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Research on Synchronous Performance Inspection System for Maritime Lanterns

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Abstract

Domestic ports are becoming increasingly complex due to the introduction of various marine 4th industry new technologies and the increase in marine logistics. Accordingly, the number of lightings behind the port is also increasing significantly, and there is a great demand for improving the visibility of the AtoN used as a means of transmitting information to vessel operators. This paper describes the development of the performance inspection system that can verify the synchronization and sequential flashing of maritime lanterns that is being introduced to enhance the visibility of AtoN.

Keywords: Synchronous performance, Rhythmic Characters, Maritime Lanterns

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1. Introduction

To support the safe navigation of vessels, there are artificial facilities marked with means such as lamp light, shape, colour, sound, and radio waves that are called AtoN(Aids to Navigation), in routes, ports, bays, and straits with high traffic volume. At night, a lantern installed on a AtoN is used to guide vessels that are in operation. Recently, it has become difficult to recognize AtoN due to the influence of the backlights such as streetlights, neon signs, and various lighting facilities in land facilities around the port, and this can cause marine accidents such as deviation from the route and ship grounding. Synchronous/sequential flashing is therefore applied to enhance the night visibility of the light buoys.

In aviation and road traffic, flashing signals are also being used to increase visibility. In the field of aviation, there are the FAA (Federal Aviation Administration) standards and the ICAO standards. South Korea, the United States, and Japan follow the FAA standards, while airports in Europe, Canada and Southeast Asia follow the ICAO standards which is similar to the FAA standards. In South Korea, the Approach Lighting System is operated in accordance with the aviation lighting installation and management standards. Among the Approach Lighting Systems, sequential flashing method can be used for the centre line indicator lamp and the Runway Lead-in Lighting System. The standard for sequential flashing of the centre indicator light is presented so that it flashes twice per second. Meanwhile, the field of road traffic also have the road traffic law and road safety facilities installation and management guidelines which stipulates the installation of gaze-inducing guidance signs and gaze-inducing guidance lights to induce safe driving, by inducing drivers' gaze road sections with sharp turns or curves. Recently, the use of flashing-type gaze-inducing guidance in the road traffic field has been increasing.

With regards to this paper, since the flashing lights method applied in the aviation and road traffic uses commercial power, it is easy to manage it intensively. However, since the flashing lights control of AtoN is operating independently on the sea applies a method of time synchronizing using GPS, there is a difference in the synchronous flashing method for each lantern manufacturer, which raises the problem of continuous timing error.

This paper was written as part of a study conducted to develop a standard timing error inspection system to minimize timing errors occurring when applying AtoN synchronization/sequential flashing.

2. Related Standards and Operational Status

2.1. Regulations Related to the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA)

In 2016, the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) issued the guidelines for selection of rhythmic characters and synchronization of AtoN, through the Guideline 1116 (Selection of Rhythmic Characters and Synchronisation of Lights for Aids to Navigation).

In the guidelines, IALA proposes to actively utilize synchronous flashing and sequential flashing to increase AtoN recognition rate and deliver accurate information for vessel operators.

In addition, the advantages and application scope of synchronous flashing and sequential flashing are proposed.

Due to its excellent visibility, it is recommended to install synchronous flashing lights at the port entrance where there is a lot of backlights. It is specified that sequential flashing can exhibit excellent performance in direction recognition, so it is effective for fairways with severe curves. In addition, it is proposed that the maximum synchronous slippage time between synchronized flashing lights should be less than 50 ms.

In the Guideline 1079 (The Use of AtoN in the Design of Fairways and Channels), IALA presents an introduction to the flashing method of AtoN in countries around the world. Examples include the Rio de La Plata Navigation Channel in Argentina, Musalo Channel and Rauma Channel in Finland, the Seekanal Rostock Channel in Germany, Malmö Port in Sweden, and Rotterdam Port in the Netherlands.

In addition, to briefly summarize the results of investigating the cases of port installation in foreign countries through the sea map, KOBE Port in Japan is operating synchronous flashing with the rhythmic characters of Fl (2) 6s.

Figure 1: Entrance to KOBE Port, Japan

At Geelong Port in Australia, synchronized flashing is being operated with the rhythmic characters of Iso 4s lights.

Figure 2: Access to Geelong Port, Australia

At Le Harve Port in France, it is operated by increasing the number of lights from Fl 4s to Fl (4) 15s.

Figure 3: Access to Le Havre Port, France

2.2. Domestic Regulations

Domestic regulations related to the synchronization and sequential flashing in South Korea include the "Functions and Specifications Standards of AtoN " and the "Standardisation Regulation for AtoN Equipment and Supplies".

The " Functions and Specifications Standards of AtoN " stipulates that the synchronous flashing and sequential flashing systems can be operated on the side markers. In addition, it is stipulated that it can be used for lanterns, bridge lights, fish farm signs, and wind power generation complexes.

The "Standardisation Regulation for AtoN Equipment and Supplies" set the standards for detailed functions for synchronous flashing. It regulates the typically use of GPS capable of 1 PPS (Pulse Per Second) signal output for synchronous flashing. The limit of the flashing signal slippage time is defined as ±0.05 s. In addition, the standard of the oscillator installed inside is set to 20 ppm or less.

In relation to this paper, despite the abovementioned regulations, the inspection of synchronous flashing function of lanterns has not so been introduced. Therefore, the demand for the introduction of an inspection system is continuously increasing.

2.3. Status of Application of Synchronous and Sequential Flashing in Domestic Ports

It was confirmed that about 25 ports in South Korea are currently operating synchronous flashing, and 2 ports are currently operating sequential flashing.

The researchers conducted field surveys on 2 synchronous flashes and 2 sequential flashes.

2.3.1. Status of Synchronous Flashing Operations

As a representative example of synchronous flashing operations in South Korea, AtoN near Gwangyang Port were surveyed.

The surrounding area of Gwangyang Port is a place where container docks and large steel mills such as Hyndai Hysco are located, and it is a port that operates a large number of port facilities and has severe backlight.

Figure 4: Placement Status of Navigational Aid near Gwangyang Port

Figure 5: Field Survey of Gwangyang Port

Navigation beacons near Gwangyang Port operate synchronous flashing on a total of 3 routes, including the direction to the Jungheung Pier (Fl (3) 7s), the Hyundai Hysco Entrance (Fl 4s), and the container pier (Fl (2) 6s). The navigational aids (light buoys) are arranged almost in a straight line. During operation, there is no obstruction to the landscape, but it is characterized by severe backlight.

A field survey was conducted on the synchronous flashing of the AtoN on the access route to Dangjin Thermal Power.

The Dangjin Thermal Power Plant access route is operated with synchronous flashing to improve visibility with the backlight from the Dangjin Thermal Power Plant. A total of 12 light buoys are in operation with Fl (4) 8s lights. The AtoN is using a 7-miles lantern at an average installation interval of about 1 mile. The depth of the route is deep at about 20 m, and the width of the route is also wide at about 600 m.

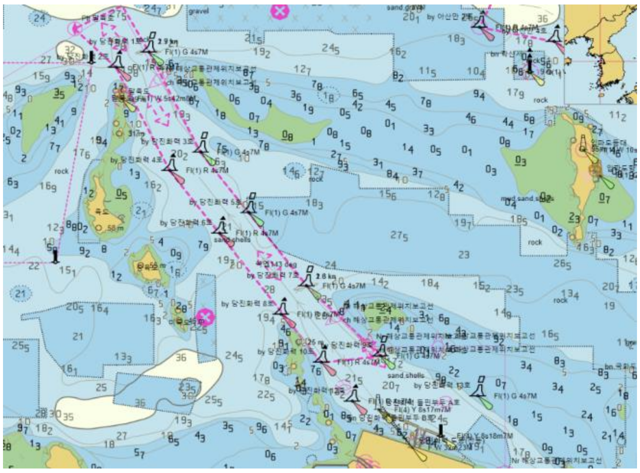

Figure 6: Placement Status of AtoN at Dangjin Thermal Power Plant Access Route

The lanterns used for synchronous flashing are mainly LED 7-miles.

LED 7-miles lanterns are divided into the integral type and the detachable type. The integral type is based on power consumption of 8 W or less and effective luminous intensity of 270 cd., while the detachable type's power consumption is 18 W or less and has an effective light intensity of 270cd.

Figure 7: Example of a LED 7-miles lantern in South Korea

2.3.2. Evaluation of Synchronous and Sequential Flashing Visibility

In relation to this research paper, a questionnaire was distributed to evaluate the visibility effect of synchronous and sequential flashing.

The survey was conducted with a total of 50 people working in the marine-related field. Through the survey, the visibility preference of synchronization and sequential flashing was investigated.

For the survey evaluation, a 3D modelling of the route and the AtoN is produced. The surveyor was asked to indicate the number and location of the AtoN recognized through the 3D modelling, and errors with the 3D modelling were checked.

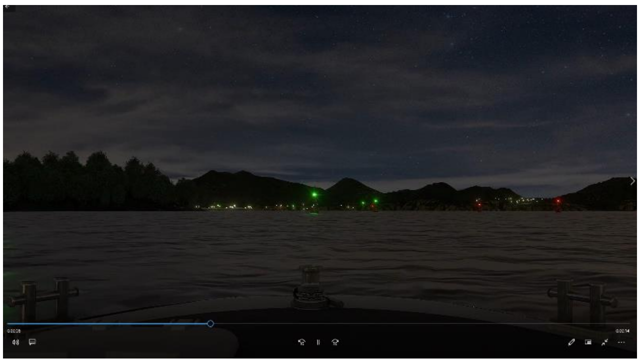

Figure 8: Sea area 3D modelling

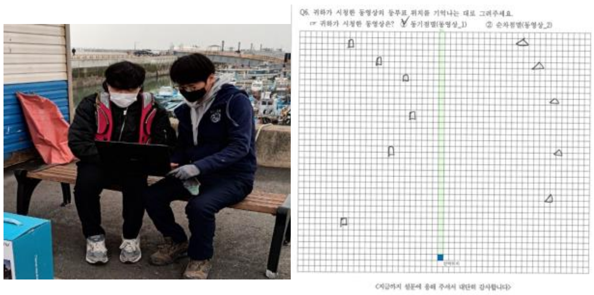

Figure 9: Conducting a Survey Evaluation

As a result of the survey evaluation, it was found that the degree of recognition of the number of the light buoy was 4.39 on average for synchronous flashes and 4.94 for sequential flashes, indicating that sequential flashes were recognized about 12.5 percent more.

As a result of evaluating the position error of the light buoys, it was found that the position error of sequential flashing was about 13.8% less than synchronous flashing, as shown in the figure below.

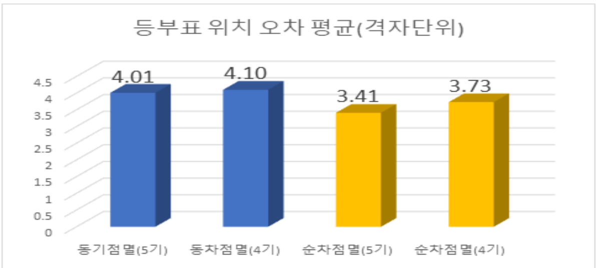

Figure 10: Light Buoy Position Error Evaluation

As a result of the evaluating operator's visibility preference between synchronous flashing and sequential flashing, it was showed that the preference for synchronous flashing was about 10% higher than sequential flashing. In the preference survey for guiding the direction of vessel's progress, sequential flashing was about 28% higher.

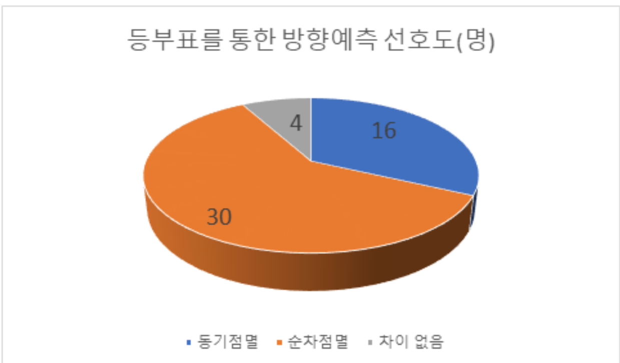

Figure 11: Preference for directional guidance by light buoys

3. The Need for Lantern Synchronous Performance Inspection

The necessity of actively utilizing the flashing method to improve visibility was reviewed through the field survey on AtoN synchronization and sequential flashing in domestic ports, and the visibility evaluation.

Despite this need, there is currently no inspection system in South Korea to measure synchronous and sequential flashing timing errors.

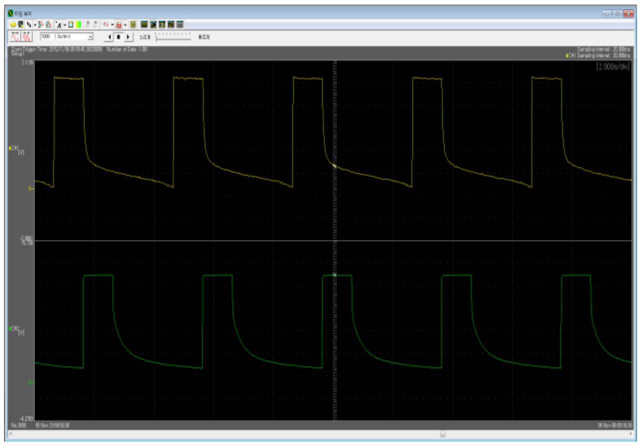

Figure 12: Lantern flashing signal synchronization error

Accordingly, the researchers analysed the waveform of the lanterns from other companies that are actually in use, for the flashing time error, which has been a continuous issue. There appears to be an error of about 1 second, but it is difficult to check which equipment is operating normally.

In order to come up with improvement measures, the problems of the existing lantern devices were analysed.

As a result of the analysis, four major problems were analysed. The first is the problem on the circuit that generates the flashing time signal. The signal received from the GPS receiver transmits the time signal to the MCU (Micro Controller Unit) at a transmission rate of approximately 9600 pps to 11.5 kbps. It is necessary to compensate for the timing error in this transmission step.

Second, it was found that the specification of the oscillator, which is a frequency generating device, are at the margin of the standard, which can be affected by the harsh marine environment.

Third, there may be an influence depending on the location of the GPS reception antenna installed in the lantern. It is necessary to adjust the installation position of the reception antenna to receive a GPS signal for constant quality.

Lastly, due to the problem of the operation of the lanterns, since the use of the lanterns operating at sea may be limited. Accordingly, it was investigated that although the GPS signal should be periodically received to correct the timing error, there are cases in which GPS signal reception and correction may not be continuously performed.

In order to improve the synchronization and sequential flashing effectiveness of the AtoN, the most basic thing is to comply with the certain period and the timing signal.

As mentioned above, up to date, there is no system for electronic inspection of AtoN (lanterns) used for synchronization and sequential flashing in South Korea, so managers must conduct timing performance inspection manually. In fact, the waveform of the flashing signal of the lantern from another company was analysed.

Therefore, during the course of this study, the researchers developed an inspection device to inspect the accuracy of the flashing signal of the lanterns.

4. Synchronous Performance Inspection Case Analysis

In this chapter, research cases conducted in relation to the synchronous performance inspection system for maritime lanterns are investigated and the relevance with this study is analysed.

4.1. eLoran Time Synchronization Services

Seo et al. (2021) designed a correction reference station (dLoran, differential Loran), a time synchronization monitoring system for eLoran time synchronization service and performance monitoring. To monitor the performance of the eLoran time synchronization service at all times, the timing comparison system between the GPS Primary Reference Source and the eLoran timing receiver in the correction reference station monitoring system is configured as shown in Figure 13. The Time Interval Counter receives 1 pps (pulse per second) output from a GPS reference time source and an eLoran time receiver, respectively, and measures the time synchronization error, and displays it on screen. It can be seen that the 1PPS signal pulse of GPS was used as a time synchronization method of the system in the corresponding system.

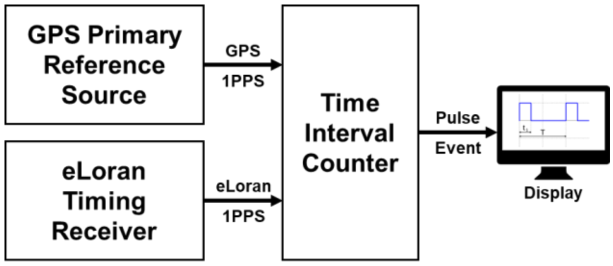

Figure 13: Configuration of eLoran Time Comparison Measurement System

4.2. Satellite Navigation System

In Global Navigation Satellite System (GNSS), various attempts have been made to increase the accuracy of time synchronization. Hwang et al. (2014) and Lee et al.(2014) proposed a method to design a time synchronization monitoring system between GPS satellites and pseudo-satellite systems. The monitoring system was used to increase the accuracy of the time synchronization of the pseudosatellite. The timing receiver of the pseudosatellite time synchronization monitoring system simultaneously receives GPS satellite signals and pseudosatellite signals to obtain timing information. To compare them, the timin error was extracted after converting to CGGTTS (CCTF Group on GNSS Time Transfer Standards) data format. The extracted timing error information is transmitted back to the pseudosatellite for timing error correction. Figure 14 shows a time synchronization monitoring system.

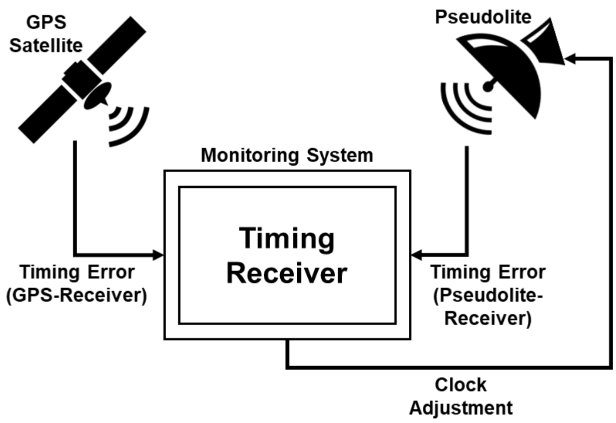

Figure 14: Clock Synchronization Monitoring System

4.3. Position Detection System

Kim, and Eom (2013) proposed a phase-synchronization method for a GPS satellite's 1PPS signal using high-precision OCXO (Oven Controlled Crystal Oscillator) and DPLL (Digital Phase-Locked Loops) to improve the time synchronization accuracy of the TDoA

(Time Difference of Arrival) based on positioning system. A more precise signal can be generated by synchronizing the 1 PPS signal from the OCXO with the 1 PPS signal from the GPS. In addition, the master and slave nodes were connected using a two-way communication leak, and the degree of time synchronization of the two nodes was compared to reduce the error. Figure 15 shows an overview of the precision time synchronization system.

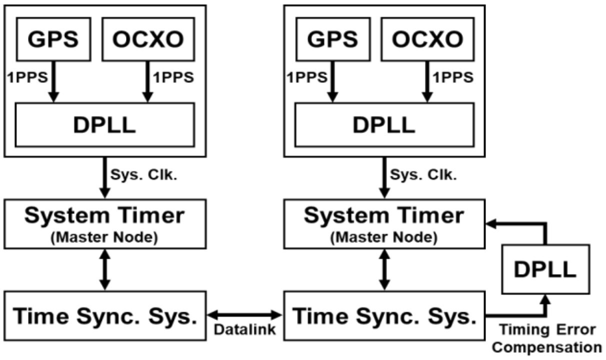

Figure 15: Precision Time Synchronization System

The 1 PPS from the GPS receiver dedicated for time synchronization is used as a reference signal to check the synchronization performance of the system, and it can be applied to check the synchronous performance of the lanterns.

5. System Configuration for Lantern Synchronous Performance inspection

To verify the synchronous performance of the lanterns, a system is constructed indoors. A re-emitting device that receives GPS signals from the outside and emits the received signals into the room is constructed. The reference signal generator and the lanterns are installed indoors to generate the same rhythmic characters, and it emits a GPS signal. The generated waveform is compared and examined with an oscilloscope.

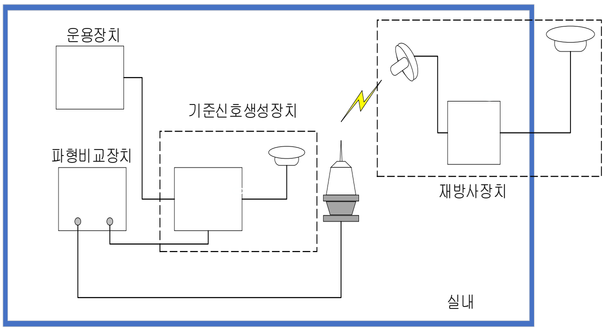

Figure 16: System configuration

5.1. Configuration of Reference Signal Generator

To generate the reference signal, 2 MCUs and a time synchronization receiver are configured. One MCU is responsible for generating a flashing signal by generating a timing of a reference signal based on a 1 PPS signal from the GPS receiver, while the other MCU control the signal generation in MCU#1 based on the GPS time information and rhythmic characters information set through an external interface.

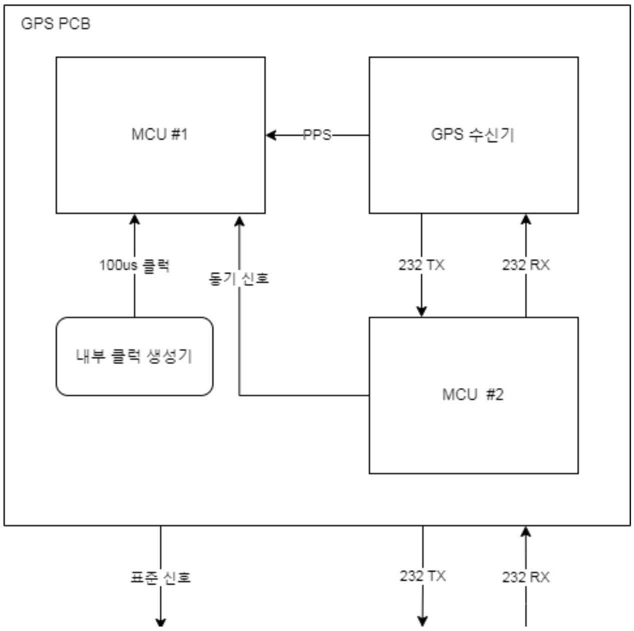

Figure 17: Block diagram of reference signal generator

5.2. Reference Signal Generator Operation Design

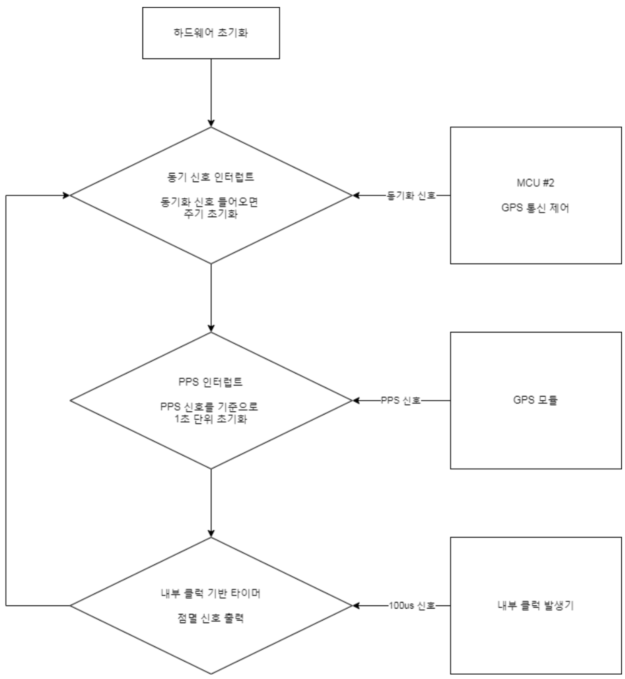

Figure 18: Signal generator flow chart

When power is applied to the signal generation unit, the MCU#1 receives a signal generation flag and equal control information from the MCU#2. When the signal generation flag is set to on, and 1PPS is entered as an interrupting signal from the time synchronous GPS module, a flashing signal according to rhythmic characters is generated using the 100us internal clock signal.

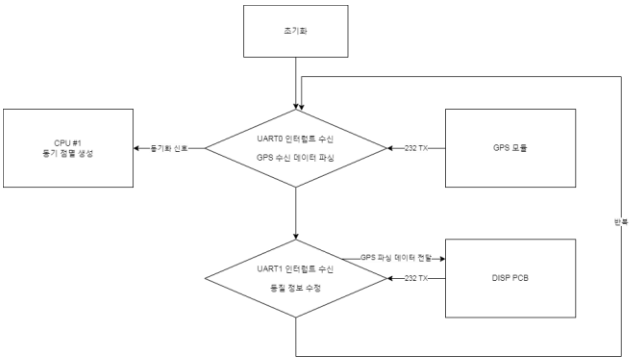

Figure 19: Signal generation control

When power is applied to the signal generation control unit, the MCU#2 sets the signal generation flag to off and prevents the flashing signal from being generated. The time synchronization GPS module receives GPS time and navigation information, and continuously checks whether the time synchronization GPS module performs 3D navigation. Rhythmic characters information is set based on the switch value of the external interface, and the signal generation flag and the rhythmic characters information are transmitted to the MCU#1. The rhythmic characters for the inspection were determined as Fl4s, Fl(4)8s, and Q1s.

6. Result of the Lantern Synchronous Performanc e Inspection

The re-emitting device is configured to satisfy the same signal strength outdoors.

The time synchronous receiver that generates 1 PPS used Trimble's Mini-TGG equipment. The device receives GPS and GLONASS L1 bands, and the time synchronization accuracy of 1 PPS is less than 15 ns.

The configuration of the reference signal generating devices is as follows.

Figure 20: Reference signal generator

On the LCD, time synchronization GPS receiver status information and set rhythmic characters information are displayed. The 1 PPS of the time synchronous GPS receiver and the reference signal output terminal are arranged as external interfaces, so that waveform comparison can be performed through an oscilloscope.

The performance of the reference flashing signal was compared with the 1 PPS from the time synchronous GPS receiver.

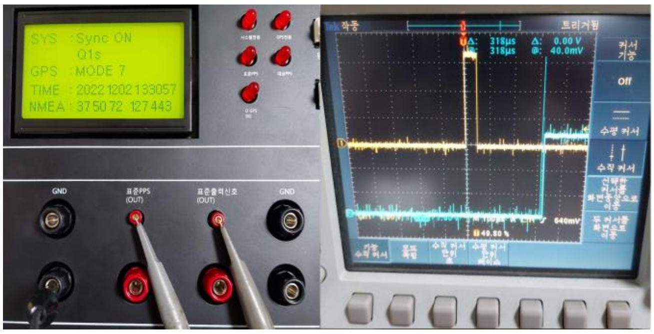

Figure 21: Reference signal and 1 PPS signal waveform comparison

The time synchronization performance was measured at about 300us, and it can be used as a reference signal for checking the flashing signal of the lantern with a very small error compared to the 50ms standard of the flashing signal synchronization performance.

The results of the synchronous performance test of the lanterns are as follows.

A synchronization error of about 300us can be confirmed for Fl4s rhythmic characters and the like.

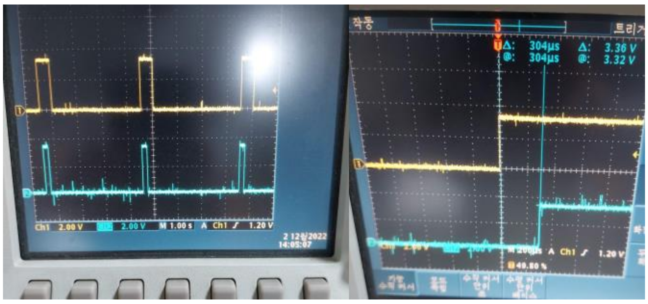

Figure 22: Waveforms of reference signal and lantern flashing signal comparison

The synchronization performance of the lantern flashing signal can be checked using the lamp synchronization performance inspection system proposed in this paper.

7. Conclusion

In the above, the current status of domestic AtoN synchronous and sequential flashing operation, related specifications, and problems of the current system were analysed. In addition, based on these analysis results, related equipment and systems were established to inspect the performance of the lantern flashing system with GPS time synchronization.

Currently, there is an inspection centre for performance inspection of AtoN equipment and supplies in South Korea. The electrical and optical characteristics of AtoN have been regularly checked for more than 20 years. The newly developed flashing signal inspection system through this study is expected to be operated at the inspection station, by changing inspection standards and optimizing the equipment in the future.

With the introduction of this inspection system, it is believed that it will be helpful for safe operation of vessels by improving the synchronous and sequential flashing performance of AtoN.

Acknowledgements

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