PRECISE DETERMINATION OF STATION COORDINATES OF LORAN-C NORTHWEST PACIFIC CHAIN †

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Abstract

The government of Japan took over the operation of Loran-C northwest Pacific chain from the government of the United States of America in 1994. Because the Barrigada (Guam) station which located in the territory of the US was not transferred to Japan, the configuration of the stations was changed, that is, the master station was moved from Iwojima to Niijima in October 1994 and the Iwojima station was terminated. The precise coordinates of these stations except Guam one in WGS 84 as well as in Tokyo Datum are determined on the basis of the results for the marine geodetic control network of the Hydrographic Department of Japan.
keywords : Loran-C, northwest Pacific chain, coordinates

1. Introduction

Several years ago, the government of the United States of America declared that the operation of Loran-C system except in the territory of its own country would be terminated by the end of 1994. The government of Japan negotiated with the US and the Maritime Safety Agency of Japan took over the operation of Loran-C northwest Pacific chain in 1994.

Since the Barrigada (Guam) station was not transferred to Japan and was terminated in 1993, it was decided to change the configuration of the stations (Fig. 1). The master station was newly constructed at Niijima and the operation began in October 1994. Iwojima station was terminated instead.

In order to utilize the new system with sufficient precision and to cooperate with other countries, precise coordinates of these stations in the world-wide geodetic system are needed and surveys of the transmitting antennas of these stations were conducted by the Hydrographic Department of Japan (JHD) based on the results of control points determined in the project of establishing the marine geodetic control network. The method and results are described in this report.

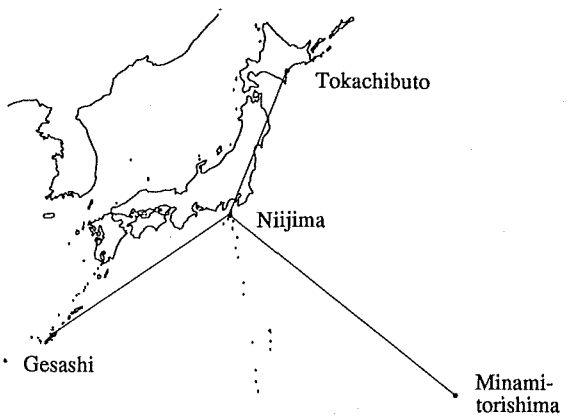

Fig. 1. New configuration of Loran-C northwest Pacific chain.

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2. Method of position determination

(1) Marine geodetic control network

Regulations to delineate the boundaries of the jurisdictional sea such as the territorial sea or the exclusive economic zone are provided in the United Nations Convention on the Law of the Sea. JHD commenced a project to establish the marine geodetic control network in 1980 utilizing methods of satellite geodesy (Kubo, 1988).

In this project, satellite laser ranging (SLR) is conducted at Simosato Hydrographic Observatory (located in Wakayama prefecture) in cooperation with other SLR stations distributed world-wide and the coordinates of the fiducial point at Simosato Hydrographic Observatory are determined precisely in the world-wide coordinate system.

First order control points in off-lying islands of Japanese territory are connected to the fiducial point at Simosato by simultaneous SLR observations of Japanese geodetic satellite Ajisai. Second order control points are connected to first order control points by simultaneous observations of Navy Navigational Satellite System (NNSS) and of Global Positioning System (GPS) lately. The coordinates of first and second order control points are thus determined in the world-wide coordinate system.

Among the stations of Loran-C northwest Pacific chain, Tokachibuto (Hokkaido), Gesashi (Okinawa), Minamitorishima (Marcus island), and the former Iwojima station are placed near first order control points and the coordinates of these nearby first order control points have already been determined by SLR method.

The position of the new master station at Niijima was determined by GPS observations of static differential method.

(2) Differences of coordinate systems

Constructing a world-wide geodetic system became realized after launches of artificial satellites and many kinds of world-wide geodetic systems have been reported since then. Differences among recent models are less than one meter and efforts to improve these systems are continuing according to the increase of satellite observational data. Among them two systems are used frequently. One is WGS 84 which is used for GPS, NNSS and Loran-C operated by US (DMA, 1991). The other is IERS Terrestrial Reference Frame (ITRF) used in the scientific community (Boucher and Altamimi, 1989). IERS stands for International Earth Rotation Service.

The coordinate system used for the reduction of satellite data in JHD (called JHDSC) is almost identical to ITRF. Differences between them are within ten centimeters level (Sengoku, 1992). WGS 84 is also nearly identical to ITRF and differences between them are reported to be fifty centimeters level (McCarthy, 1992). While these three coordinate systems are different in the scientific sense, they can be regarded as identical in the practical sense considering the precision of positioning by Loran-C. So, we take the results of marine geodetic control network as the coordinates in WGS 84 in this report.

In Japan, a unique coordinate system which covers the mainland and a part of Okinawa islands was developed and is called Tokyo Datum (TD). Since the coordinates of the origin of TD was determined by astronomical observations, the adopted values are known to have a difference from the values in world-wide coordinate system which amount to ten seconds of arc in both latitude and longitude. In addition to these

differences, because TD was constructed through conventional triangulation method, there are distortions of triangulation network which are known to reach more than ten meters in Hokkaido and Okinawa regions.

Relations between TD and the world-wide coordinate system can be obtained if both coordinates are known at the same point. We adopt the translation parameters obtained at Simosato (Tatsuno and Fujita, 1994).

Coordinates which are transformed from the world-wide coordinate system by using these translation parameters are close to the coordinates of TD but differs from TD because of the distortions existing in TD. We call this transformed coordinate system as Corrected Tokyo Datum (TDC) to distinguish it from TD in this report.

3. Observations of coordinates of Loran-C antennas

(1) Niijima

GPS Observations to connect a triangulation point in Niijima to GPS network of our Department in Sagami Bay area were conducted in 1992 (Takanashi et al., 1994). Coordinates of the GPS antennas in Sagami Bay area had been determined through other GPS observations with Simosato in 1992. Coordinates of Loran-C antenna at Niijima from the nearest triangulation point were surveyed by the 3rd Maritime Safety Regional Headquarters in 1992. The coordinates of Loran-C antenna in Niijima in WGS 84, TDC and TD are listed in Table 1.

(2) Tokachibuto (Hokkaido)

Observations of first order control point in Tokachi were conducted in 1991 and coordinates of the point were obtained (Sengoku and Uchiyama, 1994). Coordinates of Loran-C antenna at Tokachibuto had been surveyed in TD from the nearest triangulation point in 1983 (Takemura and Sawa, 1985). The results are also listed in Table 1.

(3) Gesashi (Okinawa)

Observations of first order control point in Okinawa were conducted in 1989 and coordinates of the point were obtained (Sengoku et al., 1992). Coordinates of Loran-C antenna at Gesashi had been surveyed in TD from the nearest triangulation point in 1992 by the 11th Maritime Safety Regional Headquarters. The results are listed in Table 1.

(4) Minamitorishima (Marcus island)

Observations of first order control point in Minamitorishima were conducted in 1989 and coordinates of the point were obtained (Sengoku et al., 1992). Relations between newly established control point and the Loran-C antenna at Minamitorishima had been surveyed in 1982 (Takemura and Kanazawa, 1984) and were surveyed again in 1989. Because the position of this isolated island had been determined independent from TD, coordinates of Loran-C antenna in Minamitorishima are listed in WGS 84 and in TDC in Table 1.

(5) Iwojima

Observations of first order control point in Iwojima were conducted in 1992 and coordinates of the point were obtained (Sengoku and Uchiyama, 1994). Coordinates of Loran-C antenna had been surveyed in the local datum in 1982 (Takemura and Kanazawa, 1984). The coordinates of the former Loran-C antenna in Iwojima in WGS 84 and in TDC are listed in Table 1.

Table 1. Coordinates of Loran-C antennas including the former Iwojima station in WGS 84, TDC and TD.

		WGS84	TDC	TD
Niijima	latitude(N)	34° 24' 11.942"	34° 23' 59.778"	34° 23' 59.711"
	longitude(E)	139 16 19.478	139 16 30.802	139 16 30.844
Tokachibuto	latitude(N)	42 44 37.219	42 44 28.041	42 44 28.013
	longitude(E)	143 43 09.754	143 43 23.940	143 43 23.722
Gesashi	latitude(N)	26 36 25.038	26 36 10.624	26 36 11.041
	longitude(E)	128 08 56.920	128 09 04.096	128 09 03.779
Minami-torishima	latitude(N)	24 17 08.007	24 16 50.922	---
	longitude(E)	153 58 53.779	153 59 07.679	---
Iwojima	latitude(N)	24 48 03.661	24 47 47.782	---
	longitude(E)	141 19 30.814	141 19 41.669	---

4. Discussions

As stated in section 2(2), we neglected the differences among JHDSC, ITRF and WGS 84 in this report. Strictly speaking, any coordinate system established on the surface of the earth is changing all the time because of plate motions on world-wide scale and crustal deformations on regional scale. If we stick to the accuracy of centimeter level, we must indicate the time that the coordinate system is referred such as ITRF 90, ITRF 91 etc. Time differences of observations of first order control points are also neglected in this report.

Japan is located in an especially active tectonic region. Recent monitoring of crustal deformations by static DGPS observations revealed that crustal deformations associated with major earthquakes often reach tens of centimeters even if epicenters are under sea-bottom hundreds of kilometers apart from coast. Considering such circumstances, we must repeat observations of these positions and revise the results at appropriate intervals in order to keep up accuracy of coordinates of Loran-C antennas in ten centimeters level.

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ロランC北西太平洋チェーン局の正確な位置の決定

(要旨)

金沢輝雄

ロランC北西太平洋チェーン局の配置は、米国から日本への移管に伴い、1994年に変更された。水路部では、海洋測地の推進業務の中で得られた離島の基準点の位置を基に、これらのロランC局の正確な位置を世界測地系と日本測地系の双方で決定したので、その手法と成果について報告する。