The Status of DGNSS & Experimental Test of DGPS in Korea

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<Abstract>

DGNSS(Differential GNSS) may be the most feasible positioning system to users who need the precise positioning in the future. A number of countries have carried out research and test about DGNSS based on the marine radiobeacon for improving positioning accuracy.

This paper describes the status of DGNSS in the world and the system characteristics. In special, DGNSS network of Korea to be constructed is discussed. And then DGNSS, which are operating for test, is analyzed by an experimental approach.

Introduction

The satellite navigation system, GPS(Global Positioning System), has carried out various tasks in any regions of the world. Its positioning has improved the tasks for civilian and military users at sea, air and land. In addition, GLONASS(Global Navigation Satellite System) developed by Russia has fully operated for users since 1996. Due to no intended error such as SA(Selective Availability) which is involved in GPS, it is said that the accuracy of GLONASS is better than the stand-alone GPS under SA. Therefore, the systems are the typical satellite navigation systems currently. Based on the well known differential technique to improve the accuracy of positioning, GLONASS will be also used to improve its accuracy by adapted differential system as GPS has done. Accordingly, GNSS combined GPS and GLONASS would play a key role to provide the precise positioning information to civilian and military users. However, the positioning accuracy of both systems, GPS and GLONASS has turned out to be unsufficient in various fields which require more precise position.

In accordance with the requirement of the International Maritime Organization (IMO), the accuracy of positioning for harbor and harbor approach must be provided no less than 10 meters[3]. It could be attained using DGNSS(differential GNSS) subsystem by means of the construction of network of basic terrestrial stations. Therefore, DGNSS may be the most feasible system to users who need the precise positioning in the future.

A number of countries have carried out research and test about the implemented of the marine radiobeacon based on differential correction broadcasting system using MSK(Minimum Shift Keying) technique which is economical to implement at existing radiobeacons and within user receivers. And the Radiobeacon Systems Committee of IALA(International Association Lighthouse Authorities) greatly contributed to develope DGNSS, the technical policy, the international standards, and subsystem for the system in many countries of the world.

In this paper, we investigated the status of DGNSS in the world, its service, coverage and characteristics to implementation. And then the layout for construction of DGNSS network in Korea was studied based on the result of the practical test using marine radiobeacon/DGPS.

DGNSS System Architecture and Function

DGNSS system for marine use cosists of the reference station, integrity monitor, data link communication link control and user receiver in general.

The reference station located at a known position has a GPS/GLONASS receiver. The receiver receives the GPS/GLONASS signal and compares the position solution from the received signal to its known location. The result of this comparison is then generated in the form of a correction message and sent to local users via radiobeacon broadcast. The received correction is applied by user GPS/GLONASS receiver to improve the accuracy of position. The general functions of DGNSS system are the pseudo range measurement and correction, MSK modulation, and alarm generation. The corrections are modulated in MSK and broadcasted to users in RTCM standard format[3,5].

Marine radiobeacon is generally used to transmit the corrections. In order to verify the tolerance of the broadcast corrections, integrity monitor receives the broadcast corrections. And then it checks the accuracy of DGNSS position, modulated signal, message stream, etc. If there are any problems, it should generate alarms to users through the reference station. In fig (1), the basic DGNSS system is shown. It involves the control station, communication link which are additional equipments in DGNSS system.

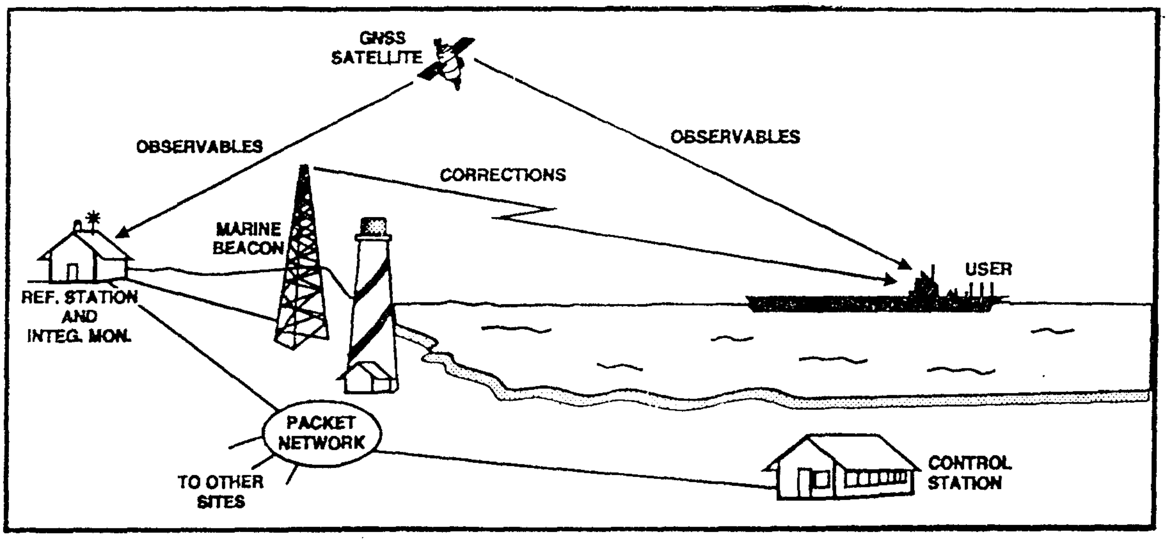


Fig.1 The basic DGNSS system

It could be possible that the connection of the reference station and integrity monitor by several communication links types such as a telephone, a switching network and radio frequency. The communication link can be also connected to a control station. The control station receives various types of data from the reference station and the integrity monitor. Using the data provided from them, it manages the modes of operation, alarm threshold and interval and equipment parameters. Further, it is also possible to monitor the problem of the whole DGNSS system by a remote control. To do this, it should be necessarly to run the appropriate software to manage the right operation of the reference station.

RTCM SC-104 Standard for DGNSS

The differential GPS standard developed 10 years ago by Radio Technical Commission for Maritime Services Special Committee-104(RTCM SC-104) has found extensive use worldwide. Radiobeacon broadcasts of differential GPS corrections in the United States, Canada, and Europe use the RTCM format[6,7,8,9] to support harbor and harbor approach navigation. It is also used for vehicle navigation and tracking throughout the world.

The first version of the standard was intended to provide a temporary reference so that experience with the operation could be gained before the final standard was established. Version 2.0 of the standard was published in 1990. Functionally, it was very similar.

Version 2.1 of the standard, which was published in January of 1994, added a number of new messages to support real-time kinematic operation, which provides decimeter-level relative positioning accuracy. It also fixed previously defined tentative messages supporting radiobeacon operation and providing satellite constellation health.

The committee has remained active, and has expanded its scope from GPS to the more inclusive Global Navigation Satellite System(GNSS), i.e., accommodating GLONASS as well as augmentations of these systems. In Version 2.2, which will be published soon, several new messages that support differential GLONASS operations have been introduced.

System Characteristics for DGNSS

The carrier frequency of the differential correction signal of a radiobeacon station is an integer multiple of 500Hz. Frequency tolerance of the carrier is ±2Hz. The general message format is Fig.2 which details the first two 30 bit words of each frame or message type. Each frame is $N+2$ words long, N words containing the data of the message. The minimum message types available for transmission are as shown in Table 1. Details of these message type contents and formats are as shown in references[10] for GPS and GLONASS.

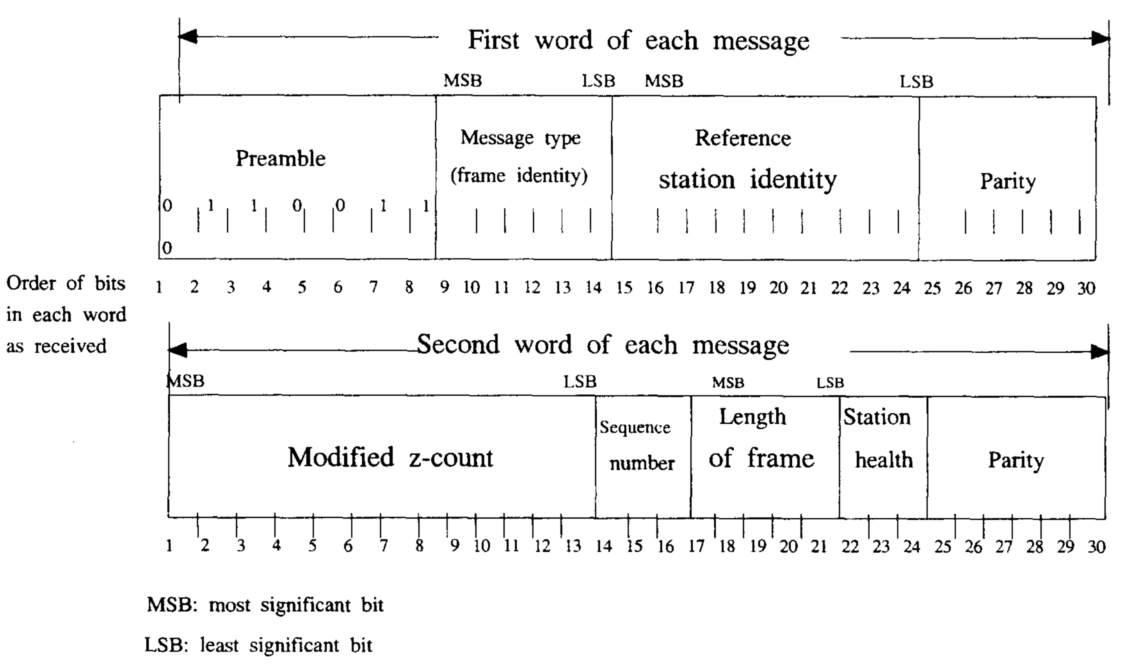


Fig.2 Two-word header for all messages

Table 1. Message types of DGNSS

GPS Message type number	Title	GLONASS Message type number
1	Differential GNSS corrections(full set of satellites)	31
2	Delta differential GNSS corrections	
3	Reference station parameters	32
5	Constellation health	33
6	Null frame	34 (N=0 or N=1)
7	Radio beacon almanacs	35
9	Subset differential GNSS corrections (this may replace Types 1 or 31)	34 (N>1)
16	Special message	36

The Message Schedule for Transmission of DGNSS

Table 2. The transmission of DGPS correction

Type	Rate
9 or 1	Should be broadcast as often as possible.
3	Should be broadcast at least twice every hour and after any change in reference station location.
5	Should be broadcast at 5 minutes past the hour and every 15 minutes thereafter.
6	Should be broadcast as required.
7	Should be broadcast at 15 minute intervals and after any change in broadcast station data. The message should include data on adjacent beacons.
16	Should be broadcast as required.

Table 2 contains the message schedule for transmissions of DGPS corrections and Table 3 contains the message schedule for the transmission of DGPS and DGLONASS corrections when they are broadcast from the same radiobeacon station.

The Status and Coverage of DGNSS in USA

The USCG DGPS Navigation Service is designed to provide coverage at the specified levels for all harbor and harbor approach areas and other critical waterways for which the U.S. Coast Guard provides aids to navigation. Montauk Point began the first continuous public U.S. DGPS broadcast on August 15, 1990. This transmission marked the beginning of the U.S. Coast Guard transition from DGPS research and development towards implementation of a U.S. maritime differential GPS service.

In 1995, the Coast Guard DGPS system began operation under a reoperational phase. This phase was used to operationally test and evaluate system performance. As a result, much was learned and many improvements to the DGPS service will be made over the next few years[3].

Table3. The transmission of DGNSS correction DGPS

GPS		GLONASS	
TYPE	RATE	TYPE	RATE
9 or 1	Should be broadcast as often as possible (approximately every 15-20 s)	34(N>1) or 31	Should be broadcast every 50-60 s
3	Should be broadcast at 15 minutes and 45 minutes past each hour	32	Should be broadcast at 15+1 minutes and 45+1 minutes past each hour
5	Should be broadcast at 5 minutes past each hour and every 15 minutes thereafter	33	Should be broadcast at 5+1 minutes past each hour and every 15 minutes thereafter
6	Should be broadcast as required	34 (N=0 or N=1)	Should be broadcast as required
7	Should be broadcast at 7 minutes past the hour and every 15 minutes thereafter	35	Should be broadcast at 7+1 minutes past the hour and every 15 minutes thereafter
16	Should be broadcast as required	36	Should be broadcast as required

On January 30, 1996, DGPS entered the Initial Operational Capability(IOC) phase in which the service is available for positioning and navigation. During IOC, enhancements to control station software and hardware will be accomplished, radiobeacon antennas will be upgraded to meet mission goals, transmitters will be replaced with new state-of-the-art equipment which operate with battery backup, and the DGPS service will undergo validation. All the while, coverage will be provided throughout North America with high time availability. Upon completion of IOC, the DGPS service will be declared Full Operational Capability(FOC) meeting all availability accuracy, integrity, and reliability performance requirements. Present needs and plans do not call for utilization of signals from GLONASS. The USCG DGPS sites are located in Atlantic and Gulf Coast, Great Lakes Region, Inland River Region, West Coast Region, Alraska, Pacific Coast, and Hawaii. Currently(April, 1996) 50 sites are providing corrections to user. The sites broadcast the correction message in 100bps or 200bps of the transmission rate. And the sites serve in various coverages depended on their specfications locally. The coverage is 50 to 180nm.

The Role of DGNSS for International Users

The U.S. Coast Guard will continue to fully cooperate on international fronts with the International Association of Lighthouse Authority(IALA) and the International Maritime Organization(IMO) to achieve global DGPS commonality. Nationally, the U.S. Coast Guard is consulting with other agencies to adapt the DGPS service to meet their needs. Agencies active in DGPS include the National Geodetic Survey(NGS) for inland surveying, the National Oceanic and Atmospheric Administration(NOAA) and the National Fish and Wildlife Association for hydrographic surveying, the Army Corps of Engineers(ACE) for dredging and coastal construction, the Department of Interior for natural resource mapping, the Federal Highway and Federal Railroad Administrations to name just a few.

The Status and Coverage of DGNSS in Russia

The implementation of DGLONASS and DGPS networks has been carried out by Russian Institute of Radionavigation and Time(RIRT), St. Petersburg, ordered by the Lighthouse Service of Head Department of Navigation and Oceanography of Ministry of Defence of Russian Federation(HDNO MD RF), in coordination with Department of Sea and River Transport of Ministry of Transport of Russian Federation. Most of agencies and organizations related to the sea and navigation are interested in the construction of DGNSS network. But there is still a national financial problem to support the construct of the network.

However, HDNO and Ministry of Transport of RF completed the equipment of DGNSS to ensure the safety of navigation from 1994 to 1995. This program would be in the federal program of making use of GLONASS for benefit of civil users, which is being worked out by theDepartment of the Ministry of Transport as a realization of resolution of the government of RF on March, 1995. It would be the first interdepartmental program of the equipping of sea coasts in Russian Federation with DGLONASS/GPS subsystem for the benefit of safety of navigation.

In order to ensure the safety of navigation, the present program provides for working out differential corrections of GLONASS/GPS and transmitting them through radiobeacons to users. The program involves the equipment productions for carrying out the differential mode to operate DGNSS system, which are providing the necessary lebel of positioning to satisfy requirement of the each department.

According to the plan, Russia will be providing DGNSS service as follow[11]:

- Baltic sea (2 sets)
- Black sea (1set)
- Caspian sea (1 set)
- Barents and White seas (4 sets)
- North sea waterway route (8-12 sets)
- Other place (4 sets)

Until 1997, total DGNSS stations of 28-32 will be constructed in plan. The transmission rate of all reference stations is 100bps and the transmitted message types involve 1, 3, 5, 6, 7, 9, 16, 31, 33, 34, 35, 36. New message types, 31 through 36, are RTCM message types which broadcast the correction message for DGLONASS. New RTCM message type, version 2.2, which supports DGLONASS will be published soon. The service range is not clearly opened but the range may be in 100-300nm based on the predicted signal strength, 20-50 micro volt/m.

The Status of China

Maritime radiobeacons began to be operational in China early in the 1950s. During the past years there were no significant changes to their basic function and the technique except that electron tube transmitters were replaced by solid-state ones and the mechanical signal generators by electronic ones. Maritime radiobeacons have been continuing their operations in China. In the past few years, new solid-state transmitters were introduced to China and more stations were established to expand service coverage. By the end of 1995, there were total 22 operational maritime radiobeacons along coast of the islands in China[12]. Considering current status of navigating areas and the situation in adjacent countries of areas, 21 maritime radiobeacon/DGPS stations are to be located along the coast. The intergrity monitor and reference stations will be at the same site and installed simultaneously. Stations will be located as much as possible in the vicinity of ports, harbors or critical water channels. 12 existing stations will be upgraded and 9 new stations will be constructed. China also would adapt the marine radiobeacon based DGPS networks with RTCM standard format. However, it is not clear to broadcast the correction data for DGLONASS in future[12,13]. It may take time to transmit correction data for supporting DGLONASS operation. In stead the present plan is to be interested in DGPS service.

DGPS Based on Marine Radiobeacon in Japan

The broadcast of DGPS correction message superimposed on the marine radiobeacon signal for test has been carried out since December 1995 at two radiobeacon stations(Turugi-saki, 35° 08' N, 139° 40' E and Daioh-saki Point, 34° 16'N, 136° 54' E). The carrier frequencies are 309Khz and 288Khz, respectively. Their output power and transmission rate are 130W and 200bps. In addition to these two stations, five more stations will service the correction data by end of 1997.
The 18 marine radiobeacon stations, which are currently operating along the Japanese shores, are preparing to begin the differential data in future. Two more stations are preparing for the aid to harbor navigation in Tokyo and Nagoya Ports. Totally 27 DGPS broadcasting networks will be completed by Japanese Marine Safety Agency until beginning of 2000. The coverage is about 100nm. Fig.3 shows the coverages of DGNSS Network in Northeast of Asia[1,11,14,15].

Other Countries

There are many countries which are operating, testing and planning DGNSS networks using marine radiobeacon in the world. All stations of the countries are broadcasting RTCM messages in 100 or 200bps. Although the list in ref.[16] shows the reference numbers of the countries, the more additional stations may be constructed in the future. The reference stations of United Kingdom and Republic of Ireland, Sweden and France are operational in a coded format. Therefore, vessels will need specialized equipment in order to utilize these aids. The reference stations are at least included in type 1 or type 9.

Overview of DGNSS in Korea

A maritime radiobeacon/DGPS system should be established along the coast of Korea in order to satisfy the requirement of navigators sailing on our major harbor waters, critical fairways and offshore waters.
As mentioned previously, usage of DGNSS is a recent trend in the world. Most of countries to construct DGNSS network would follow a direction of the RTCM recommendations to standardize

the system internationally.

In Korea, DGPS correction data has not been broadcasted before 1996. In early 1996, a DGPS message was begun to send from Changgi Gap Lighthouse. It was the first test broadcast of DGPS correction data based on midium frequency of marine radiobeacon whose transmission power and rate are 300W and 100bps, respectively. The service coverage is roughly 100nm. In Korea , the responsibility to construct the network of DGNSS along the coast of Korea has been vested on the government. However, it has not studied that the detail on accuracy related to coverage, fild strength and other characteristics of transmission of the correction data. Due to the rapid development of DGNSS technique and various users' requirements, the network of DGNSS seems to be constructed in a few years. Marine application of DGNSS in Korea seems more obvious as the government office have thought of these in mind. In order to set up the network, the ploblem may be where the reference stations are located and how to satisfy the accuracy and the coverage of various users in marine activities.

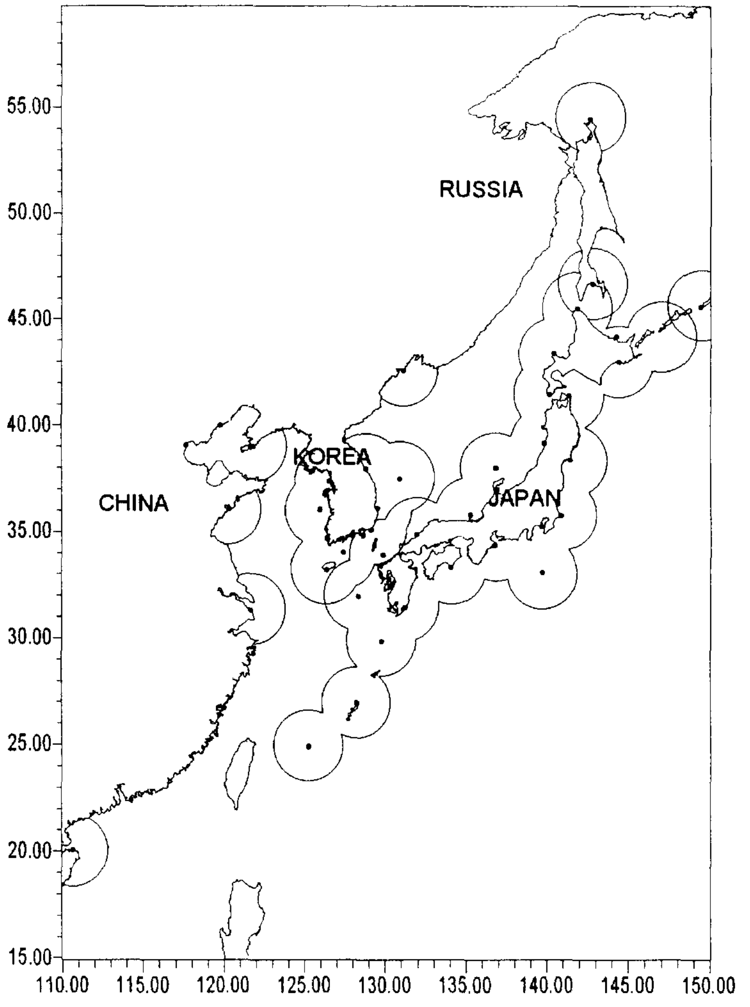


Fig. 3 The predicted coverage of DGNSS network in Northeast Asia

Radiobeacon Stations in Korea

There are 7 operating marine radiobeacons along the coast of Korea currently. All are located in the lighthouse along coast or on the island. The locations of the radiobeacons are shown in table 4. The 7 air radiobeacons are also activated for air navigation in Korea. The radio frequency of radiobeacons of marine and air is in medium frequency band. The coverage of the radiobeacons is generally in 100nm.

At this point, the coverage of marine radiobeacon/DGPS is only considered. The service of the radiobeacons can cover most of harbors and coastal areas in Korea. However, it does not cover area of Ulnung Do, Bakyung Do and Mara DO. Accordingly, if the present radiobeacon stations are used to install the equipments of DGPS, the resolution on some shadow zone should be considered to ensure the safety of navigation and the economic activity in ocean. A possible way is to overcome such lack of coverage is that the several locations of the current stations move into new places. Therefore the stations of Changgi Gap and Chuk Do may be considered to be moved into Ulnung Do and Mara Do, respectively[1,2].

Table 4. Marine Radiobeacon in Korea

STATION NAME	POSITION	FREQUENCY(KHZ)	TRANSMISSION POWER(W)	COVERAGE(nm)
Chumunjin	37 53.7 128 50.2	295	150	100
Changgi Gap	36 04.5 129 34.3	310	150	100
Yong Do	35 02.9 129 05.6	300	100	100
Geomun Do	34 00.2 127 19.5	287.5	150	100
Chuk Do	34 13.4 125 58.1	290	150	100
Eocheong Do	36 07.2 125 58.1	295	150	100
Palmi Do	37 21.3 126 30.8	313	150	100

Table 5. Air Radiobeacon in Korea

STATION NAME	POSITION	FREQUENCY(KHZ)	TRANSMISSION POWER(W)	COVERAGE(nm)
Sokcho	38 08.4 128 36.0	378	400	100
Ulsan	35 35.3 129 21.5	317	400	100
Sachon	35 05.7 128 04.8	222	100	100
Yosu	34 50.5 127 37.3	396.5	200	100
Cheju	33 30.7 126 32.5	375	400	100
Cheju	33 27.6 126 23.9	335	50	100
Mokpo	34 45.3 126 23.2	267	400	100

In the case, a shadow zone around Changgi Gap is occured. Therfore, a new reference station should be constructed in Ulnung Do without moving the Changgi Gap station to the place. In addition, it can be a possible consideration that Palmi Do station is moved to the west in order to cover Backyoung Do region, however, it would not be a feasible way because the differential service will be required to users who will increase in narrow channel and waterways in the future. Due to the reason, it looks better for the station of Palmi Do to be located in the present position. The reference stations recommended by Dr. Chung[1,2] are shown in Fig (4). Still the critical shadow zone occurs around the west region of Mokpo. It also should be investigated. To cover the zone, it is not necessary that an additional station is constructed around the place. In stead, it can be a way that the transmission power of several stations(Eocheong Do and Mara Do) increase. Otherwise, the air radionavigation located may be a role as a reference station.

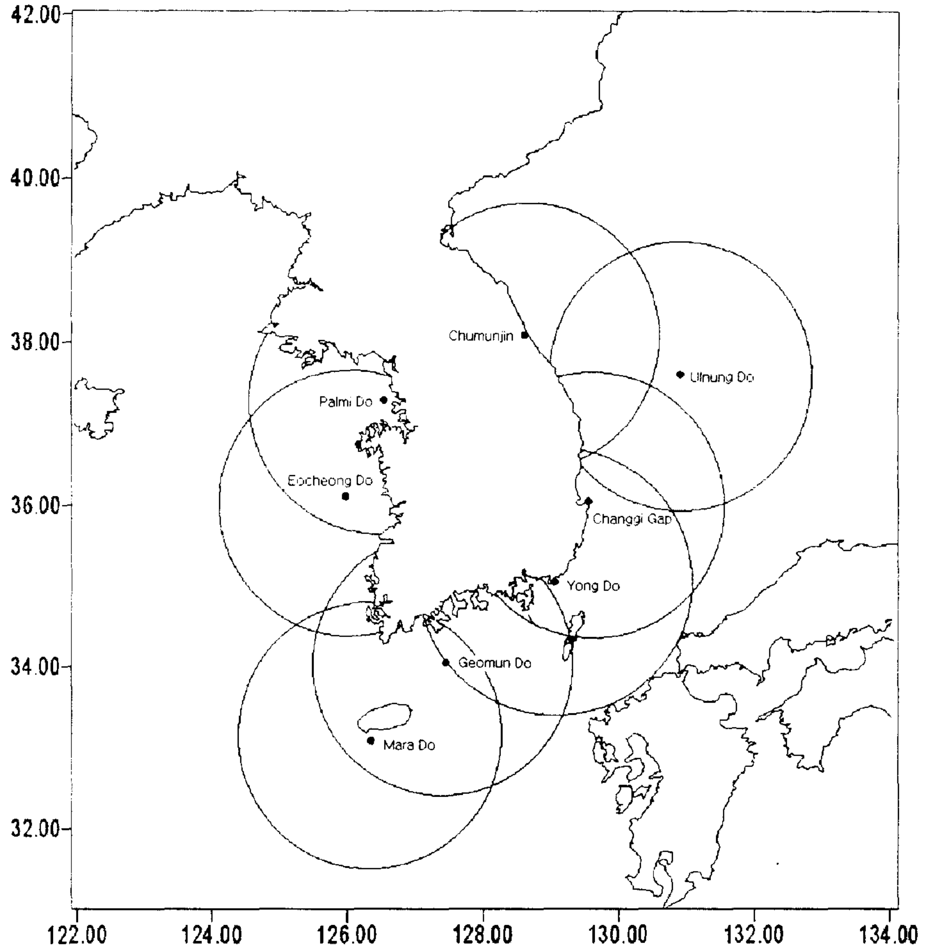
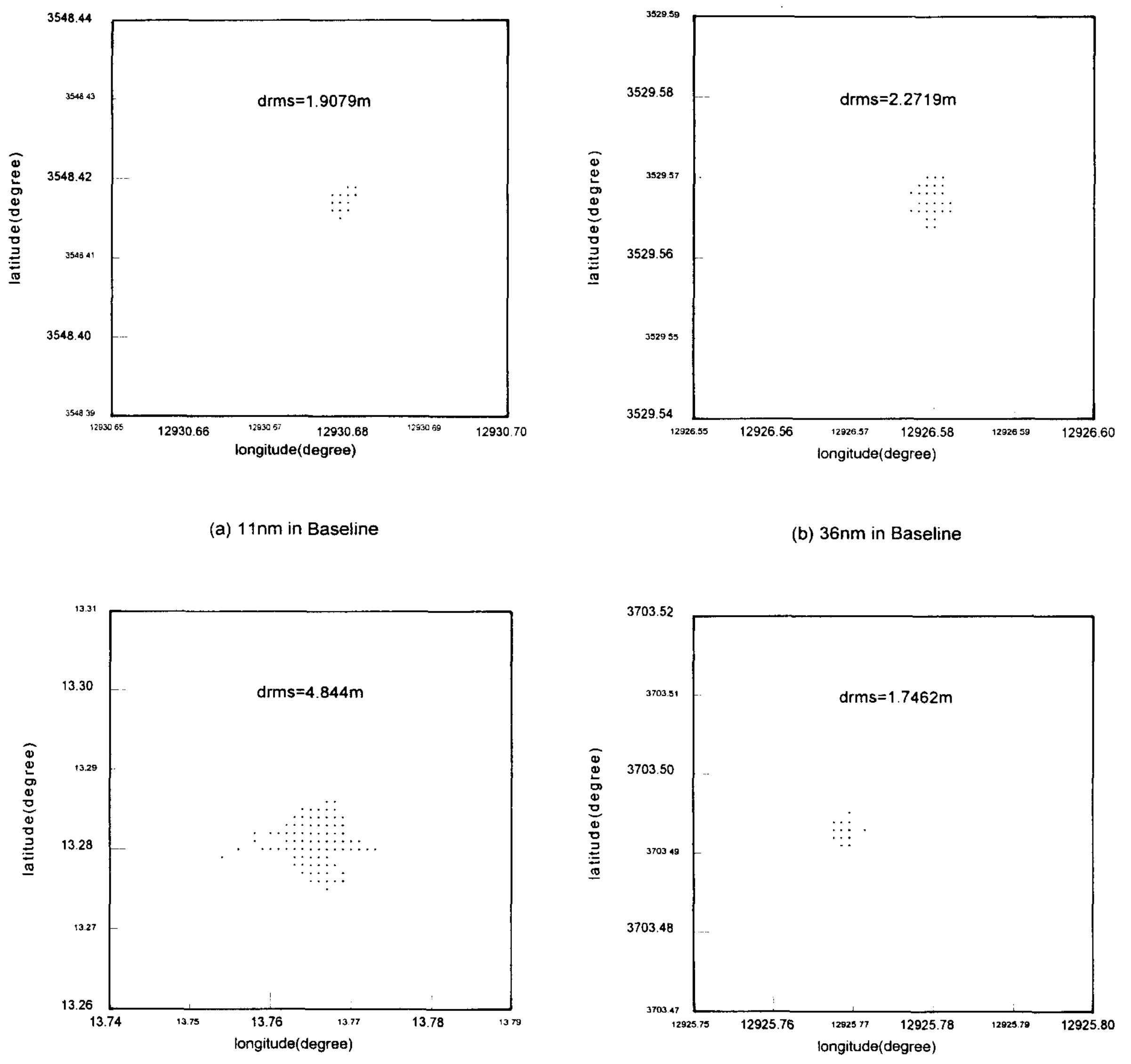


Fig. 4 The recommeced reference stations of DGNSS

Test and Result Using Marine Radiobeacon/DGPS in Korea

Trial transmission of DGPS correction message(Type 9) is superimposed on the radiobeacon at Changgi Gap station. The test was carried out along the eastern coast of Korea for 4 days in various baselines. To analyze the positioning accuracy, the real time differential corrections in RTCM data was collected in an implemented system. And then we evaluated the positioning accuracy related to the coverage of the radiobeacon/DGPS. In the test, we choosed the lighthouses located along the coast as a static point. In case of existing natural blocks due to geographical features, SNR was not enough to receive the DGPS signal even in short baseline. In the case, differential mode of the receiving system was not operated. In fig (5), the positioning accuracy is shown based on the baseline from the reference station to the receiving points.

As the result of the test we recognize that positioning accuracy of radiobeacon/DGPS in Korea is sufficent to give users 10m accuracy.



(a) 11nm in Baseline

(b) 36nm in Baseline

(c) 55nm in Baseline

(d) 60nm in Baseline

Fig. 5 The result of experimental test for positioning accuracy

Summary & Conclusion

In accodance with the requirement of IMO, the accuracy of positioning for harbor and harbor approach must be provided no less than 10 meters. DGNSS may be the most feasible system to users who need the precise positioning in the future.

There are many countries which are operating, testing and planning DGNSS network based on marine radiobeacon in the world.

In early 1996, it was begun to send differential correction messages from a marine radiobeacon station located in Changgi Gap Lighthouse in Korea. It was the first test broadcast from DGNSS based on a marine radiobeacon in Korea.

In the paper, we have investigated the status of DGNSS in the world and characteristics of transmission messages based on a new RTCM standard fromat for DGNSS. And then the predicted DGNSS network of Korea was studied. In addition, the positioning accuracy was examined using real differential corrections broadcasted from the reference station.

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