JPNT 4(4), 187-193 (2015)
http://dx.doi.org/10.11003/JPNT.2015.4.4.187

JPNT Journal of Positioning, Navigation, and Timing

A Maritime DGPS Reference Station Configuration Proposal for Operation Improvement

Yong Kwon Choi[1], Seok Bo Son[2†], Sang Jeong Lee[3]
[1]National Maritime PNT Office, Daejeon 34150, Korea
[2]Navcours Co., Ltd., Daejeon 34014, Korea
[3]Department of Electronics Engineering, Chungnam National University, Daejeon 34134, Korea

ABSTRACT

A maritime Differential Global Positioning System (DGPS) reference station broadcasts correction information to users having a DGPS receiver so that the navigation performance can be improved. A maritime DGPS reference station consists of a reference station (RS) that generates and broadcasts correction information, an integrity monitor (IM) that monitors the integrity of correction information, and a control station (CS) that controls them. A maritime DGPS reference station is continuously operated for 24 hours, and thus improvement in the ease of operation is a major element that can improve the performance of the system. In this study, a configuration of a maritime DGPS reference station that can improve the ease of operation and a relevant protocol were proposed, and an example of the implementation of the proposed system was presented.

Keywords: RSIM, DGPS, control station

1. INTRODUCTION

A maritime Differential Global Positioning System (DGPS) reference station system that generates and broadcasts Global Positioning System (GPS) error correction information consists of a reference station (RS), an integrity monitor (IM), and a control station (CS). A reference station generates correction information, an integrity monitor monitors the integrity of the generated correction information, and a control station sets, controls, and monitors the major functions and operations of the reference station and integrity monitor so that the entire system can operate normally. A lot of users utilize the error correction information broadcasted from a DGPS system, and thus there should be no error in the broadcasted information. To minimize an error, the correction information broadcasted to users is standardized (GNSS Central Office; http://www.ndgps.go.kr), and the data exchanged among a reference station, an integrity monitor, and a control station are also standardized (US Coast Guard (USCG); http://www.navcen.uscg.gov/?Do=constellationstatus). This standard protocol can satisfy the minimum requirements for system operation, and a nonstandard protocol is separately established and reflected in system design depending on the necessity of performance improvement and the addition of a function.

A reference station and an integrity monitor were hardware-based systems in the early stage, and USCG suggested a software-based system so that additional establishment cost and new technology application could be easily dealt with. A software-based system has better flexibility than a hardware-based system. In Korea, a software architecture that simplified the components and increased the ease of installation and operation was also suggested, and it was shown that a software-based system could reflect the design intent of a system designer as well as essential functions (Jang et al. 2014).

Received Aug 09, 2015 **Revised** Oct 06, 2015 **Accepted** Oct 23, 2015
†**Corresponding Author**
E-mail: sbson@navcours.com
Tel: +82-42-363-9212 Fax: +82-42-363-9290

http://www.gnss.or.kr Print ISSN: 2288-8187 Online ISSN: 2289-0866

A DGPS system is continuously operated for 24 hours. Thus, if an error cannot be found as the demand of a system operator is not sufficiently reflected, service could not be provided in some cases. In this study, a configuration of a maritime DGPS reference station system with strengthened operation function and a protocol necessary for this were proposed. In Chapter 2, an existing maritime DGPS reference station system configuration is analyzed and relevant problems are identified; and in Chapter 3, a system configuration that improved the problems and a necessary function are proposed. In Chapter 4, an example of implementation is presented; and in Chapter 5, conclusions are drawn.

2. ANALYSIS OF AN EXISTING MARITIME DGPS REFERENCE STATION SYSTEM CONFIGURATION

As shown in Fig. 1, an existing maritime DGPS reference station system consists of software-based reference station and integrity monitor and a control station, and the reference station and integrity monitor have a dual structure. The software is operated by a commercial server computer, and the data for DGPS correction information generation and monitoring are supplied from a Global Navigation Satellite System (GNSS) receiver.

The control station stores information on the operation status as well as controls, sets, and monitors the reference station and integrity monitor. The information on the operation status is stored because the stored data are analyzed to identify and fix an abnormal status that has not been detected in real time during operation or to identify performance improvement elements. To perform this function, the control station is connected to the reference station and integrity monitor via Ethernet communication; and in some cases, it is directly connected to a GNSS receiver, a modulator, a demodulator, and a transmitter as necessary and directly controls each component as well as the entire system. In recent years, a control station could be located far from a reference station through a network, and thus integrated operation of maritime DGPS reference stations installed throughout the country could be implemented.

In the early stage, a control station and a reference station were installed at the same location; but recently, remote integrated operation via a network is preferred. In the case of long-distance installation, the ease of operation is improved; but when a problem occurs such as communication failure, normal operation of a maritime DGPS reference station cannot be guaranteed, and the operation status during the failure period cannot be known even when the communication is restored. To resolve this problem, the same control station could be added to the location where the reference station is installed. However, in this case, two control stations with the same function

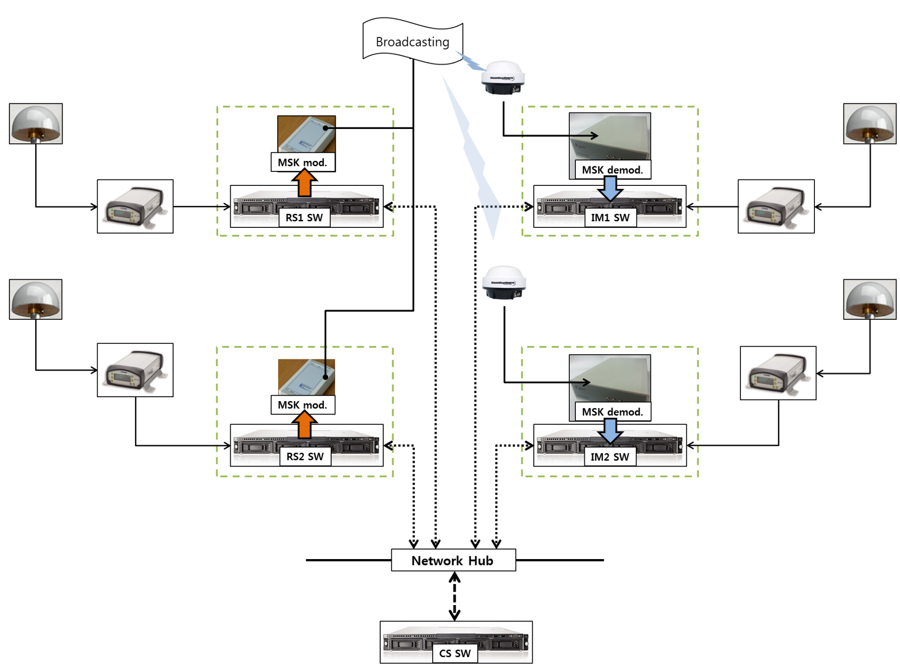

Fig. 1. The existing maritime DGPS reference station configuration.

control, set, and monitor the reference station and integrity monitor, and thus a problem of authority priority occurs and confusion about the current status identification of the reference station is induced. In other words, due to another control station that has been added for the ease of operation, system operation could be difficult from the standpoint of an operator, and the difficulty in the operation of the system that should operate continuously in real time could lead to the deterioration in the system performance.

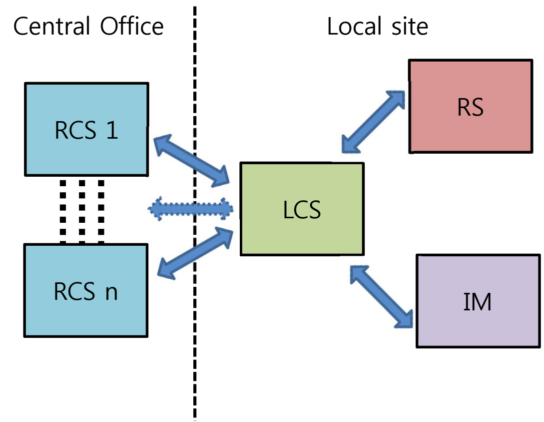

Fig. 2. A maritime DGPS reference station configuration with RCS.

3. PROPOSAL OF A SYSTEM CONFIGURATION INCLUDING A REMOTE CONTROL STATION

As a method for resolving the problem identified in Chapter 2, a system configuration including Remote CS (RCS) was proposed as shown in Fig. 2.

In the proposed system configuration, RCS is added to the central office for an existing system configuration, and the RCS exchanges necessary data with only Local CS (LCS) and thus the problem of priority could be avoided. In other words, LCS controls, sets, and monitors the reference station and integrity monitor and stores necessary data; and RCS can perform all the functions of LCS, but it performs these functions via LCS at all times. In the end, RCS controls, sets, and monitors the entire maritime DGPS reference station including LCS. In addition, RCS can perform the functions although it is installed in any computer as long as the network is connected to LCS. Also, more than two RCSs can be operated at the same time, which can maximize the operator operability. When a number of control stations are operated at the same time, the operability is improved; but problems of priority or data consistency could occur and thus function for resolving this needs to be added.

Table 1 summarizes the major Reference Stations and Integrity Monitors (RSIM) standard messages (RTCM SC-104 2006) and the role of each component necessary for normal operation of a maritime DGPS reference station system including a number of reference station systems.

As summarized in Table 1, LCS and RCS play the same

Table 1. Main RSIM standard messages and each component role.

RSIM #	Function	RS	IM	LCS & RCS
1	RSIM MESSAGE# QUERY/REPORTING INTERVAL	Receive	Receive	Send
5	RSIM DIAGNOSTIC REPORT/ALARM	Send	Send	Receive
6	GPS RECEIVER PARAMETERS	Receive	Receive	Send
7	GPS RECEIVER SATELLITES STATUS	Send	Send	Receive
8	SATELLITE HEALTH CONTROL	Receive	Receive	Send
9	SATELLITE HEALTH STATUS	Send	Send	Receive
10	RS DATA LINK PARAMETERS	Receive	-	Send
11	RS ALARM THRESHOLDS	Receive	-	Send
12	RS ALARMS	Send	-	Receive
13	RS CORRECTION DATA	Send	-	Receive
14	IM DATA LINK PARAMETERS	-	Receive	Send
15	IM DATA LINK STATUS	-	Send	Receive
16	IM ALARM THRESHOLDS	-	Receive	Send
17	IM ALARMS	-	Send	Receive
18	IM DGPS STATUS	-	Send	Receive
19	IM CORRECTION DATA	-	Send	Receive
20	IM SYSTEM FEEDBACK	-	Send	Receive
21	RTCM BROADCAST ALMANAC PARAMETERS	Receive	-	Send
22	RTCM BROADCAST SCHEDULING	Receive	-	Send
23	RTCM UNIVERSAL MESSAGE	Receive	Receive	Send
24	TRANSMITTER CONTROL AND STATUS	Receive	-	Send
25	BROADCAST CONTROL AND STATUS	Receive	-	Send
26	GENERAL TEXT MESSAGE*	Send/Receive	Send/Receive	Send/Receive
31	PRE-/POST-BROADCAST INTEGRITY MODE PARAMETERS	Receive	Receive	Send
39	PRE-BROADCAST IM DGPS STATUS	-	Send	Receive
40	PRE-BROADCAST IM CORRECTION DATA	-	Send	Receive

*RSIM message No. 26 is a universal text message and the priority is based on the order of occurrence.

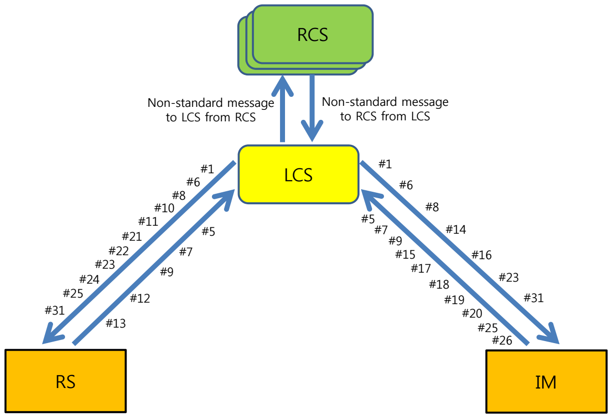

Fig. 3. RSIM message flow diagram.

```
Header   Destination   PRCM   Data        Check sum
  ^          ^           ^      ^            ^
 xxx,       xxx,         #,   (x,x…x,x),     *x
```

Fig. 4. Message structure.

Table 2. Nonstandard messages for exchanging information between RCS and LCS.

No	HEADER	DATA
1	STATION_ID	Station name string
2	CONNECTION	All server IP, port string
3	LOG_SETUP_READ	Log path, log number
4	LOG_SETUP_WRITE	Log path, log number
5	SIDE_CHANGE_RS_READ	Threshold check, threshold value
6	SIDE_CHANGE_RS_WRITE	Threshold check, threshold value
7	SIDE_CHANGE_IM_READ	Threshold check, threshold value
8	SIDE_CHANGE_IM_WRITE	Threshold check, threshold value
9	UPDATE_ALARM	Alarm section, enable alarm
10	DEMOD_SETUP	Server, frequency, bitrate, interval
11	FILE_CHECK_READ	File path, file ext., file, interval file time, file alarm
12	FILE_CHECK_WRITE	File path, file ext., file, interval file time, file alarm
13	TRANSMITTER	TRANSMITTER set, state
14	INTEGRITY_MODE_READ	INTEGRITY_MODE set
15	INTEGRITY_MODE_WRITE	INTEGRITY_MODE set

Table 3. Destination identifier for transmitting from RCS to the integrity monitor or the reference station.

No	Destination identifier	Contents
1	REMOTECS_to_RS1	Message to RS1 from RCS
2	REMOTECS_to_IM1	Message to IM1 from RCS
3	REMOTECS_to_RS2	Message to RS2 from RCS
4	REMOTECS_to_IM2	Message to IM2 from RCS

role in the maritime DGPS reference station system. Therefore, when each control station has different information or sends different commands, the reference station and integrity monitor could malfunction and there could be an error in the information on the status of the reference station and integrity monitor that each control station knows. To resolve this problem, the control commands for the reference station and integrity monitor and the storage of their information were based on LCS, and RCS and LCS were made to control the flow of commands by defining nonstandard messages, as shown in Fig. 3.

Two kinds of protocols need to be additionally defined between RCS and LCS. One is to exchange information between RCS and LCS, and the other is to transmit the signals sent from RCS, to the reference station or integrity monitor through LCS. To exchange information between RCS and LCS, an additional protocol is necessary, and it is summarized in Table 2.

In order to transmit the signals sent from RCS, to the reference station or integrity monitor through LCS, separate information that the data has been transferred from RCS is necessary, and a message structure for this is shown in Fig. 4.

The message of the communication protocol has five structures, where the front end of the message starts with Header, followed by Destination, PRCM message type, Data, and Check sum. Among the message structures, Destination is used to identify the fact that the corresponding message has been generated from RCS, and to identify the destination. This is summarized in Table 3.

The standard RSIM messages of the reference station and integrity monitor are transmitted based on LCS. The command of RCS is transmitted to LCS through a nonstandard message, and the reference station and integrity monitor finally receive the message from LCS. In this regard, to resolve the problem of data consistency and priority, two cases can be considered. The two cases are when a command is sent from LCS that is the center of the maritime DGPS reference station and when data is sent from RCS.

First, when data is sent from LCS, data is sent to the reference station and integrity monitor, and this can be shared with the remaining RCSs. Fig. 5 shows the command processing procedure that starts from LCS.

As shown in Fig. 5, every command is classified as display setting or communication input, and the classified command is transmitted by identifying the target among the reference station, integrity monitor, RCS, and LCS. After carrying out the command, the corresponding command is transmitted to RCS so that the information can be shared. In other words, after the processing of any command, LCS and a number of RCSs share the same information.

When data is sent from one of the RCSs, the function necessary for the corresponding RCS is carried out first, and then the command processing procedure that starts from LCS is carried out once again as shown in Fig. 5. This is shown in Fig. 6. As shown in Fig. 6, when a command starts from RCS, it is classified as display setting or communication input, and then the remaining procedure is performed as if the data started from LCS.

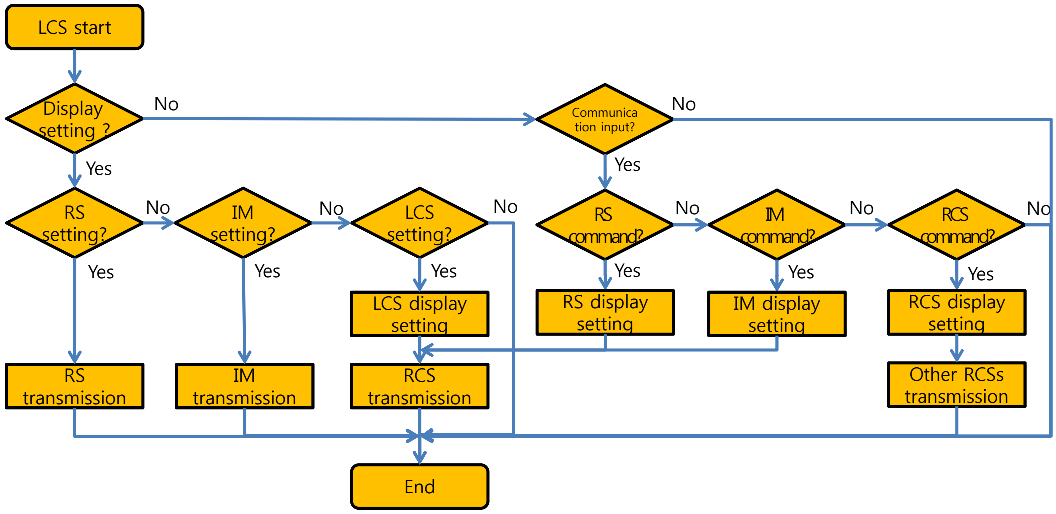

Fig. 5. Command process starting from LCS.

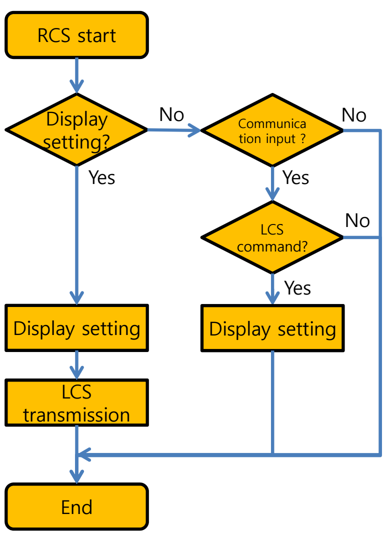

Fig. 6. Command process starting from RCS.

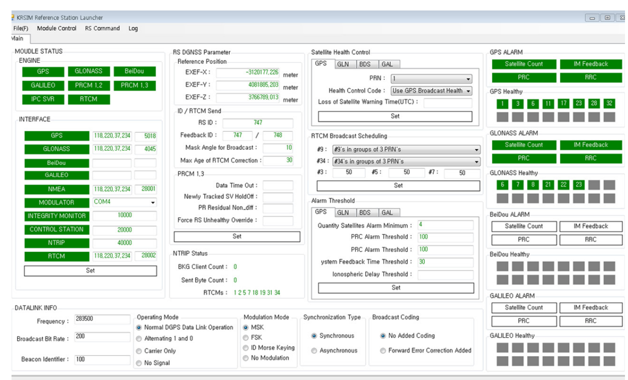

Fig. 7. Reference station display.

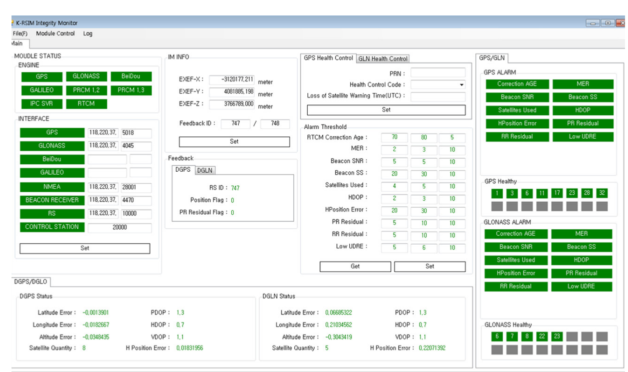

Fig. 8. Integrity monitor display.

4. EXAMPLE OF THE IMPLEMENTATION OF THE DEVELOPED SYSTEM

In this chapter, the functions of the developed control station, integrity monitor, and reference station were presented through the actual developed software; and by examining the result of data exchange following the command processing of RCS and LCS, it was shown that the system with the simultaneous operation of a number of control stations operated efficiently. Fig. 7 shows the display of the reference station.

The reference station generates correction information based on satellite information, and sends it to the transmitter. To perform this without an error, 11 windows are generated on the reference station display and these can be managed by an operator. Table 4 summarizes the major contents. Fig. 8 shows the display of the integrity monitor.

The integrity monitor receives the correction information generated from the reference station and monitors the error of the information so that wrong information cannot be broadcasted. To perform this without an error, 13 windows are generated on the integrity monitor display and these can

Table 4. Reference station main display contents.

No	Window name	Function
1	RS receiver data reception	Data type and time display from GPS receiver
2	Connection status	CS & IM connection status display
3	Server status	Server port display
4	Integrity monitor system feedback	IM mode setting and status display
5	RS alarms	RS alarm status display
6	(#7) GPS receiver satellites status	RS GPS receiver tracking satellite status display
7	RTCMs	RTCM message transmission status (#5, #7, #9, #16)
8	(#13) RS correction data	Correction data status display
9	DOP	DOP display
10	C/N0	Signal power display
11	System messages	System message display

Table 5. Integrity monitor main display contents.

No	Window name	Function
1	IM receiver data reception	Data type and time display from GPS receiver
2	Connection status	CS & RS connection status display
3	Server Status	Server port display
4	Integrity monitor system feedback	IM status display
5	IM alarms	IM alarm status display
6	(#15) IM data link status	Demodulation status display
7	RTCMs	RTCM message transmission status (#5, #7, #9, #16)
8	(#7) GPS receiver satellites status	IM GPS receiver tracking satellite status display
9	(#19) IM correction data	Correction data integrity monitoring result display
10	Scatter plot	Navigation result display with correction data
11	DOP	DOP display
12	C/N0	Signal power display
13	System messages	System message display

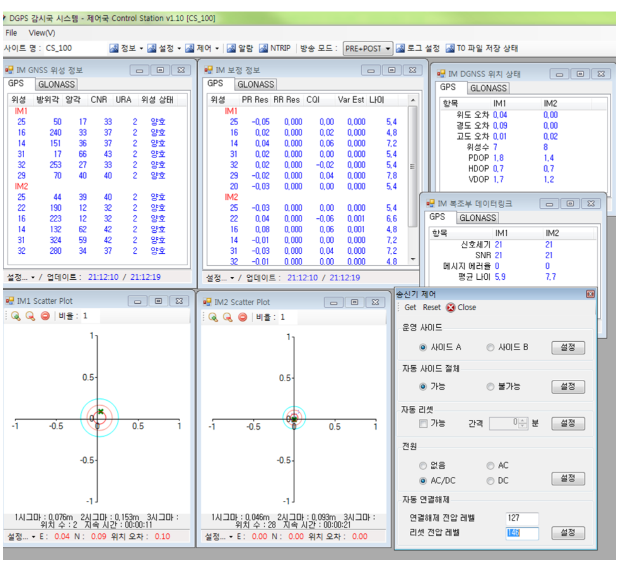

Fig. 9. Control station display.

be managed by an operator. Table 5 summarizes the major contents.

Fig. 9 shows the display of the control station. The control station controls the reference station and integrity monitor, and can display every data that is necessary for an operator by receiving data from them. The display window was configured so that the functions such as transmitter control and status checking could be performed.

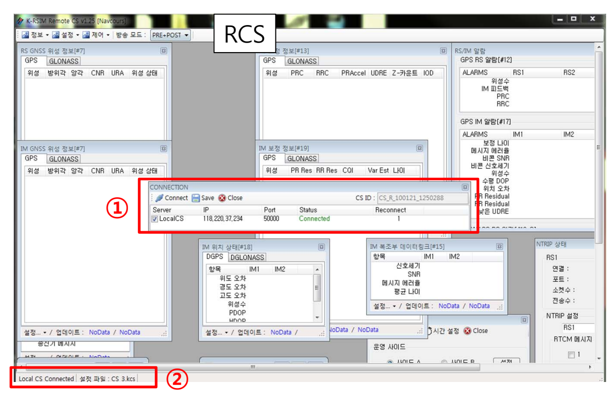

Fig. 10. LCS connection status monitored by RCS.

Fig. 10 is the result where the command performed by RCS or LCS has been shared. As shown in Fig. 10, the connection status and connection information of LCS can be checked based on the connection window marked as ①, and the connection status of LCS can also be checked at the lower left part of the window marked as ② without opening the window.

Fig. 11 is the result display where RCS has set the satellite information output interval and it has been identically applied to LCS. Fig. 12 is the result display where LCS has set a threshold value and it has been identically applied to RCS.

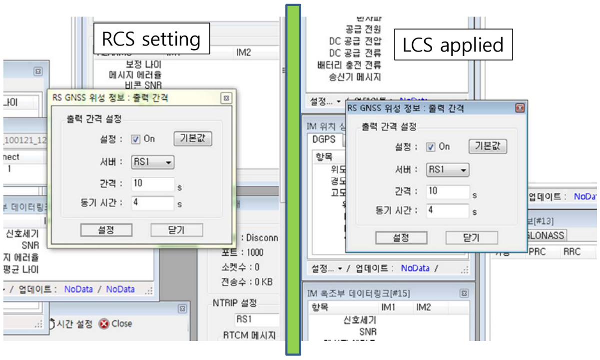

Fig. 11. LCS display set by RCS message transmission.

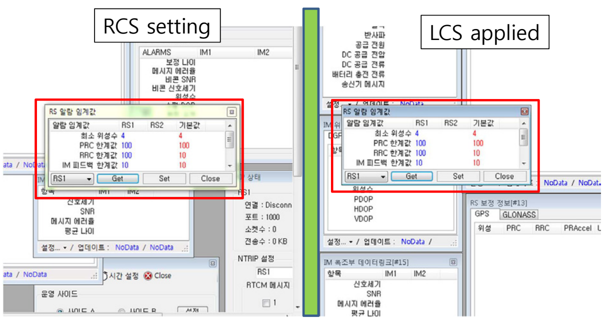

Fig. 12. RCS display set by LCS message transmission.

5. CONCLUSION

In this study, a system configuration for improving the operability of a maritime DGPS reference station system was proposed. As for the proposed major elements, RCS was included in an existing system, and a protocol for performing the added function was proposed. The most important consideration during the design of configuration and protocol was to prevent the conflict of authority priority due to the installation of more than two control stations in a system, and this was examined in detail through an example of implementation. It was found that stable long-distance operation of the system could be implemented as RCS was included in an existing system.

REFERENCES

Jang, W. S., Kim, Y. G., & Seo, G. Y. 2014, Architecture Design for Integration of Software RS and IM of Maritime DGPS Reference Station System, Journal of the Korea Institute of Information and Communication Engineering, 18, 282-288, http://dx.doi.org/10.6109/jkiice.2014.18.2.282

RTCM SC-104 2006, RTCM STANDARD 10401.2 for Differential NAVSTAR GPS Reference Stations and Integrity Monitors (RSIM), December 18, 2006.

Yong Kwon Choi received M.S. degree in electronics engineering from Chungnam National University in 2012. He has worked with National Maritime PNT Office. His current research interests include DGNSS system.

Seok Bo Son received B.S, M.S and Ph.D degrees in electronics engineering from Chungnam National University in 1996, 1998 and 2002, respectively. He has worked with Navcours co., ltd. and now is a division director. His current research interests include alternative navigation system, high quality antenna and jamming test equipment.

Sang Jeong Lee received the Doctor's degree in Control and Measurement in Seoul National University in 1987. His research interests include GNSS and Robust Control.