Journal of Advanced Marine Engineering and Technology, Vol. 47, No. 6, pp. 385~392, 2023
J. Advanced Marine Engineering and Technology (JAMET)
https://doi.org/10.5916/jamet.2023.47.6.385

ISSN 2234-7925 (Print)
ISSN 2765-4796 (Online)
Original Paper

The development of electronic buoy monitoring system with antenna comparison experiments to reduce data loss rates

Jeong-Wook Lee[1] · Jae-Hoon Kim[2] · Seong-Dae Lee[†]

(Received December 1, 2023 ; Revised December 14, 2023 ; Accepted December 14, 2023)

Abstract: Fishing nets are tools used in fishing floating in the ocean for a period of 10 to 48 hours, while being able to travel in multiple directions. This leads to problems such as uncertainty in the location of fishing gear, losses. The marine environment has experienced increased severity due to the disposal of fishing gears. The government is working to reduce dumping and loss of discarded fishing gears by tracking location of nets using Styrofoam and flags. Moreover, companies are also developing electronic buoys for monitoring fishing nets and gears. However, conventional electronic buoys have disadvantages, such as limited range, increase in power consumption, data loss, and unreliable communication. In this paper, we developed an electronic buoy to monitor fishing nets in real-time. The buoy aims to prevent fishing gear loss and theft by monitoring the location of fishing gears, fishing grounds, and catch information. This system attaches to fishing gears during hauling and transmits real-time location information and operation data of the fishing net to vessels, allowing for easy monitoring. To overcome limitations, we improved communication distance by making our own transmitter antennas through comparative experiments. In addition, we improved performance of low-power and long-distance communication functions by introducing LoRa (Long Range) communication technology.

Keywords: Fishing net, Electronic buoy, LoRa

1. Introduction

Over the past few decades, the issue of marine debris and its impact on the environment has become increasingly severe. Discarded fishing gears account for a significant majority of marine debris **[1]**. Discarded fishing gears, transported by winds and currents, cause various problems, including uncertainty in location and loss of fishing gears. The negative impact on marine ecosystems has led to a decline in marine biodiversity and an increasing issue of marine pollution.

It is challenging for marine management organizations to respond effectively when the whereabouts of discarded fishing gear is unknown. In response, the government has announced a plan to reduce marine debris by 60% by 2030 and complete elimination by 2050 **[2]**. The plan provides comprehensive coverage of the entire process of generating, moving, and collecting marine debris, providing systematic solutions. Other measures that support the government's policy include the establishment of a fishing gear buoy deposit system to promote recovery and recycling of discarded fishing gears, as well as strengthening the management of discarded fishing gears. Recently, the government has been making efforts to decrease marine litter by minimizing dumping and loss of discarded fishing gears. This is achieved by utilizing buoys made of Styrofoam and flags to identify nets while hauling. Buoys at sea have a limited visibility as they are not easily noticeable to the human eye. Furthermore, it requires a minimum of 30 minutes of sailing time to find a buoy, and additional time is needed at night and in fog.

In addition to government efforts, private companies are also addressing marine environmental problems caused by discarded fishing gears. To tackle the issue of discarded fishing gears, electronic buoys capable of providing real-time data on the whereabouts and conditions of fishing nets are proposed **[3]-[5]**. With accurate tracking of hauling locations using electronic buoys, gear loss and theft can be prevented, and reduce fishing costs by identifying gear locations. However, these electronic buoys have limited functionality due to short range, legal regulations, battery

† Corresponding Author (ORCID: http://orcid.org/0000-0002-8133-535X): Research Professor, Department of Artificial Intelligence Engineering, Korea Maritime & Ocean University, 727, Taejong-ro, Yeongdo-gu, Busan 49112, Korea, E-mail: omega@kmou.ac.kr, Tel: 051-410-5294

1 Ph. D. Candidate, Department of Control & Automation Engineering and Interdisciplinary Major of Maritime AI Convergence, Korea Maritime & Ocean University, E-mail: wjddnr96177@naver.com, Tel: 051-410-4896

2 Professor, Department of Artificial Intelligence Engineering, Korea Maritime & Ocean University, E-mail: jhoon@kmou.ac.kr, Tel: 051-410-4574

life and performance, as well as high prices, ultimately limiting system utilization.

This paper presents the development of an electronic buoy designed to monitor the location information of fishing gears, fishing grounds, and catch information in real-time in order to prevent loss and theft of fishing gears. During fishing operations, an electronic buoy is affixed to fishing gears to facilitate wireless transmission of both the fishing gear's position information and data relating to operation of fishing nets to vessels in real-time. Additionally, the information received can be monitored and observed on a vessels' display.

Unlike conventional electronic buoys, the electronic buoy transmitter for monitoring fishing nets utilizes GNNS (Gobal Navigation Satellite System) antennas and GNSS modules to collect data, thereby overcoming the limitations of a maximum range. In addition, LoRa long-range, a low-power wireless communication technology, enables efficient data transmission and reception between sensors and devices. A Sub-Ghz RF radio frequency front-end is used for battery optimization, and the electronic buoy receiver communicates via an RS-232 interface. Despite recent advances in communication technology, these devices allow longer-distance communication with fewer wires, making it ideal for use on fishing boats with poor installation. They also minimized data loss rate between the electronic buoy and the onboard receiver by utilizing the antenna that we developed in our experiments.

The implementation of a real-name system for fishing gear has been made possible due to the development of electronic buoys for monitoring fishing net. It enables the early collection of discarded fishing gear while preventing gear loss and theft. It also reduces lost fishing gear, reducing marine accidents caused by discarded fishing gear and protecting marine ecosystems. The aim of monitoring fishing gear management is to prevent duplicate installation of fishing gear in the same fishing grounds and effectively manage stolen fishing gear. This, in turn, contributes to resolving disputes among fishermen and rationalizing management.

This thesis is organized as follows: Chapter 2 reviews the current status of existing electronic buoys in Korea and compares it with the current status of electronic buoys abroad. Chapter 3 describes the design of an electronic buoy for fishing net monitoring. In Chapter 4, we implement and experiment with an electronic buoy for monitoring fishing nets, and provide the conclusion in Chapter 5.

2. Related Work

2.1 Status of Domestic Electronic Buoy Status

Electronic buoys are developed to address the environmental problems in the littoral sea caused by discarded fishing gears and fishing nets. The proposed system aims to check the location and status of fishing nets by connecting to a smartphone, which is different from the existing electronic buoys **[6]**. The system utilizes 890 MHz band of the WCDMA/LTE (band 8) cellular network frequencies and employs Advanced Encryption Standard (AES) encryption for data transmission in order to safeguard information pertaining to fishing activities. To lower power consumption, it is designed to minimize power consumption by blocking power after information is received. The system can also be used to check the location and status of fishing nets in real-time during fishing or shipboard activities, even when the onboard electronic chart display is not visible.

Research has been conducted to develop electronic buoys that utilize low-cost, non-toxic, and stable materials **[7]**. This system proposes the use of non-toxic and stable low-cost materials in electronic buoys, considering the marine environmental problems caused by toxicity of lithium and cobalt-based materials found in batteries in electronic buoys. In addition, a current-counting-based SBMS (Seawater Batteries Management System) was introduced to identify the state of charge and discharge, thereby significantly extending the lifespan of seawater batteries.

Research has been conducted and proposed on drifting buoys capable of monitoring marine environmental information **[8]**. The focus of this research was to effectively configure a drifting buoy system using a Lagrangian Drifter for marine environmental monitoring and optimized device development. In addition, we developed a system to observe water temperature and salinity as a fundamental survey element of the marine environment. We also proposed a method for calibrating sensor gain to enhance precision of measured data.

2.2 Status of Global Electronic Buoy

An electronic buoy monitoring system developed to track the position of buoys by utilizing GNSS devices combined with Internet of Things (IoT) technology has been proposed **[9]**. The name of this system is BMS (Buoy Monitoring System), and a case study was conducted for all signals operating in the port of Taranto. The system that has been developed is primarily designed to ensure the safety of navigation and to continuously measure signal conditions. All Signals proposed an IoT-based method to collect and monitor maritime conditions, including buoys, nautical markers, and beacons.

To address problems of meteorological and oceanographic monitoring in the Adriatic Sea, an aluminum-plastic coated buoy is proposed **[10]**. The system is specifically designed to ensure reliable operation in the high waves and wind speeds that may occur in the Adriatic Sea. What was also suggested is the introduction of solar panels specifically designed to address buoy power, to ensure continuous operation of the buoy's electronic sensors.

The problem of pollution in the marine environment was noted, and a proposal was made to use an electronic buoy with advanced sensors to detect oil spills **[11]**. The designed system samples the air above water and generates data for classifying the overall level of contamination detected. The study also sought to tackle problems of classifying contamination levels from data generated using two artificial neural networks.

3. System Design

3.1 Data Transmitter

information in real-time.

The electronic buoy transmitter for fishing nets utilizes a Low Power Wide Area Network (LPWAN) module to communicate with sensors and devices through Long Range (LoRa) transmission and reception technology. LPWAN is a wireless communication network technology primarily suited for long-distance and low-power device communication, offering low-power, wide-area communication **[12]**.

LoRa transmission and reception technology use LoRa modulation for data transmission and reception, facilitated by a LoRa modem. This technology enables frequency spreading, multiple access, low-power operation, and transmits data using frequency modulation.

The electronic buoy transmitter for fishing nets enables low-power data communication between sensors and devices, while LoRa transmitting and receiving technology extends their coverage to a larger area. In addition, efficient data communication with onboard receivers can be achieved by combining LPWAN and LoRa technologies.

Sub-Ghz RF radio frequencies are used to optimize transmitter

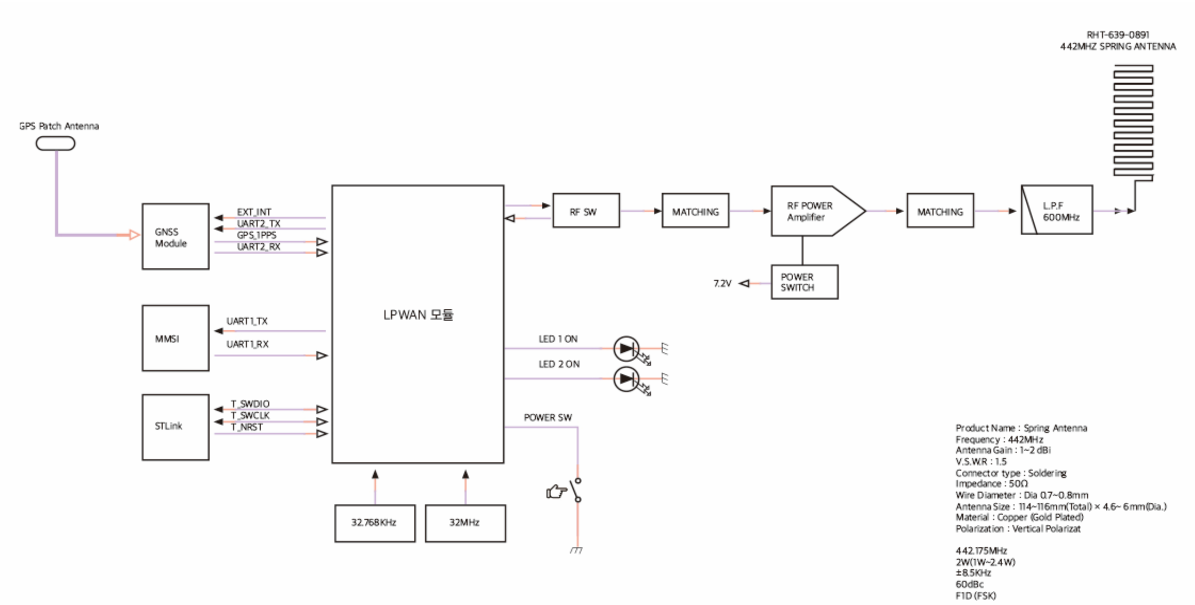


Figure 1: Block diagram of an electronic buoy transmitter for fishing net surveillance

Figure 1 shows a block diagram of a data transmitter. It collects data via GNNS antennas and GNSS modules. GNSS refers to a network of multiple satellites, including the Global Positioning System (GPS), which provide location and time information around the world. The system provides various location information of fishing gears with high accuracy and updates location batteries. This provides the advantages of low power consumption and long distance communication. Sub-GHz radio frequency refers to the lower 1 GHz frequency band in wireless communications, and electronic buoys for monitoring fishing nets utilize it to demonstrate several advantages such as low power consumption, long-range communication, expandable networking capabilities, and cost-effectiveness.

Figure 2 depicts a block diagram of the power supply of an electronic buoy transmitter.

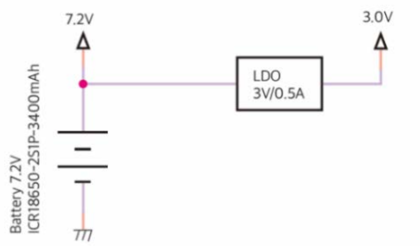


Figure 2: Block diagram of the power supply of an electronic buoy transmitter

Low dropout (LDO) regulator is a type of linear voltage regulator that maintains stable operation even when the input voltage exceeds the output voltage. This allows for accurate voltage regulation while maintaining a stable output voltage with low variation. Low-dropout regulators generate less heat, making them ideal for small and lightweight designs, such as electronic buoys. Battery ICR18650-2S1P-3400mAh(7.2Vdc) is developed for low power and extended operation.

3.2 Data Receiver

Figure 3 depicts an onboard block diagram data receiver.

The data transmitted by transmitter communicates with a receiver onboard using a 442 Mhz frequency antenna. The 442 Mhz frequency is a commonly used low frequency in wireless communication. It is used to efficiently overcome obstacles and minimize power consumption **[13]**. These characteristics promote long-range communication between transmitters and receivers, ensuring an effective distance of communication between antennas.

The received data is modulated using LoRa technology in LPWANM1 and M2. RS-232 is a standard protocol and hardware interface specification for serial communication, providing a continuous transmission method of data bits **[14]**. This is commonly used as a standard for simple communication between terminal devices, sensors, and computers.

The RS-232 interface is used in electronic buoys for monitoring fishing nets to ensure reliable data transmission and enable long-range communication with fewer wires. In addition, the RS-232 has the advantage of being able to operate reliably in unfavorable installation environments, such as fishing boats.

ST-Link, developed by STMicroelectronics, is an integrated tool used for programming and debugging microprocessors and microcontrollers **[15]**. The ST-Link enables users to monitor and debug behaviors of a developed software in real-time. A program developed using the ST-Link is used to display the data

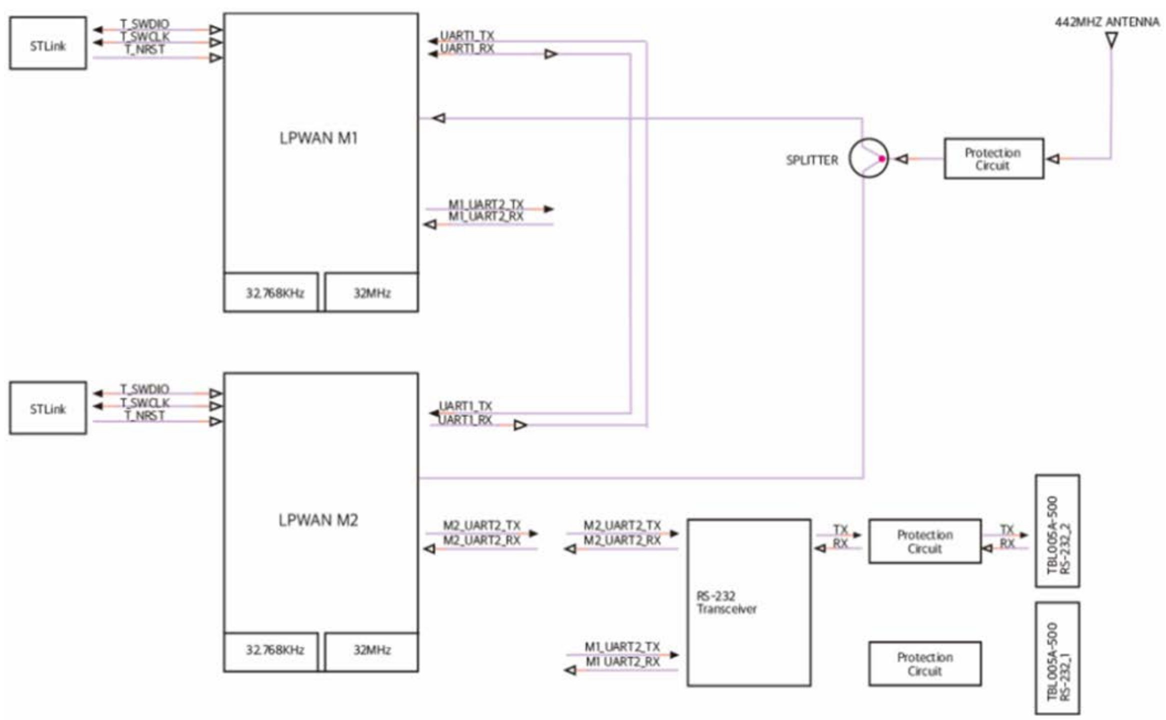


Figure 3: Block diagram of an electronic buoy receiver for fishing net surveillance

transmitted by an electronic buoy for monitoring fishing nets.

Figure 4 depicts a block diagram of the power supply of an electronic buoy receiver.

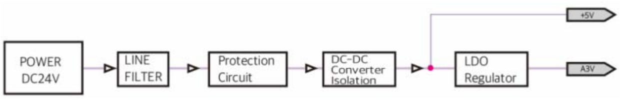


Figure 4: Block diagram of the power supply of an electronic buoy receiver

Line filters are connected in power circuits in electrical and electronic devices to control and filter noise and electrical waves **[16]**. The line filter removes noise from power entering circuits. This improves the performance of an electronic buoy and helps maintain electrical stability.

DC-DC Converter Isolation is used in power supply circuits primarily for converting and isolating power between various voltage levels **[17]**. This maintains an electrically isolated circuit to prevent any noise or problems encountered during power conversion from propagating to other parts of electronic buoys. Maintaining isolation, especially particularly between high- and low-voltage circuits, is crucial for protection of electronic buoys.

3.3 Format of Data

The type, size, and storage of the data received are shown in **Table 1**.

Table 1: Format of Electronic Buoy Data

Type of data	Data size	Storing method
ID	22 bit	Flash Memory
Latitude	24 bit	Internal RAM
Longitude	24 bit	Internal RAM
Battery level	2 bit	Internal RAM
Check-Sum	8 bit	Internal RAM

The types of data received are ID, latitude, longitude, battery level, and check-sum. Data is 10 bytes in size and consists of 22 bits of ID, 24 bits of latitude and longitude, 2 bits of battery level, and 8 bits of check-sum. Data storage method is ID; important data is stored in the internal flash memory, and other data is stored in the internal RAM.

4. System Implementation and Experimentation

4.1 System Implementation

Based on the design, a transmitter and receiver of the electronic buoy for monitoring fishing nets were developed. The developed transmitter, shown in **Figure 5**, is waterproof and can float on the sea surface. The average transmit power is 2 watts, with a range of 1 to 2.4 watts. The occupied frequency bandwidth is set to 8.5Khz or lower. The neighboring channel leakage power is set to 60 Dbc or higher.

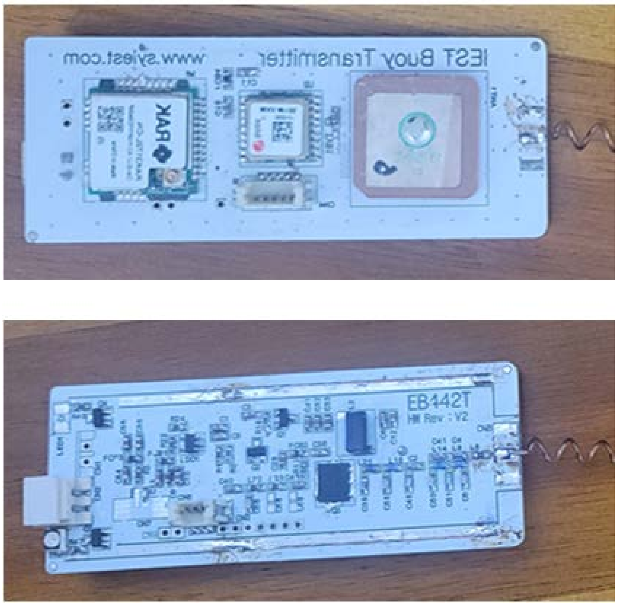


Figure 5: Electronic buoy transmitter device for monitoring fishing nets

The developed receiver is shown in **Figure 6**. The receiver in put voltage is DC24V. The receiving antenna is set to MRF120 C.

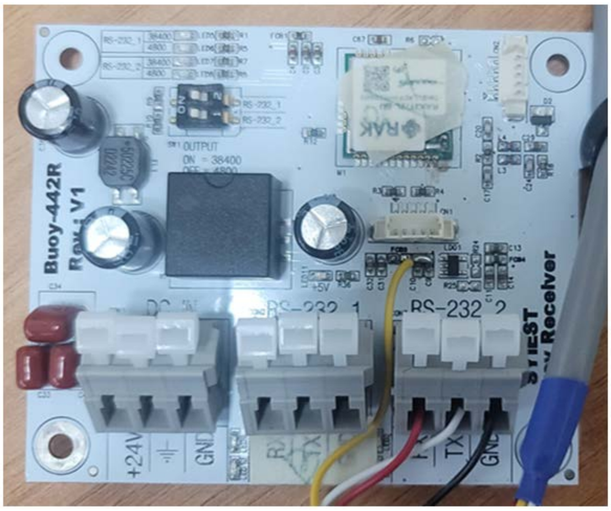
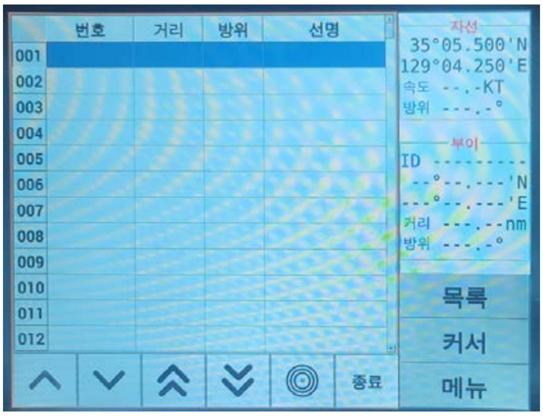


Figure 6: Electronic buoy receiver device for monitoring fishing nets

The data received from the developed electronic buoy for monitoring fishing nets is shown in **Figures 7(a)** and **7(b)**.

(a)



(b)

Figure 7: (a) Electronic buoy for monitoring fishing nets, (b) Display for electronic buoy for monitoring fishing nets

4.2 System Experiment

Data loss rate is evaluated using the Received Signal Strength Indicator (RSSI), which is a metric that measures strength of signal received in wireless communications. The signal quality is typically expressed in dBm, and the higher it is, the better the quality of the signal.

In the experiment, the size of RSSI sensitivity and transmits were checked once per minute, and checks data for an hour to determine the amount of data transferred. This allows monitoring the amount of data transmitted through wireless communication and generating statistics. **Figure 8** shows the data received. It stores the buoy's ID, latitude and longitude, received signal strength, and SNR. The buoy that transmits data is set at 35 kilometers, as shown in **Figure 9**. At 35 kilometers, the maximum reception strength was measured to be -87 and the minimum reception strength to be -106.

```
$GPRMC,000425,A,3453.072,N,12844.286,E,0.0,0.0,040922,,,A,0000023,R=-105,S=-18,3,O*20
$GPRMC,000430,A,3453.072,N,12844.288,E,0.0,0.0,040922,,,A,0000023,R= -87,S=-22,1,O*3A
$GPRMC,000435,A,3453.071,N,12844.288,E,0.0,0.0,040922,,,A,0000023,R=-102,S=-16,2,O*24
$GPRMC,000440,A,3453.070,N,12844.288,E,0.0,0.0,040922,,,A,0000023,R=-104,S=-19,3,O*2F
$GPRMC,000450,A,3453.069,N,12844.288,E,0.0,0.0,040922,,,A,0000023,R=-105,S=-16,2,O*29
$GPRMC,000455,A,3453.069,N,12844.288,E,0.0,0.0,040922,,,A,0000023,R=-105,S=-17,3,O*2C
$GPRMC,000500,A,3453.069,N,12844.288,E,0.0,0.0,040922,,,A,0000023,R=-105,S=-14,1,O*2C
$GPRMC,000505,A,3453.069,N,12844.288,E,0.0,0.0,040922,,,A,0000023,R=-106,S=-18,2,O*25
$GPRMC,000510,A,3453.069,N,12844.288,E,0.0,0.0,040922,,,A,0000023,R=-102,S=-18,3,O*24
$GPRMC,000520,A,1610.764,N,11318.192,E,0.0,0.0,040922,,,A,0197415,R=-105,S=-20,2,X*37
$GPRMC,000545,A,3453.065,N,12844.288,E,0.0,0.0,040922,,,A,0000023,R=-106,S=-16,1,O*20
$GPRMC,000550,A,3453.065,N,12844.288,E,0.0,0.0,040922,,,A,0000023,R=-106,S=-16,2,O*27
```

Figure 8: Receive data and server-stored data

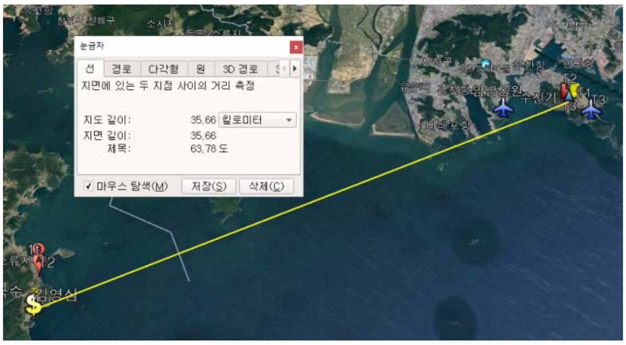


Figure 9: Buoy data transmission location

Comparative experiments were conducted on transmitting antennas we built in order to increase a communication distance for both transmission and reception in the 442Mhz band.

번호	감도R	감도S	합계	순위	사진
기준 1	-102	-10	-112	6	
2	-102	-15	-117	10	
3	-102	-17	-119	12	
4	X	X	X		
5	-101	-11	-112	5	
6	-102	-8	-110	2	
7	-102	-11	-113	7	
8	X	X	X		
9	-101	-15	-116	9	
10	X	X	X		
11	X	X	X		
12	X	X	X		
13	-102	-19	-121	13	
14	X	X	X		
15	X	X	X		
16	-102	-16	-118	11	
17	X	X	X		
18	-101	-10	-111	3	
19	-101	-11	-102	1	
20	-102	-13	-115	8	
21	101	-11	-112	4	

Figure 10: Reception sensitivity by transmit antenna

Figure 10 shows the reception sensitivity by transmit antenna of the many antennas, antenna number 19 has the lowest sensitivity, which is represented by -102. The antennas with the second lowest sensitivity are numbers 6 and 18, which have sensitivities of -110 and -111, respectively. The experimental results demonstrate the difference in reception sensitivity among the antennas, aiding in the selection of antennas for optimizing transmission and reception distances in communication.

길이	22PCB + 91nH			24PCB + 43nH			27PCB + 27nH		
63mm	-75.31	6.92	-68.39	-64.73	7.23	-57.50	-69.03	7.03	-62.00
70mm	-75.13	6.91	-68.22	-62.58	7.71	-54.87	-67.48	7.32	-60.16
80mm	-75.57	8.11	-65.46	**-61.58**	**7.08**	**-54.50**	-64.90	6.97	-57.93
90mm	**-72.78**	**7.34**	**-65.44**	-61.91	7.29	-54.62	-63.81	8.28	-55.53
100mm	-73.27	6.91	-66.36	-63.14	8.07	-55.07	-61.38	7.18	-54.21
110mm				-63.48	7.39	-56.1	-59.91	8.41	-51.50
120mm							**-59.84**	**8.38**	**-51.47**

Figure 11: C4 reception sensitivity by antenna coil length

Figure 11 shows the results of an experiment where the length of the C4 antenna coil was varied in order to enhance the communication distance. The experiment utilized three antenna configurations consisting of 22 PCB + 91 nH, 24 PCB + 43 nH, and 27 PCB + 27 nH, with reception sensitivity measured for each antenna length. The reception sensitivity has the lowest value of -65.44 at 22 PCB + 91 nH when the antenna is 90 mm long. When the antenna is 24 PCB + 43 nH, and its length is 80 mm, the reception sensitivity reaches its lowest value of -54.50. The reception sensitivity has the lowest value of -51.47 at 27PCB + 27nH when the antenna is 120 mm long.

The experimental results demonstrate the impact of antenna length on communication distance and indicate that optimal performance is attained at a specific length.

5. Conclusion

The electronic buoy, developed throughout this research, monitors the status and performance of fishing nets in real-time to prevent indiscriminate capture of fish species and extend the life of fishing nets. In addition, GPS and wireless communication systems can be used to track the location and activity of fishing nets, allowing for prompt action against illegal use of fishing nets. Electronic buoys are considered essential tools in the fishing industry with a positive impact in many ways, including improving the efficiency of fishing nets, protecting the environment, preventing illegal activities, and increasing productivity. For this reason, the development and introduction of electronic buoys for monitoring fishing nets are expected to play a vital role in enhancing sustainability of the fishing industry and conserving fish stocks. Furthermore, the study addressed the limitations of electronic buoys from previous research by incorporating a self-made antenna into a transmitter, thereby reducing data loss rate through experimental methods. Additionally, LoRa communication technology was implemented to optimize power usage and extend the range.

Acknowledgements

Following are results of a study on the "Leaders in INdustry-university Cooperation 3.0" Project, supported by the Ministry of Education and National Research Foundation of Korea.

Author Contributions

Conceptualization, S. D. Lee; Methodology, S. D. Lee ; Hardware, J. W. Lee; Formal Analysis, J. H. Kim and J. W. Lee; Investigation, J. W. Lee; Resources, J. W. Lee; Writing-Original Draft Preparation, S. D. Lee and J. W. Lee; Writing-Review & Editing, J. H. Kim; Visualization, J. W. Lee; Supervision, S. D. Lee; Project Administration, S. D. Lee; Funding Acquisition, S. D. Lee.

References

[1] Ministry of Oceans and Fisheries, The management policy of fishing nets for life cycle (press release on October 25, 2015).

[2] Ministry of Oceans and Fisheries, The management policy of Marine Litter (press release on August 5, 2019).

[3] J. H. Lee, J. M. Kim, S. S. Moon, and K. O. Moon, “A study on the fishnet management method with automatic identification system for the prevention of ship accidents,” The Institute of Electronics and Information Engineers, pp. 117-119, 2010 (in Korean).

[4] N. H. HEO, K. B. KANG, M. S. KOO, K. H. KIM, J. B. KIM, M. S. JWA, J. T. KIM, J. M. YOUNG, B. Y. KIM, and S. J. KIM, “A fundamental study on the installation methods of automatic identification buoy on coastal gill net,” Journal of the Korean Society of Fisheries and Ocean Technology, vol. 55, no. 4, pp. 294-302, 2019 (in Korean).

[5] S. Y. Kim, D. C. Lee, K. O. Kim, and C. S. Yim, “LTE Cat. M1 communication module for fishing gear automatical

identification monitoring system," Proceedings of the Korean Institute of Information and Communication Sciences Conference, pp. 682-685, 2021 (in Korean).

[6] H. G. Hwang, B. S. Kim, Y. T. Woo, I. S. Shin, Y. H. Yu and W. S. Baek, "A development of smartphone-connected fishing net tracking and management system," Journal of the Korea Institute of Information and Communication Engineering, vol. 21, no. 2, pp. 401-408, 2017.

[7] J. Cho, M. W. Kim, Y. Kim, J. S. Park, D. H. Lee, Y. Kim and J. J. Kim, "Seawater battery-based wireless marine buoy system with battery degradation prediction and multiple power optimization capabilities," IEEE Access, vol. 9, pp. 104104-104114, 2021.

[8] Y. H. Yu, Y. S. Gang, and W. B. Lee, "Development of a floating buoy for monitoring ocean environments," Journal of the Korean Society of Marine Engineering, vol. 33, no.5, pp. 705-712, 2009.

[9] S. Del Pizzo, A. De Martino, G. De Viti, R. L. Testa, and G. De Angelis, "IoT for buoy monitoring system," Proceedings of 2018 IEEE International Workshop on Metrology for the Sea; Learning to Measure Sea Health Parameters, pp. 232-236, 2018.

[10] T. Tomisa, S. Krajcar, and D. Pinezic, "Multipurpose marine buoy," Proceedings of 2008 50th International Symposium ELMAR, IEEE, vol. 2, pp. 401-405, 2008.

[11] D. Moroni, G. Pieri, O. Salvetti, M. Tampucci, C. Domenici, and A. Tonacci, "Sensorized buoy for oil spill early detection," Methods in Oceanography, vol. 17, pp. 221-231, 2016.

[12] S. Devalal and A. Karthikeyan, "LoRa technology - An overview," Proceedings of 2018 second international conference on electronics, communication and aerospace technology (ICECA), pp. 284-290, 2018.

[13] Z. H. Hu, J. Kelly, C. T. P. Song, P. S. Hall, and P. Gardner, "Novel wide tunable dual-band reconfigurable chassis-antenna for future mobile terminals," Proceedings of the Fourth European Conference on Antennas and Propagation, IEEE, pp. 1-5, 2010.

[14] P. Smulders, "The threat of information theft by reception of electromagnetic radiation from RS-232 cables," Computers & Security, vol. 9, no. 1, pp. 53-58, 1990.

[15] F. Basık, B. Gedik, Ç. Etemoğlu, and H. Ferhatosmanoğlu, "Spatio-temporal linkage over location-enhanced services," IEEE Transactions on Mobile Computing, vol. 1, no. 2, pp. 447-460, 2017.

[16] D. M. Mitchell, "Power line filter design considerations for DC-DC converters," IEEE Industry Applications Magazine, vol. 5, no. 6, pp. 16-26, 1999.

[17] M. H. Taghvaee, M. A. M. Radzi, S. M. Moosavain, H. Hizam, and M. H. Marhaban, "A current and future study on non-isolated DC–DC converters for photovoltaic applications," Renewable and Sustainable Energy Reviews, vol. 17, pp. 216-227, 2013.