -204\ \text{dBW} + NF \qquad (3)$$

The value of -204 dBW or equivalent to -174 dBm is the noise temperature that represents the noise level at room temperature, , $T = 290$ K. For a bandwidth (B) of 1 Hz, the noise temperature (P) can be obtained by $P = kTB$, where k is the Boltzmann constant with a value of $1.38 \times 10^{-23}\,J/K$, and the ambient temperature (room temperature) T is 290 K. Thus, the noise temperature is $\approx 4 \times 10^{-21}$ W, or if expressed in dBW and dBm, $P_{dBW} = 10\log(P/1W) \approx$ *-204* dBW is equivalent to -173.98 dBm.

The parameter of E_b/N_0 measures how much energy is allocated to each bit compared to the noise level. The higher the E_b/N_0 ratio, the better the potential performance of the communication system, because the signal will be easier to distinguish from the noise. The energy per bit, E_b, can be expressed as RSL (Received Signal Level) divided by the bit rate or in decibels (dB), can be expressed as in equation 4.

$$E_b\ (\text{dBW}) = RSL\ (\text{dBW}) - 10\log(\text{bit rate}) \qquad (4)$$

Bit rate is a measure of the number of bits transmitted or processed in one second which represents the speed of data transfer in a communication system. The bit rate of wireless technologies that support IoT is shown in Table 2. The minimum bandwidth size required for data transmission over a radio channel is influenced by the bitrate level that must be achieved. In the context of IoT, bit rate is an important parameter because IoT devices have limitations in terms of power consumption and bandwidth. In IoT sensor nodes, antennas play a role in transmitting and receiving radio waves in wireless communication systems. Antenna gain affects the range and quality of communication. Antenna gain as the ratio of output power (P_{out}) to input power (P_{in}) on the antenna is expressed as $G_A = P_{\text{out}}/P_{\text{in}}$. In decibels (dB) or isotropic decibels (dBi), the antenna gain is obtained by $G_{A_{\text{dB}}} = 10\log_{10} P_{\text{out}}/P_{\text{in}}$. [12]

Omnidirectional antenna can be used for IoT nodes that require uniform gain in all horizontal directions. Directional antenna can be used for one-way IoT communication between nodes, which provide higher gain in a particular direction, increasing range and signal strength, although with a narrower coverage area. Low-power IoT sensor nodes have omnidirectional antenna gains between 2-5 dBi. Antennas working in specific frequency e.g., 2.4 GHz for WiFi or Zigbee, 900 MHz for LoRa, are shown in Table 3.

In deployment IoT sensor networks in remote areas, such as shrimp pond investigated in this study, using antennas with higher gain can increase communication range. For Arduino-based IoT sensor nodes that use omnidirectional antennas, antenna gain generally ranges from 2 to 5 dBi. Antenna gain affects the power consumption of IoT nodes, especially for IoT devices that use batteries or utilize energy from the environment. The use of antennas with high gain can reduce the required transmitter power, thereby saving

Table 2. IoT Communication technologies

Technology	Bit Rate
WiFi	- 802.11b: upto11 Mbps - 802.11g: upto 54 Mbps - 802.11n: upto 600 Mbps (MIMO) - 802.11ac: upto 1.3 Gbps (3x3 MIMO) - 802.11ax: upto 9.6 Gbps (optimal)
LoRa	0.3 kbps – 50 kbps
Sigfox	100 bps – 600 bps
NB-IoT	20 kbps – 250 kbps
Zigbee	20 kbps – 250 kbps
BLE	1 Mbps – 2 Mbps
5G	upto 10 Gbps in optimal condition

Table 3. Working frequency of IoT Radio

Technology	Working Frequency
WiFi	2.4 GHz, 5 GHz, 6 GHz
LoRa	433 MHz, 868 MHz, 915 MHz
Sigfox	862-876 MHz, 902-928 MHz
NB-IoT	700–2100 MHz
Zigbee	2.4 GHz, 868 MHz, 915 MHz
BLE	2.4 GHz
5G	Sub-6 GHz (600 MHz–6 GHz), mmWave (24–100 GHz)

energy in the longer term. The shrimp pond environment has special characteristics such as watery environmental conditions and the pond structures in the form of large ponds surrounded by low vegetation. The propagation model in the application of IoT systems that are suitable for the transmission environment of shrimp pond areas must consider the fairly long transmission distance and the possibility of obstacles from vegetation around the pond and reflections from the water surface. [13]

Propagation models that can be applied in shrimp pond environments include the free space path loss model, the two-ray ground reflection model, the log-distance path loss model, and the Okumura-Hata model. The Free Space Path Loss (FSPL) model is suitable for implementation in open areas without many obstacles. Because shrimp ponds are generally located in open areas, FSPL can provide a basic estimate of the level of signal attenuation between the transmitter and receiver. In the Two-Ray Ground Reflection model, signal reflection from the ground or water surface is taken into account. In shrimp pond environments where nodal sensor devices are installed at low altitudes, reflection from the water surface has the potential to strengthen or weaken the signal. The Log-Distance Path Loss propagation model involves calculating the reduction in signal power based on distance by adding propagation exponent parameters that represent environmental propagation factors. Shrimp pond environments that have obstacles such as trees around the pond or equipment placed around the pond area can increase the variability of signal loss. If the farm is located in a semi-rural area or near residential areas, the Okumura-Hata propagation model can be used to calculate the level of signal attenuation, especially at frequencies below 1 GHz, which is common for IoT technologies such as LoRa or Sigfox. The Okumura-Hata model takes into account more complex environmental factors, such as surface changes and trees, so it can be useful for shrimp farms located in propagation locations with many obstacles around the farm.

In this study, an analysis was conducted on the use of the Free Space Path Loss propagation model where the antenna on the sensor node is a transmitting antenna placed at a low height. The arrangement of the receiving antenna placement on the gateway node is carried out to achieve line of sight conditions at a certain level. The calculation of Free Space Loss (FSL) can be derived by calculating electromagnetic wave propagation in free space. By involving the distance parameters in km (D_{km}) and working frequency in MHz (F_{MHz}), FSL can be calculated using equation 5.

$$FSL = 32.45 + 20\log(D_{km}) + 20\log(F_{MHz}) \quad (5)$$

Received Signal Level (RSL) in dBW can be calculated with equation 6,

$$RSL_{dBW} = EIRP_{dBW} - FSL + G_r - L_{L_r} \quad (6)$$

The calculation of RSL involves the value of the effective isotropic radiated power (EIRP) or $EIRP_{dBW}$, the gain of the receiving antenna in dB (G_r) and the transmission line losses at the receiver (L_{L_r})) in dB.

III. RESULTS AND DISCUSSIONS

Shrimp farming is highly dependent on good water quality. Parameters such as oxygen levels, salinity, pH, temperature, ammonia, nitrate, and turbidity have a significant impact on shrimp growth and health. Poor water quality increases the risk of stress, slow growth, and disease in shrimp. The Internet of Things (IoT) system is an effective solution for real-time water quality monitoring, which allows data from various sensors to be collected and sent to a monitoring platform.

A. 2.4 GHz Radio Transmission System Design

The reliability of the IoT radio transmission system depends on the proper adjustment of the transmit power to prevent signal interference. To obtain an approximate value for the transmit power, the radio transmission channel must be modeled with an appropriate propagation model. In this study, the Free Space Path Loss propagation model was implemented, because the surface contour in the pond environment is relatively flat and has minimal trees (it can be assumed that there are no trees), and the pond is located in a remote area far from residential areas. In addition, the transmitter antenna on the sensor and the receiver antenna on the gateway are raised in such a way as to ensure that the line of sight conditions at a certain level can be met.

In radio wave propagation, signals not only propagate directly but can also experience phenomena such as reflection, refraction, diffraction, and scattering, depending on environmental conditions and obstacles in the propagation path. Radio wave diffraction occurs when waves encounter obstacles that are large compared to the wavelength of the signal. This phenomenon allows the signal to bend around obstacles, so that it can still be received by the receiving antenna even though the straight line path is blocked.

Determination of path profile using linear method can be done by including additional height on several obstacles along the radio wave transmission path. The additional height is the total sum of the possible height

Table 4. Total additional height to reach free altitude 0.3 F_1

Obstacle	d1 (km)	d2 (km)	0.3 Fresnel F_1	Earth curvature (m)	Vegetation height (m)	Total additional height (m)
1	0.296	0.974	1.60	0.02	0.2	1.82
2	0.46	0.81	1.81	0.03	0.2	2.05
3	0.763	0.507	1.85	0.03	0.2	2.08
4	0.857	0.413	1.77	0.03	0.2	2.00

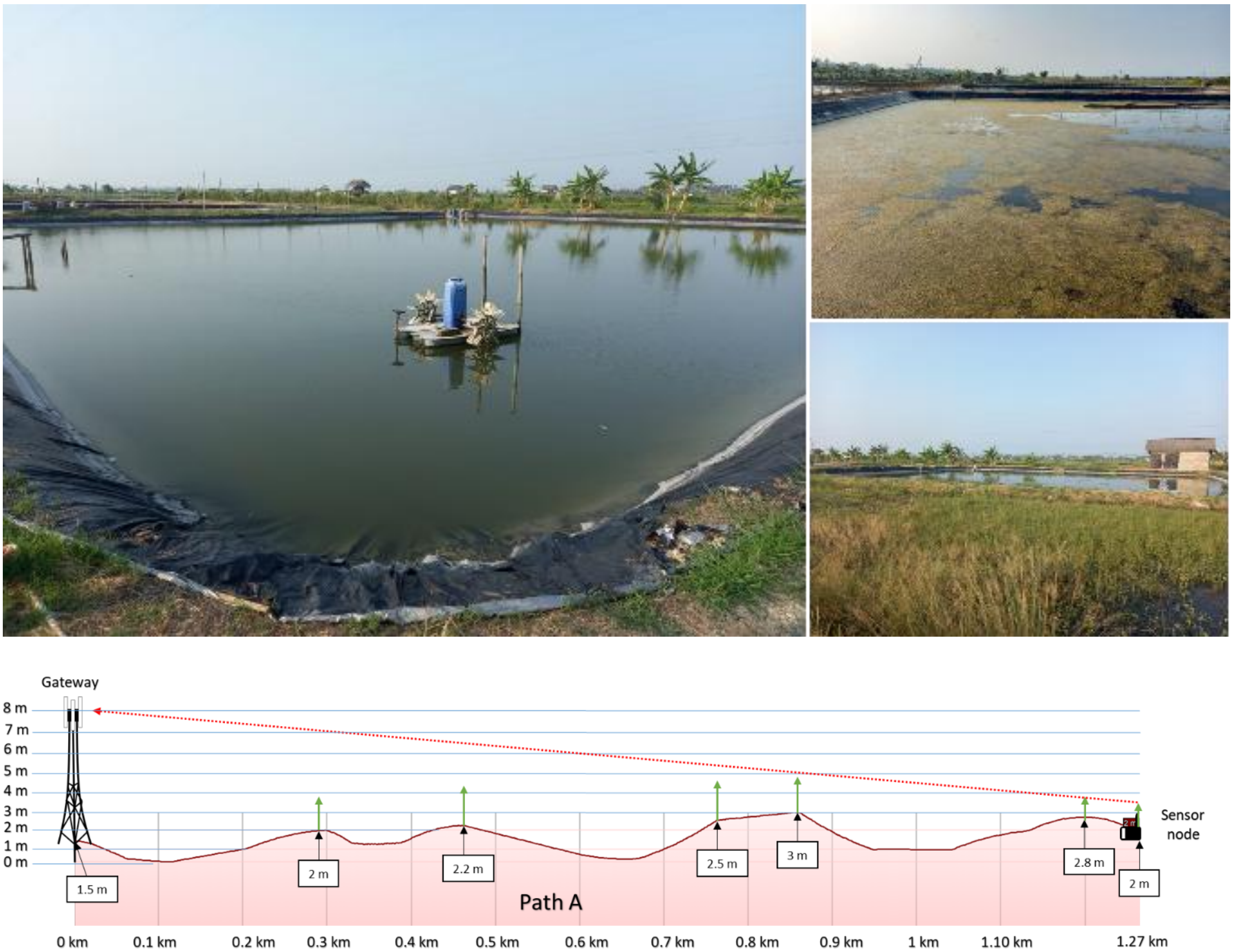


Figure 3. Radio propagation environment in shrimp pond area (top), and Antenna height setting (bottom)

of vegetation, earth curvature, and first Fresnel zone clearance as shown in table 4. Vegetation is assumed to have a maximum height of 20 cm. Earth curvature and first Fresnel zone clearance can be calculated respectively using the approach of equations 1 and 2. In this study, the standard value of 0.3 F_1 or 30% first Fresnel zone clearance was used. This value was chosen because the characteristics of the shrimp pond environment which is flat, has minimal obstacles, and is dominated by water surfaces do not require higher clearance such as 60% or 100%. A value of 0.3 F_1 can ensure an efficient system design while maintaining good signal propagation quality for IoT applications in the environment. To obtain 30% of the First Fresnel Zone Clearance, the sensor antenna is required to be placed at a height of 1.5 meters above the water surface. On the other hand, the gateway antenna must be placed at a minimum height of 6.5 meters above the ground surface, where the elevation of the ground surface where the gateway node is placed is 1.5 m above the average sea level, as shown in Figure 3.

In Table 4, the height and distance data of obstacles along the communication path (Path A) are presented, as shown in Figure 2(b). The working frequency of the radio transmission system used is 2.4 GHz which is part of the Industrial, Scientific, and Medical (ISM) frequency band which is free of license in many countries, including Indonesia. The use of 2.4 GHz working frequency is also closely related to the availability of cheap and easily available IoT sensor modules in the community, such as Wi-Fi modules (ESP32, ESP8266).

Based on the Path profile generated with a K-factor of 0.92, as shown in Figure 3, the gateway node can be placed on the ground with an elevation of 1.5 meters with a minimum antenna height of 6.5 m, while the sensor node is placed on the water surface with an elevation of 2 meters. The red dashed line in the diagram shows the LOS (line of sight) path with an approach of $0.3F_1$. Green arrows indicate obstacles along the path with heights marked at each point, such as 2 m, 2.2 m, 2.5 m, 3 m, and 2.8 m. Each obstacle is marked along the horizontal distance with its height relative to the ground surface.

B. Bit Error Rate

The relationship between Bit Error Rate (BER) and the ratio of energy per bit to noise density (E_b/N_0) in digital communication with Binary Phase Shift Keying (BPSK) modulation can theoretically be obtained by the following Equation 7,

$$\mathrm{BER} = \mathrm{Q}\left(\sqrt{2E_b/N_0}\right) \quad (7)$$

BPSK is the simplest digital modulation technique where binary data 0 and 1 are represented by two signal phases that differ by 180°. In transmission conditions through Additive White Gaussian Noise (AWGN) channels, the bit error probability for BPSK can be calculated by the Q function as in equation 7. BPSK has good performance against noise because the distance between its symbols in the constellation diagram is maximum, which is 180°, thus minimizing the possibility of errors compared to several other digital modulation techniques with higher symbol orders.

The relationship graph between BER and E_b/N_0 based on equation 7 is shown in Figure 4. From the graph, it is obtained that BER is inversely proportional to the value of E_b/N_0. The greater the value of E_b/N_0, the smaller the probability of bit error (BER), which indicates that the quality of the received signal is better. Conversion of $E_b/N_0$from linear form to logarithmic scale or decibel (dB) can be done with $E_b/N_0(\mathrm{dB}) = 10\log_{10}(E_b/N_0)$. With the increasing ratio of E_b/N_0, the communication system will experience better performance since reduction in the probability of bit error.

In the design of the radio transmission channel, the Gain of the transmitter antenna (omnidirectional antenna at the sensor node) G_t is 2 dBi. The transmission channel losses on the transmitter side L_{L_t} and on the receiver side L_{L_r} are assumed to be the same, which is 1.5 dB. The modulation loss is assumed to be 2 dB. The FSL value based on equation 5 for a transmission distance of 1.27 km at a working frequency of 2.4 GHz is 102.13 dB. For a bit rate of 50 kbps with a BW bandwidth of 50 kHz with a target BER of 1×10^{-6} then based on the graph in Figure 4 the E_b/N_0 value is 10.5 dB.

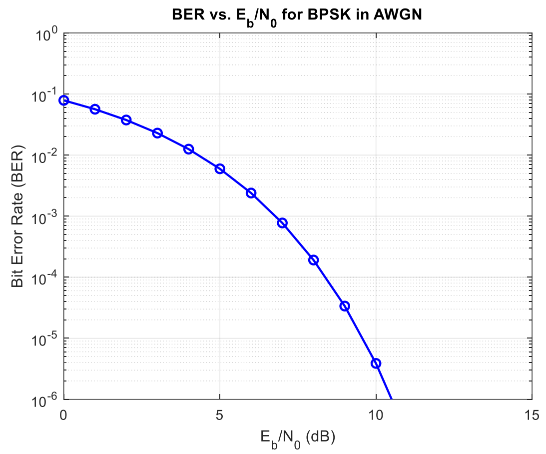
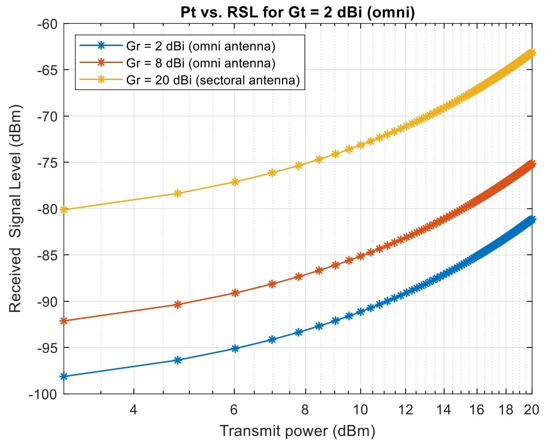


Figure 4. BER BPSK with AWGN (theory)



Gambar 5. RSL Profil with $f = 2.4$ GHz

The RSL profile obtained from the design of the radio transmission system between the sensor node and the gateway node in this study is shown as a comparison graph of RSL and transmit power for several types of receiver antenna gains for a working frequency of 2.4 GHz as shown in Figure 5. In this profile, the transmit antenna is an omnidirectional antenna with a gain of 2 dBi. The receive antenna has a gain (G_r) of 2 dBi (omni antenna), 8 dBi (omni antenna), and a gain of 20 dBi (sector antenna). The received signal level (RSL) increases with the increase in transmit power (P_t). Antennas with higher gain (G_r = 20 dBi) provide a stronger signal level than antennas with lower gain (G_r = 2 dBi or 8 dBi), even though the transmit power is the same.

Receiver modules in IoT systems have different sensitivities, which determine the minimum RSL limit required. The recommended RSL value is 10^{-15} dBm above the minimum receiver sensitivity limit. The minimum Received Signal Level limit in an IoT system depends on the type of communication technology used. In the use of Wi-Fi (IEEE 802.11), the minimum RSL limit is -80 dBm to -90 dBm. If the RSL is less than -90 dBm, it has the potential to cause interference to the communication system (unstable or interrupted transmission). Based on the graph in Figure 5, to achieve an RSL of -80 dBm, with an 8 dBi antenna, a transmission power of around 12 dBm is required. Using a 20 dBi antenna, the transmission power required is smaller, around 8 dBm. Using an antenna with high gain (20 dBi) can produce better RSL with lower transmission power. At shorter transmission distances, the FSL level decreases, increasing the RSL without the need to increase the transmission power. The use of lower frequencies (such as 2.4 GHz) has better penetration capability than 5 GHz, which can help maintain RSL. To achieve RSL -80 dBm, the use of an antenna on the receiving side is an omni antenna with a gain of 2 dBi (Omni) Requires a transmission power of about 20 dBm. The use of an omni antenna with a gain of 8 dBi and a sector antenna with a gain of 20 dBi, respectively, required a transmit power of about 12 dBm and 8 dBm.

IV. CONCLUSIONS

The IoT based real-time water quality monitoring using radio transmission to connect sensor nodes and gateway nodes. Using Free Space Path Loss model, for shrimp ponds propagation environment with distance of 1.27 km at a frequency of 2.4 GHz, a 30% clearance condition is required in the first Fresnel zone. To meet this requirement, the sensor antenna needs to be mounted at 1.5 meters height above the water surface, and the gateway antenna must be installed at a height of 6.5 meters above ground level, with a gateway ground surface elevation of 1.5 meters AMSL. To achieve a minimum RSL of -80 dB on a WiFi system with a working frequency of 2.4 GHz, a minimum transmit power of 12 dBm and 8 dBm is required for a gateway antenna gain of 8 dBi and 20 dBi respectively, assuming transmitter antenna gain is 2 dBi.

V. ACKNOWLEDGMENT

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