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**□** ARM **X** ENG **□**PAP **□** Input

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Agenda item[[2]](#footnote-2) 3.1

Technical Domain / Task Number2

Working Group 3

Author(s) / Submitter(s) CHINA MSA

**Progress on the Study of RBN-based Differential Loran-C Technologies**

# Summary

Following the project on test broadcasting of differential Loran-C information via a RNB-DGNSS station in 2019, China Maritime Safety Administration (China MSA) further expanded the research by conducting the long-term, long-distance, and multi-scenario broadcasting tests to verify the performance of differential Loran-C signals. At the same time, an industry standard on broadcast of differential Loran-C information is also under development.

This document is presented to share the latest progress of China MSA in the research of differential Loran-C technologies since 2020, including the contents, parameters and results of tests, as well as development of relevant standards.

## Purpose of the document

This document shares the latest progress on research of RBN-based differential Loran information broadcasting technologies, with the aim of providing reference for development of relevant IALA Recommendations and Guidelines as well as the further research of Loran technologies by other member states.

## Related documents

None

# Background

In order to verify and evaluate the performance of RBN-based differential Loran information in improving the positioning and timing accuracy of traditional Loran-C system, China MSA launched a project in 2019 to broadcast differential Loran-C information via a RBN-DGNSS station on a test basis. During the test, the differential Loran-C information was broadcast through a RBN station and received both at a fixed point and on board during the voyage to evaluate its performance under different conditions. The results showed that the accuracy of existing Loran-C system were significantly improved with the differential data broadcast by the RBN station, with the positing accuracy improved from the several hundred meters to dozens of even several meters, timing accuracy improved from several hundred nanoseconds to dozens of nanoseconds, and the average positioning accuracy during the voyage reaching 53 meters and the best one as high as 6.3 meters.

In 2020, China MSA continued its research on differential Loran-C technologies by further expanding the scope and duration of the test. A series of tests, including a one-year long-term test at fixed point, two tests during long-distance voyages on board and a series of multi-scenario tests were conducted to evaluate the performance of differential Loran-C information in improving the accuracy of Loran-C system under various conditions. In addition, an industry standard on broadcast of differential Loran information via RBN stations was also under development to facilitate the future study and construction of relevant systems.

# Discussion

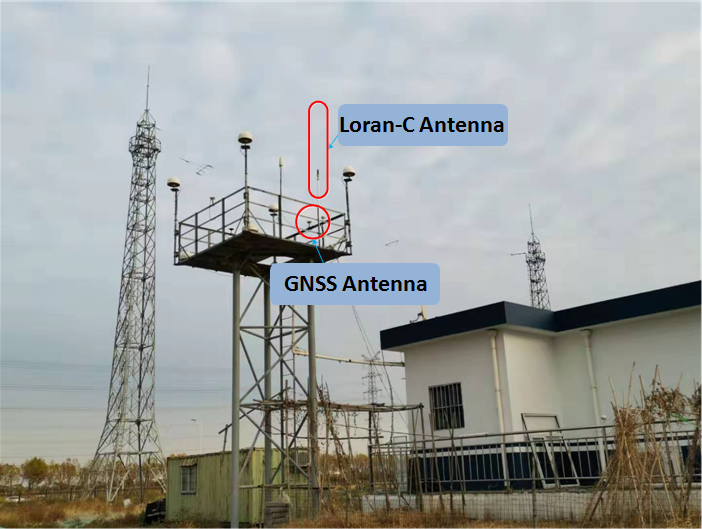
## Performance Test

## 3.1.1 Long-term Test of Differential Loran-C Performance at Fixed Point

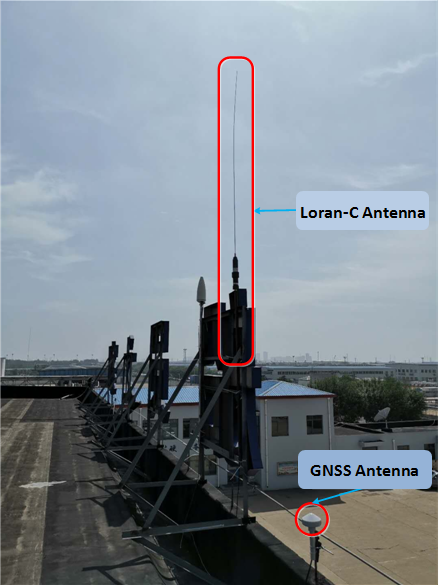
The one-year-long test of differential Loran-C performance started from August 2020, which selected Beitang RBN Station (Tianjin) to broadcast the differential Loran-C information and Nanjiang Dock, 25 km away from Beitang RBN Station, to receive differential signals as the fixed user point, in order to analyze the relevance between differential Loran-C information with time.



*Figure 1: Positional relationship of Beitang RBN Station with Loran-C stations of North Sea Chain*

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*Figure 2: Antenna Deployment at Beitang RBN Station*

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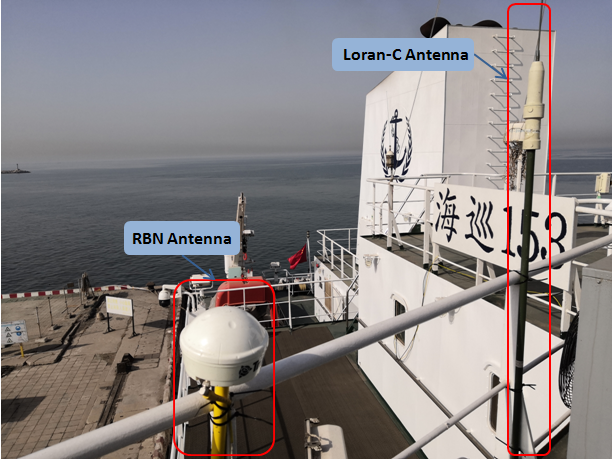
*Figure 3: Antenna Deployment at Nanjiang Dock*

## 3.1.2 Long-distance Test of Differential Loran-C Performance during Voyages

In order to collect more data to analyze the relevance of differential Loran-C information with space, dynamic tests were conducted on board during voyages: one was on M/V “Haixun 1503” buoy tender during its operations from Qinhuangdao Port (222 km away from Beitang RBN Station) to Jingtang Port (135 km away from Beitang RNB Station) on 22 August 2020, and the other was on M/V “Haixun 153” buoy tender from Nanjiang Dock (25 km away from Beitang RBN Station) to Bayuquan Port (425 km away from Beitang RBN Station) from 16 to 17 March 2021.



*Figure 4: Antenna Deployment at M/V “Haixun 1503”*

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*Figure 5: Antenna Deployment at M/V “Haixun 153”*

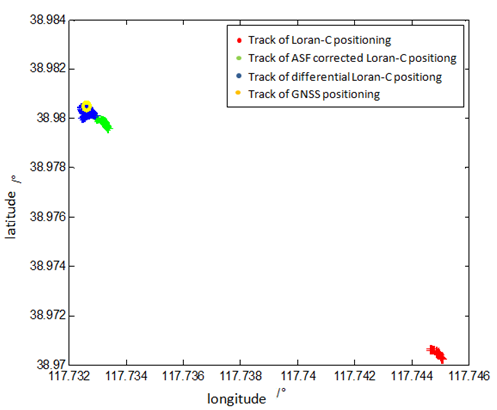
## 3.1.3 Multi-scenario Tests of Differential Loran-C Performance

Based on simulation analysis of the test results obtained in 2019, the project team defined the main contents of the multi-scenario broadcasting tests. The test lasted 26 hours from 29 to 30 October 2020, simulating different scenarios by inserting differential Loran-C message at different intervals of 2s, 5s, 10s, 15s, 1min, 5 min and 10 min to broadcast, with the purpose of analyzing the performance at different broadcasting intervals.

## 3.1.4 Test Results

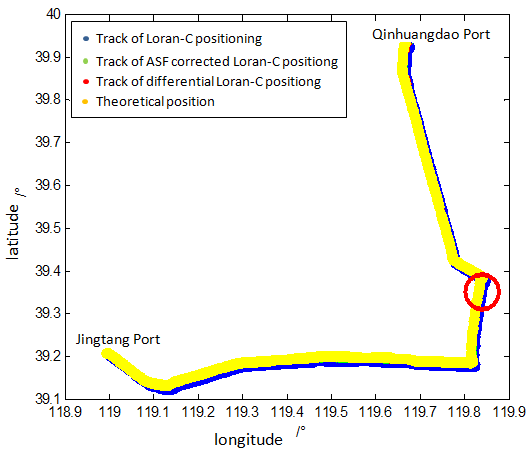
As the overall performance test is yet to be completed, and a large amount of data needs to be collected and processed, here this document will only present a part of the results that have been obtained:

As for the test at fixed point, the monitored data on 18 August 2020 was selected and processed. It showed that the positioning accuracy of original Loran-C system was improved from 1179.758m to 75.7817m after basic ASF correction, and further to 27.1609m after real-time differential correction, and the timing accuracy reached 38.8965ns after differential correction. The results demonstrated that both the positioning and timing accuracy were significantly improved after real-time differential correction.



*Figure 6: Positioning Results at Nanjiang Dock*

As for the tests at sea, the first test during the voyage from Qinhuangdao Port to Jingtang Port on 22 August 2020 showed that the positioning accuracy of the original Loran-C system was improved from 1024.5004m to 92.4488m after ASF correction，and further to 57.8538m after real-time differential correction, and the timing accuracy reached 94.9615ns。From the results, we could also see that the positioning accuracy was improved from over one thousand meters to lower than one hundred meters after the correction of propagation time-delay with ASF, and further improved to dozens of meters after real-time differential correction.



*Figure 7: Sailing Track of the first test at sea*

The multi-scenario broadcasting tests showed that different intervals of broadcasting did have impacts on the positioning accuracy of the differential Loran-C system. The positioning accuracy was the worst at the interval of 10 min, and displayed best performance at the interval of 15s. When the broadcasting interval was longer than 15s, the positioning accuracy decreases with the increase of the interval While at the interval of 15s, the positioning accuracy reached 26.1502m, much better than that of other intervals. However, due to the limited duration of the test and amount of data collected, the test results had a certain level of randomness. Nevertheless, both the simulation analysis before the test and the field test results demonstrated that differential correction, as a forecast correction method, will lose its timeliness with the increase of broadcasting intervals, thus deteriorate in the performance of accuracy.

|  |  |  |
| --- | --- | --- |
| **#** | **Broadcasting Interval** | **Accuracy of Differential Positioning** |
| 1 | 2s | 32.0999m |
| 2 | 5s | 38.2831m |
| 3 | 10s | 36.2961m |
| 4 | 15s | **26.1502m** |
| 5 | 60s | 56.9203m |
| 6 | 300s | 60.4135m |
| 7 | 600s | 76.2727m |

*Table1：Positioning accuracy at different broadcasting intervals*

The test also found that the positioning and timing accuracy were greatly improved if local regression method was used for smooth filtering during data procession. When processing the data collected during voyages, it’s also helpful to further improve the positioning accuracy to call the grid ASF nominal value, which should be divided based the longitude and latitude. However, due to the limited amount of test data, this method can not be fully evaluated.

## Development of Standard on Broadcasting of Differential Loran-C Information

Based on the preliminary research and test results, China MSA initiated a project to formulate an industry standard, ie Marine Radio Beacon-Differential Loran-C Information Broadcasting Standard. The Standard will specify the composition of the stations, message, transmission characteristics and system performance of RBN-based differential Loran-C system, so as to provide guarantee for the construction and wide application of the system. At present, the draft standard has been completed and the work is being progressed according to relevant procedures.

## Future Plan

When the overall test is completed, further data processing and analysis will be carried out to lay a technical foundation for the subsequent research and construction of RBN-based differential Loran-C system. Meanwhile, the development of a series of standards related to differential Loran-C will be promoted, so as to create favorable conditions for the wide application of relevant technologies. China MSA will also continue to share with the members of the Committee the experience gained in the research and construction at the future meetings.

# References

None

# Action requested of the CommitteE

1. The Committee is requested to note this document.
2. The Committee is invited to consider the information provided in this document in discussion of agenda item “Monitor developments in GNSS, DGNSS, radar, resilient PNT, e-Pelorus, terrestrial systems, R-Mode, inertial and any other relevant areas etc.”

1. Input document number, to be assigned by the Committee Secretary [↑](#footnote-ref-1)
2. Leave open if uncertain [↑](#footnote-ref-2)