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Agenda item [[2]](#footnote-2) 5.1

Technical Domain / Task Number 2 …………………………………

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Time synchronization methods of R-mode base stations and slot map of VDE ranging signal

# Abstract

Based on the research of AIS/VDES R-Mode Testbed Project, this paper gives two suggestions on the key technical issues of R-mode implementation. One is the Time synchronization of VHF / MF R-mode base station. Another is the transmission slot map of VDE ranging signal for VDES R-mode. This paper presents three Time synchronization methods for R-mode base station, and analyses their characteristics. It also gives the transmission slot map of VDE ranging signal and analyses the reason. The committee is invited to review the suggestions given in this document and discuss whether to adopt them.

The purpose of this proposal is to give suggestions on Time synchronization of VHF/MF R-mode base station and the transmission of VDE ranging signal for VDES R-mode, to provide support for the writing of the <DRAFT on Implementation of R-Mode on MF and VHF frequencies> and <GUIDELINE VDES R-MODE>.

# BACKGROUND

In order to reduce the impact of GNSS service interruption on maritime navigation and ensure the safety of ships, ships should be equipped with both space-based and land-based positioning and navigation systems. R-Mode is a low-cost land-based positioning and navigation system that utilizes the existing maritime radio communication infrastructure.

The "AIS Ship Autonomous Navigation System" AAPS project in China (2012-2015) initially realized the positioning function of the AIS R-Mode system, and conducted theoretical research on the VDES R-Mode in 2016-2017. Based on the above researches, the Project of VDES R-Mode Testbed (2018-2020) has built an R-Mode testbed in the Yellow and Bohai Sea. At present, the project has completed ranging and positioning experiments in the laboratory, on land and at sea. At present, we are improving the synchronization accuracy of base station to further improve the positioning accuracy.

This paper is based on the research results of the AIS/VDES R-Mode Testbed Project, and gives suggestions on the key technical issues of the implementation of R-Mode.

# discussion

## High precision synchronization methods of VHF / MF R-mode base station

The Time synchronization of R-mode base station is an important premise to realize the Time autonomous positioning of R-mode system. The synchronization error of base station directly causes the positioning error. In order to achieve positioning accuracy better than 10 meters in R-mode system, the synchronization accuracy of base station should be better than 10 ns. In order to meet the requirement, this proposal gives the R-mode base station Time synchronization methods including:

1. GNSS satellite common view time comparison.

2. Two-way satellite time and frequency transfer (TWSTFT).

3. Optical fiber time transfer.

These three methods can meet the requirement of synchronization accuracy better than 10ns.

### GNSS satellite common view time comparison

GNSS satellite common view time comparison is that GNSS timing receivers located in different places observe the same satellite signal at the same time to realize time comparison, as shown in Figure 1.



**Figure1．Framework ofGNSS satellite common view system**

GNSS satellite common view method is suitable for the situation that two stations can observe the same satellite at the same time. Since the GNSS signal transmission medium is basically the same, this method can be used to reduce the influence of the satellite clock stability and the ionospheric delay error. The time synchronization accuracy can be 5 ~ 10ns, and even better than 3ns using multi satellites (e.g. four satellites) common view. However, the GNSS satellite common view method can not be used when the two places can not observe the same satellite.

### TWSTFT

Two way time transfer (TWSTFT) is a time comparison technology with high accuracy. It can achieve nanosecond accuracy and is widely used in UTC traceability. The ground workstation of TWSTFT is mainly equipped with atomic clock, very small aperture terminal (VSAT), modem, time interval counter (TIC), etc, as shown in Figure 2.



**Figure2. Framework of TWSTFT system**

TWSTFT system has the same receiving and transmitting paths, which can eliminate the influence of position error of satellite and satellite communication station, and minimize the influence of tropospheric and ionospheric delay error. TWSTFT is one of the methods with the highest accuracy at present. The accuracy of TWSTFT is generally better than 1ns.

### Optical fiber time transfer

Optical fiber timing technology is a new Time time and frequency signal transmission technology based on optical fiber. This technology uses communication optical fiber as the carrier to transfer time and frequency signal. It has the advantages of anti-interference, low noise, low loss, sufficient channel resources and so on. It has achieved time transmission accuracy of tens of PS and frequency transmission accuracy of E-19 on 100 km and 1000 km level experimental lines. It is far superior to the widely used satellite based timing technology and others. The basic structure of optical fiber time transfer system is shown in Figure 3.

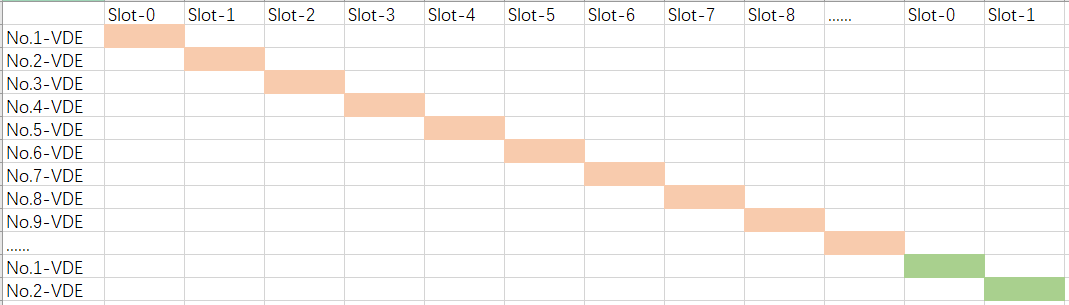


**Figure3.** **Framework of optical fiber time transfer system**

As optical fiber time transfer system has highest timing accuracy, the cost is relatively high. The main cost is the construction of optical fiber link, followed by laser and other transmission equipment. The cost of the system mainly depends on the distance.

## Slot map of VDE ranging signal

The slot map of the VDE base station ranging signal can be as shown in Figure 4. The base station management system firstly numbers the base stations according to the position as No. 1, 2, 3, 4, 5, 6..... At the beginning of the transmission period (e.g. 6s), the ranging signal is transmitted on VDE channel in the order of numbers. Repeat the work in the next transmission period. In this way, the nearby base stations can transmit the ranging signal in the minimum time interval, to minimize the positioning error caused by the clock error of the ship.



**Figure4. Slot map of VDE ranging signal**

# ACTION REQUESTED

The committee is invited to review the information of this paper and write the relevant contents into the R-mode related guidelines.

ANNEX1 introduction of background

# background

GNSS has inherent vulnerability. In order to ensure the navigation safety of ships, IMO recommends that ships should be equipped with both space-based and land-based ship positioning and navigation systems. R-Mode is a land-based positioning and navigation system that uses the existing maritime radio communication infrastructure to transmit synchronized ranging signals for distance measurement and positioning. It can reduce the impact of GNSS service interruption on maritime navigation and make full use of the existing shore equipment to minimize the cost of infrastructure. IALA's application for R-Mode technology has been passed at the ITU Conference, and it is planned to issue R-Mode technical standards in 2023.

Countries are actively carrying out R-Mode technology research. The European ACCSEAS project (2012-2015) demonstrated the feasibility of R-Mode technology, and the R-Mode Baltic project (2017-2020) will build R-Mode testbeds in the Baltic Sea. "AIS Ship Autonomous Navigation System" AAPS project in China (2012-2015) initially realized the positioning function of the AIS R-Mode system, and conducted theoretical research on the VDES R-Mode in 2016-2017. Based on the above researches, the Project of VDES R-Mode Testbed (2018-2020) has built an R-Mode testbed in the Yellow and Bohai Sea, mainly focusing on: (1) shipborne terminal without Rubidium clock; (2) Long-term autonomous synchronization of multiple base stations; (3) Specific VDES navigation messages. At present, the project is working on improving the synchronization accuracy of base station to further improve the positioning accuracy.

# system framework

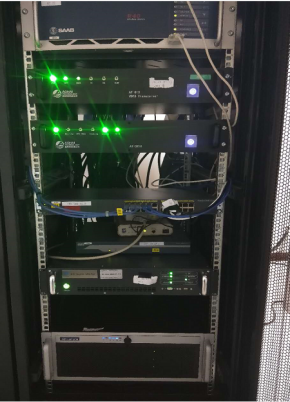
The system framework of the VDES R-Mode Testbed Project is shown in Figure 1. The system mainly includes a base station synchronization system, AIS/VDES R-Mode autonomous positioning system, integrity monitoring system, and VHF wireless channel measurement and correction system.

**Figure1. System framework of VDES R-Mode Testbed Project**

# construction status

At present, the Project of VDES R-Mode Testbed has completed ranging and positioning experiments in the laboratory, on land and at sea. And R-Mode base station devices have been installed in 3 locations, as shown in Figure 2.



1. Huangbaizui (b) Beihuangcheng (c) Laotieshan

**Figure2. Construction status of VDES R-Mode Testbed Project**

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