Accuracy of the Position by Automatic Loran-C Receiver in the East Sea and Southern Sea of the Korean Peninsular

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A series of observations was conducted in order to study the accuracy of the position by automatic Loran-C navigation system with two Loran-C chains, namely 5970 and 9970 Chain, in the East Sea and Southern Sea of the Korean Peninsular from July to September 1986.

Diurnal variation of positional error measured by 5970 Chain was almost stable throughout a whole day, and it was fairly stable in the daytime but fluctuated more or less by night at each station by 9970 Chain.

Daily mean values of positional error by 5970 Chain were 6'.44 SW at Ulreungdo, 0'.22 SE at Jugbyeon, 0'.91 NE at Guryongpo, 0'.37 SE at Pusan, 0'.30 SE at Yokchi, 0'.37 NW at Cheju and 12'.51 SE at Taeheuksan.

By 9970 Chain, they were 0'.27 SW at Ulreungdo, 0'.27 SE at Jugbyeon, 0'.09 SW at Guryongpo, 0'.19 SE at Pusan, 0'.16 SE at Yokchi, 0'.17 SE at Cheju and 0'.52 SE at Taeheuksan.

Introduction

The automatic Loran-C receiver is a navigation system which is designed to be served within the range of 1,200 nautical miles from the transmitting stations by utilizing ground wave only to put emphasis on improvement of ship's position.

However, Loran-C pulse wave transmitted is 100 KHz of low frequency, so that the phase velocity of Loran-C signal is constant when it is propagated over the sea surface, but the phase velocity error increases under the influence of ground conductivity if propagation path over the ground becomes longer.

On the other hand, the atmospheric noise makes the signal-to-noise ratio increase rapidly at low frequency. Error of Loran-C LOP is affected greatly by the atmospheric noise, and it varies according to latitude, season and time[1].

Consequently, bringing light on error distributional phase of this system by the sea area, season and daily time zone is a very important subject for efficient fishing operation and safe navigation.

Many researches concerning the accuracy of Loran-C navigation system within limited areas were already made[2)~7)], and Kenji et al.[8)~11)] presented the realizable possibility of the full automatic Loran-C navigation system by employing the pocket calculator.

In order to evaluate the macroscopic error distributional phase of this system, the authors carried out 24 hours definite point observation at the seven stations selected in the East Sea and Southern Sea of the Korean Peninsular from July to September 1986 by means of the full automatic Loran-C receiver(LC-86) which was developed very recently and has been come into wide use on the coastal fishing vessels.

Materials and Method

1. Equipments and observation stations

The automatic Loran-C navigation systems(LC-86, Furuno) fitted on the training ship Pusan 403 (280톤) and Pusan 404(160톤) which belong to the National Fisheries University of Pusan were employed as the observation equipments. This receiving system searches and tracks Loran-C pulse waves automatically to measure time difference between the master and slave stations. This system also furnishes necessary informations such as the present position, ship's speed and true course etc. continuously by the computer program inserted, and it is a very convenient instrument because the processes of modulating wave mode, LOP interpolation and plotting on Loran chart are not required.

The operational procedure and principal functions of this system are shown in Fig. 1.

The location of observation stations and the disposition of Loran-C pulse wave transmitting stations employed for observation are shown in Fig. 2, and Table 1 shows the positions of observation stations which are datum positions for calculation

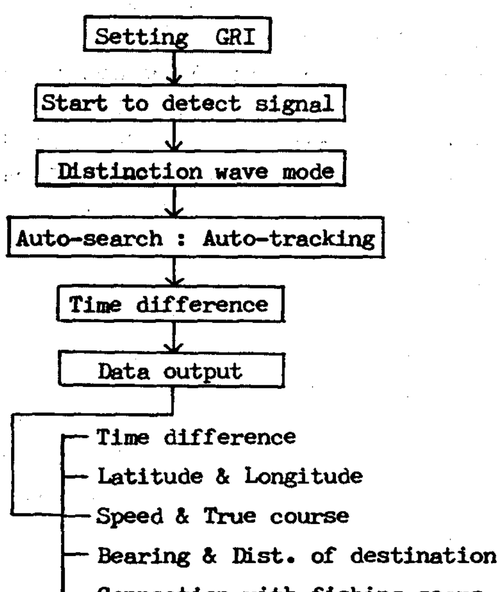

Fig. 1. Principal functions of the full automatic Loran-C navigation system

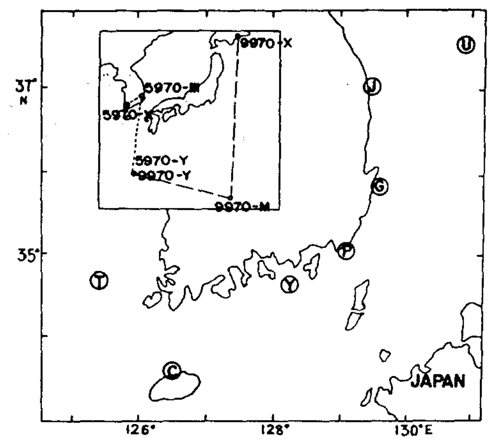

Fig. 2. Location of observation stations and the disposition of Loran-C transmitting stations employed for observation
Ⓤ: Ulreungdo, Ⓙ: Jugbyeon, Ⓖ: Guryongpo,
Ⓟ: Pusan, Ⓨ: Yokchi, Ⓒ: Cheju,
Ⓣ: Taeheuksan

Table 1. Datum positions of observation stations obtained from harbour chart

Obs. station	Latitude(N)	Longitude(E)
Ulreungdo	37°29′.87	130°54′.73
Jugbyeon	37°03′.30	129°25′.38
Guryongpo	35°59′.15	129°33′.50
Pusan	35°07′.15	129°03′.37
Yokchi	34°37′.87	128°16′.27
Cheju	33°31′.07	126°32′.05
Taeheuksan	34°40′.95	125°26′.67

of positional error.

It can be presumed that the ground wave, without any mixture of sky wave, was used for the position fix, because all the seven observation stations are located within 1,000 nautical miles from the transmitting stations of two Loran-C chains.

2. Observational method

As a preliminary observation, it was ascertained that the data obtained from simultaneous observation with the same chain at the same station by the same type of receivers fitted on both training ships had no difference in value compared with each other.

Latitude and longitude with time differences indicated continuously on the receiver indicator were recorded at every ten minutes throughout a whole day by employing M-X and M-Y pairs of 5970 Chain on Pusan 403 and the same pairs of 9970 Chain on Pusan 404 respectively. The research activity was made to minimize the variation of positional error resulted from weather condition, two ships were made alongside each other at the same wharf, and then observation activity was performed simultaneously on both ships.

Datum positions were obtained from harbour chart.

Positional errors at each station were analyzed by comparing datum positions with the obtained positions which had been transformed to the Bessel geodetic system without any corrections of local magnetic attractions[12].

All operations of the electro-navigational equipments including radar were suspended during observation for the purpose of minimizing the interferences from jamming or induction disturbances with the exception of atmospheric noise.

Results and Discussion

1. Diurnal variation of positional error

Fig. 3 shows the phase of diurnal variation of positional error by chain at each station. By 5970 Chain, daily mean value reached to 12′.5 and positional error fluctuated remarkably by night at Taeheuksan, while, it was fairly stable during day and night at Ulreungdo to be daily mean value of 6′.4 with the exception of striking fluctuation at sun-rise and set. The reason of showing high fluctuation with large value of positional error at Taeheuksan and Ulreungdo can be explained that these stations are located very closely to the base line extension of M-X pair of this chain[1].

Daily mean value at Guryongpo was 0′.9 showing slight fluctuation by night, but very stable in the daytime. At the other stations, daily mean values were not exceeding 0′.4 with stable state on the whole through day and night.

On the other hand, by 9970 Chain, it was found

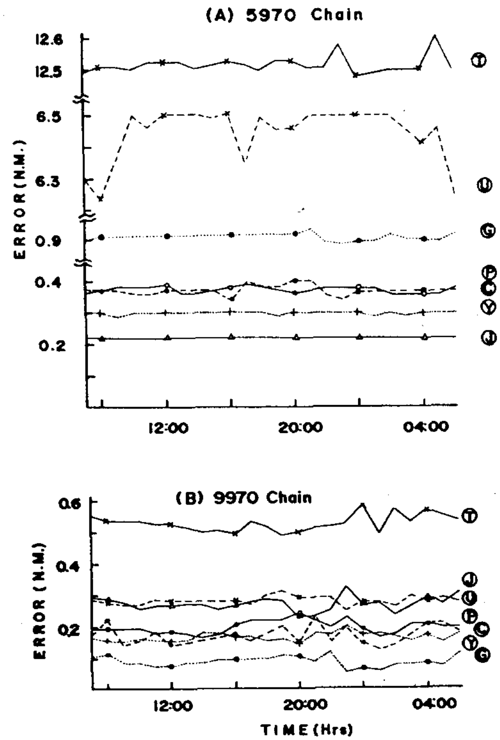

Fig. 3. Diurnal variation of positional error at each station(nautical miles)

that the receiving state was stable in the daytime with the exception of slight fluctuation by night at all stations.

Daily mean values were 0′.5 at Taeheuksan and less than 0′.3 at the other stations. This phenomena might be caused by the variation of atmospheric density[1].

2. Evaluation of positional error

The maximum, mean and minimum values with standard deviations of latitudinal and longitudinal error at each station are enumerated in Table 2 according to time zone and Loran-C chain separately.

A. Commando Lion Chain, GRI 5970 (5970 Chain)

Standard deviations of latitudinal error at Jugbyeon,

Table 2. Error evaluation of latitude and longitude by time zone at each station

A) 5970 Chain

Obs. Station	Obs. time	△lat. Max.	△lat. Mean	△lat. Min.	△lat. S. dev.	△long. Max.	△long. Mean	△long. Min.	△long. S. dev.
Ulreungdo	D	5.41	5.37	5.23	0.011	3.66	3.57	3.41	0.093
	S.R	5.40	5.31	5.15	0.095	3.60	3.54	3.40	0.079
	N	5.40	5.33	5.35	0.025	3.60	3.60	3.52	0.028
Jugbyeon	D	0.19	0.19	0.19	0.000	0.11	0.11	0.11	0.000
	S.R	0.19	0.19	0.19	0.000	0.11	0.11	0.11	0.000
	N	0.19	0.19	0.19	0.000	0.11	0.11	0.11	0.000
Guryongpo	D	0.25	0.25	0.25	0.000	0.88	0.88	0.87	0.007
	S.R	0.25	0.23	0.25	0.000	0.87	0.87	0.85	0.010
	N	0.25	0.25	0.24	0.005	0.90	0.86	0.85	0.017
Pusan	D	0.14	0.14	0.14	0.000	0.36	0.34	0.33	0.011
	S.R	0.14	0.14	0.14	0.000	0.36	0.34	0.33	0.013
	N	0.14	0.14	0.14	0.000	0.35	0.34	0.33	0.010
Yokchi	D	0.17	0.17	0.17	0.000	0.25	0.25	0.24	0.003
	S.R	0.17	0.17	0.17	0.000	0.25	0.25	0.23	0.009
	N	0.17	0.17	0.16	0.007	0.25	0.25	0.23	0.009
Cheju	D	0.01	0.01	0.01	0.000	0.40	0.37	0.34	0.014
	S.R	0.01	0.01	0.01	0.000	0.40	0.38	0.37	0.012
	N	0.01	0.01	0.00	0.000	0.40	0.37	0.34	0.018
Taeheuksan	D	4.31	4.30	4.28	0.009	11.76	11.75	11.73	0.009
	S.R	4.33	4.31	4.30	0.011	11.83	11.74	11.72	0.043
	N	4.32	4.30	4.28	0.015	11.81	11.73	11.70	0.036

B) 9970 Chain

Obs. Station	Obs. time	△lat. Max.	△lat. Mean	△lat. Min.	△lat. S. dev.	△long. Max.	△long. Mean	△long. Min.	△long. S. dev.
Ulreungdo	D	0.25	0.25	0.23	0.009	0.15	0.12	0.12	0.011
	S.R	0.25	0.24	0.22	0.013	0.18	0.15	0.12	0.028
	N	0.27	0.24	0.21	0.017	0.15	0.13	0.10	0.020
Jugbyeon	D	0.18	0.17	0.15	0.009	0.23	0.21	0.19	0.012
	S.R	0.20	0.17	0.16	0.014	0.24	0.23	0.21	0.012
	N	0.19	0.17	0.15	0.014	0.26	0.20	0.17	0.033
Guryongpo	D	0.05	0.03	0.02	0.010	0.10	0.08	0.07	0.010
	S.R	0.05	0.03	0.02	0.011	0.10	0.09	0.07	0.012
	N	0.05	0.03	0.02	0.012	0.10	0.07	0.01	0.029
Pusan	D	0.18	0.17	0.16	0.008	0.09	0.06	0.03	0.022
	S.R	0.20	0.19	0.18	0.009	0.09	0.08	0.05	0.016
	N	0.21	0.18	0.16	0.017	0.13	0.08	0.03	0.034
Yokchi	D	0.17	0.16	0.15	0.008	0.05	0.04	0.03	0.008
	S.R	0.17	0.15	0.13	0.016	0.05	0.03	0.01	0.020
	N	0.17	0.17	0.15	0.009	0.04	0.02	0.00	0.016
Cheju	D	0.17	0.14	0.11	0.021	0.17	0.08	0.00	0.050
	S.R	0.16	0.14	0.11	0.018	0.15	0.12	0.07	0.029
	N	0.19	0.14	0.10	0.029	0.13	0.09	0.06	0.030
Taeheuksan	D	0.44	0.43	0.42	0.007	0.34	0.30	0.23	0.034
	S.R	0.45	0.43	0.41	0.015	0.35	0.31	0.25	0.050
	N	0.48	0.45	0.42	0.021	0.35	0.30	0.26	0.033

D: daytime, S.R: sun-rise and set, N: night,
△lat.: error of latitudinal element, △long.: error of longitudinal element

Guryongpo, Pusan, Yokchi and Cheju were almost 0.000. But those of longitudinal error at Ulreungdo and Taeheuksan were enormous and variable according to time zone, while, not exceeding 0.018 at the other stations.

Standard deviations of latitudinal error were outstandingly less than those of longitudinal error at every station commonly.

This means that the reception state of latitudinal element is quite stable on account of the dispositional feature of transmitting stations and receiving points to be not far away from transmitting stations.

B. North West Pacific Chain, GRI 9970 (9970 Chain)

Standard deviation of latitudinal error was the smallest in the daytime at Taeheuksan with the value of 0.007 and the largest by night at Cheju with the value of 0.029.

But that of longitudinal error was the smallest in the daytime at Yokchi, with the value of 0.003 and the largest in the daytime at Cheju and during sun-rise and set at Taeheuksan with the value of 0.050. The distributional tendency of standard deviations at each station appeared same as in 5970 Chain, that is, latitudinal errors were smaller than longitudinal ones. The reason of fluctuational width in 9970 Chain to be larger than that in 5970 Chain is that the receiving pulse signal is fairly weak on account of long distance from the transmitting stations to receiving points. [2]

C. Biasing trend and the mean value of positional error

Table 3 shows the biasing trend and the mean value of positional error at each station.

Obtained positions by 5970 Chain were under a bias toward SW at Ulreungdo, NE at Guryongpo, NW at Cheju and SE at the other stations, while, the trend of those by 9970 Chain was SE except at Ulreungdo and Guryongpo to be SW.

The reason to be biased at each station is due to the biasing direction with intersectional angle of Loran-C LOP, that is, a LOP by M-X pair is under a bias toward north or south and by M-Y pair east or west[4].

Considering the value of positional error, it was ascertained that 5970 Chain is advantageous at only Jugbyeon, but the value can be reduced by 9970 Chain at the other stations.

Especially at Taeheuksan and Ulreungdo, by M-X and M-Y pairs of 5970 Chain, a large quantity of positional error to a dangerous extent came into existence. And so it is recommended to use 9970 Chain in these sea areas, or M-W pair of 5970 Chain must be used instead of M-X pair to improve the accuracy of ship's position around Ulreungdo.

Conclusion

In order to evaluate the macroscopic distributional phase of positional error of two Loran-C chains which are mainly employed to get ship's position within the offshore area around the Korean Peninsular, a series of observations was made at seven

Table 3. Biasing trend of mean obtained positions at each station by both chains

Obs. station	5970 chain			9970 chain		
	△lat.	△long.	△dist.	△lat.	△long.	△dist.
Ulreungdo	5'.36 S'ly	3'.57 W'ly	6'.44	0'.24 S'ly	0'.13 W'ly	0'.27
Jugbyeon	0'.19 S'ly	0'.11 E'ly	0'.22	0'.17 S'ly	0'.21 E'ly	0'.27
Guryongpo	0'.25 N'ly	0'.87 E'ly	0'.91	0'.03 S'ly	0'.08 W'ly	0'.09
Pusan	0'.14 S'ly	0'.34 E'ly	0'.37	0'.18 S'ly	0'.07 E'ly	0'.19
Yokchi	0'.17 S'ly	0'.25 E'ly	0'.30	0'.16 S'ly	0'.03 E'ly	0'.16
Cheju	0'.01 N'ly	0'.37 W'ly	0'.37	0'.14 S'ly	0'.09 E'ly	0'.17
Taeheuksan	4'.30 S'ly	11'.75 E'ly	12'.51	0'.43 S'ly	0'.39 E'ly	0'.52

stations selected by using the automatic Loran-C navigation system (LC-86, Furuno) from July to September 1986.

The results obtained are summarized as follows :

1. Diurnal variation of positional error measured by 5970 Chain was almost stable at five stations except Ulreungdo and Taeheuksan, while, it was fairly stable in the daytime and fluctuated more or less by night at each station by 9970 Chain.

2. Mean values of positional error at Pusan, Yokchi and Cheju measured by 5970 Chain were almost two times as large as those by 9970 Chain, while, Jugbyeon was the only station that it was smaller in value by 5970 Chain than 9970 Chain.

3. On the other hand, at Taeheuksan, Ulreungdo and Guryongpo, mean values of positional error measured by 5970 Chain reached to 12'.5, 6'.4, 0'.9 respectively, and accordingly it was ascertained that 9970 Chain should be used for safe navigation around these three stations.

Acknowledgement

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Accuracy of the Position by Automatic Loran-C Navigation System in the East Sea and Southern Sea of the Korean Peninsular

韓半島 東海 및 南海海域에서의 自動 Loran-C 位置의 精度

崔 宗 和 · 金 鍾 華

최근 小型電子計算機를 응용한 自動 Loran-C 航法裝置가 개발되어 沿近海漁船에 널리 보급되고 있다. 이 航法裝置의 東海 및 南海海域에 있어서의 測位誤差分布를 究明하기 위하여 釜山水產大學 實習船 부산 403호와 부산 404호에 장비되어 있는 LC-86型 受信機로써 1986년 7월부터 9월에 걸쳐, 7개 지점을 선정, 24시간 定點觀測을 행하고 誤差의 日週期變動 및 地域別 分布持性을 분석·검토한 결과는 다음과 같다.

1. 測位誤差의 日週期變動幅은 9970 Chain을 이용한 경우, 全觀測地點에서 대체로 주간에는 작고 야간에는 다소 크면서 불규칙한 반면, 5970 Chain의 경우는 鬱陵島와 大黑山을 제외하고는 큰 변화를 보이지 않았다.

2. 平均測位誤差의 크기는 釜山, 欲知, 濟州에서 5970 Chain에 의한 것이 9970 Chain에 의한 것보다 거의 2배에 가까웠으며, 竹邊에서만 5970 Chain을 이용한 것이 작았다.

3. 한편, 大黑山, 鬱陵島, 九龍浦에서는 5970 Chain의 誤差量이 각각 12′.5, 6′.4, 0′.9에 달하므로 이들 세 지점의 近海에서는 9970 Chain을 이용하는 것이 안전할 것으로 판단된다.