A Brief Introduction to the Application of AIS Aids to Navigation in the Lingang Dagusha Channel and the Remote Management and Use of AIS Aids to Navigation from the Perspective of E-Navigation

Qiang Guo*

Tianjin Aids to Navigation Division, The Navigation Guarantee Centre of North China Sea, Tianjin, People's Republic of China

*969679014@qq.com

Abstract

Since the beginning of the 21st century, AIS has been widely used and has made outstanding contributions to maritime safety; AIS technology updates and application research have developed rapidly, and have achieved remarkable results; AIS navigation marks not only play a role in assisting navigation, but also bring revolutionary changes to modern maritime monitoring, digital navigation mark construction, port management, maritime search and rescue, and other fields. In December 2022, after expert discussions, the navigation mark management department decided to deploy 18 AIS physical navigation marks in the Dagusha waterway near Tianjin Port. The extensive deployment of AIS physical aids to navigation provides convenience for sailors and effectively meets the needs of the development of navigation aids in the era of e-navigation; It not only enables remote management, but also provides convenience for the management of visual navigation marks for other entities. AIS navigation mark equipment is constantly updated, and management and use are constantly changing, which is worth continuous research and exploration.

Keywords

AIS Aids to Navigation, Dagusha Channel, E-Navigation, Remote Management and Usage.

1. Introduction to AIS Technology and its Application in Navigation Marks

AIS stands for Automatic Identification System for Ships, which enables mutual recognition between ships, ships and shore, and ships and navigation marks. The AIS navigation mark refers to an AIS station that uses the 21st telegram to broadcast information for ship navigation, positioning, avoidance, or providing other navigation assistance. Due to the characteristics of straight line propagation and being unaffected by sea conditions, AIS signals have a higher recognition rate compared to radar signals. As a result, AIS navigation marks have been rapidly promoted and applied worldwide. At present, AIS navigation marks include physical AIS navigation marks, virtual AIS navigation marks, synthetic AIS navigation marks, and AIS navigation mark chains. The main parameters that AIS navigation marks can display include the name, purpose, MMSI code, location, size, and broadcast parameters of the navigation mark. Early AIS aids to navigation equipment was an independent unit equipped with independent solar panels and batteries, or powered by mains electricity. With the development of aids to navigation technology, current AIS signal units can be integrated into integrated aids to navigation lights, which provide convenience for the deployment of physical AIS aids to navigation. The latest navigation beacon lights are shown in Figure 1.

Figure 1. Integrated navigation beacon light with AIS module

2. Introduction to Physical AIS Navigation Marks and Virtual AIS Navigation Marks

At present, the most common AIS navigation marks in northern China are physical AIS navigation marks and virtual AIS navigation marks. Physical AIS navigation marks refer to AIS navigation marks with physical AIS equipment located at the design position of the navigation mark. Generally, physical AIS navigation marks are installed at lighthouses and light stakes with high navigation risks. Typical installation locations include offshore stations, cape stations, shore stations, stations serving as waypoints, stations marking featureless coastlines and isolated dangerous objects, such as the physical AIS navigation mark of the headlight stake on the south breakwater of Tianjin Dagang[1].

In addition, in areas with low visibility, physical AIS navigational aids can effectively improve the visibility of navigational aids. According to the importance of floating markers, it is necessary to determine whether to install physical AIS navigation markers. Large buoys and buoys in important locations should be equipped with physical AIS navigation markers. Typical installation locations are narrow waterway entrances, waypoints, isolated dangerous objects, and shallow water boundary floating markers, such as the No. 203 physical AIS navigation marker in the Tianjin Dagusha Navigation Channel.

Virtual AIS navigation marks are not intended to replace physical navigation marks, but rather serve as a supplement to physical navigation marks to improve the safety of ship navigation. The risk of virtual AIS navigation marks is that some shipborne navigation devices cannot display virtual navigation mark information; The vulnerability of GNSS; Easy to experience electronic deception and interference; The limitations of VDL capacity and FATDMA planning. The advantages of virtual AIS navigation marks are: timely notification of navigation assistance information; Accurate location display; Intuitive information; Easy to set up; Simple modification; The installation and maintenance costs are low, and the setting of virtual AIS navigation marks should fully consider the above factors.

Virtual AIS navigational aids are generally divided into temporary and permanent types. Temporary virtual AIS navigational aids can provide temporary or preparatory warning information for ship drivers, especially if the information is not yet included in the electronic chart due to time constraints, The setting time generally does not exceed 6 months. When applying temporary virtual AIS navigation marks, attention should be paid to avoiding multiple

information coverage of a navigation mark when these temporary or preparatory information are also included in the navigation notice. Commonly used for identifying restricted navigation areas, temporary recommended routes, and identifying faulty or displaced navigation marks.

Permanent virtual AIS navigational aids can generally be deployed in deep water areas or harsh sea conditions, as well as environments that dynamically change over time, ocean currents, or weather conditions. Permanent virtual AIS navigation marks should be included in electronic charts, paper charts, and nautical publications, while avoiding multiple information coverage. Commonly used for identifying obstacles, marking route boundaries, marking safe water boundaries, and marking special areas.

3. The Role of AIS Navigation Marks in E-Navigation Perspective

In May 2006, The International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) held its 16th conference in Shanghai with the theme of "Navigation Marks in the Digital World", officially proposing the concept of E-Navigation for the first time[3]. E-Navigation is the collection, integration, and display of maritime information on board and onshore through electronic means to enhance the full navigation capability of ships from berth to berth, enhance corresponding maritime services, safety and security capabilities, and marine environmental protection capabilities. The eight functions that AIS navigation marks can theoretically play (as listed in Table 1) are highly compatible with the concept of digital navigation marks proposed by The International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA). The promotion of AIS navigation marks not only provides many conveniences for users and managers of navigation marks, but also promotes the development of international shipping towards digitization and intelligence.

Table 1. The theoretical role that AIS navigation marks can play[3]

1	Provide a reliable, all-weather method for identifying navigation marks on shipborne AIS and shipborne radar displays.
2	Used as a physical AIS beacon or as a virtual AIS beacon to supplement the signals of traditional visual beacons.
3	Return the accurate position of the buoy, indicate its displacement, and provide meteorological, tidal, and sea state data.
4	Provide reference points for marine radar and supplementary services for racon.
5	Marking or delineating boundaries for ship trajectories, routes, areas, and restricted zones.
6	Annotate offshore buildings and mark isolated hazardous materials through virtual navigation markers.
7	Monitor the status of navigation marks, track displaced navigation marks, and use AIS navigation mark trajectories to find the hit and run ship that collided with the navigation mark.
8	Real time collection of information on the health status of navigation marks, and changing navigation mark parameters through remote control technology.

4. Characteristics of the Dagusha Navigation Channel in Lingang, Tianjin

The Dagusha Channel in Lingang, Tianjin (indicated by the red arrow in Figure 2) is the second 100000 ton waterway in Tianjin Port. It is a large manually excavated waterway with a total length of over 30 kilometers. In August 2006, the 5000 ton waterway was officially opened. In July 2009, it was upgraded to a 50000 ton waterway. After a long period of dredging, the 100000 ton waterway was put into trial operation in January 2014, and by March 2019, the 100000 ton waterway and the 70000 ton two-way waterway were officially opened, as well as night navigation. On both sides of the channel are various types of docks such as special equipment, grain and oil, and energy fossils. As the channel is a manually excavated channel,

the average depth inside the channel is about 15.8 meters. The average width of the channel from the Dagusha channel entrance light float to buoy No. 236 is about 0.2 nautical miles, while the average depth outside the channel is only 7 to 8 meters. There are many shallow points around the channel, and various isolated dangerous objects such as sunken ships are scattered around the channel. Therefore, large ships rely more on various navigation marks and facilities near the channel. At present, there are a total of 86 buoys, 32 light stakes, and 3 radar responders around the waterway. In December 2022, after expert discussions, the navigation mark management department decided to set up 18 AIS physical navigation marks in the Dagusha waterway near Tianjin Port. As of December 2024, there are a total of 25 AIS navigation marks in the jurisdiction, including 23 physical AIS navigation marks and 2 virtual AIS navigation marks. Table 2 lists three common types of AIS navigation marks.

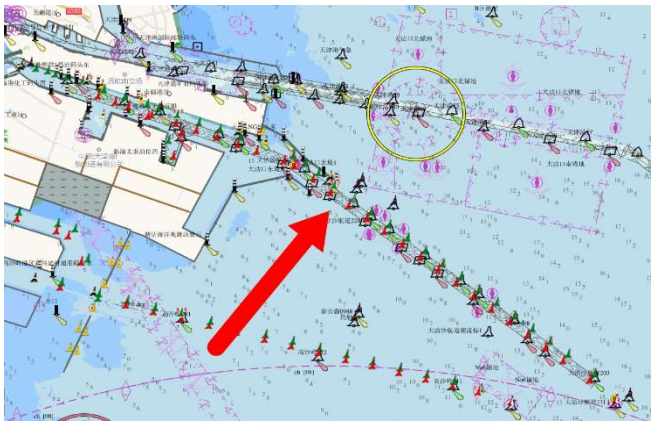

Figure 2. Tianjin Lingang Dagusha Channel

Table 2. Three Different Types of AIS Navigation Aids

Name of AIS navigation mark	**GRAIN&OIL BERTH EAST**	**DAGUSHA NO. 203**	**OBSTRUCTION NO. 1**
Navigation mark type	Light Beacon	Right navigation mark	Isolated Danger Mark
location	38°56′05″.2N 117°48′11″.3E	38°48′05″.0N 118°05′41″.7E	38°55′15.5” N 117°49′29.0”E
MMSI code	994141153	994121025	994146057
Signal broadcasting cycle	180S	180S	180S
Theoretical operating distance	10nm	10nm	10nm
Date of installation	2024.5.30(Adjust MMSI code)	2022.12.07	2024.6.11
Is there a physical AIS device	Yes	Yes	No

5. Remote Management of AIS Navigation Marks

At present, navigation mark managers in the northern sea areas of China can monitor and manage physical AIS navigation marks and virtual AIS navigation marks 24/7 through computer network systems. Commonly used systems include navigation support operation management systems and AIS VDL monitoring systems. The navigation support operation management system is an operating system developed entirely based on navigation mark management personnel. The system includes two sections: daily management of navigation marks and monitoring of work status. The daily management section includes basic

information of navigation marks, inspection and maintenance, emergency response for abnormalities, etc., which plays a role in the paperless office of navigation mark management. The working condition monitoring section can query detailed management records of each navigation mark and visually view and monitor them through nautical charts. AIS physical navigation marks are located at the same position as their corresponding physical visual navigation marks, and the feedback of information is based on GPS or Beidou system on the physical navigation mark lights. Currently, this system can be synchronized with smartphone apps, and navigation mark managers can monitor and operate in areas covered by mobile networks. Figure 3 shows the display interface of the system on the computer, where navigation mark managers can intuitively query and modify relevant information.

Figure 3. AIS Navigation Mark Interface Displayed in the Navigation Support Operation Management System

The other one is the VDL monitoring system, which has been built by the Beihai Navigation Support Center since 2017. Currently, the main functions have been completed. This system can collect and analyze various AIS data nationwide, providing operational support for AIS networks and having significant implications for the development of future VDE core networks. The VDL monitoring system display interface has four query blocks: real-time business statistics, real-time chart display, operation status monitoring, and management system. The backend data access system is mainly responsible for the collection and storage of AIS message data, which can analyze the compliance of AIS node devices and provide cross regional data support for the intelligent identification of the effectiveness of AIS shipborne equipment. Through statistical analysis of AIS navigation marks, joint monitoring can be achieved nationwide. Thanks to the powerful integrated computing capability of the system, users can analyze the behavior of all online AIS devices within a fixed area in real time. By generating whitelists, blacklists, and various statistical data, it can effectively serve AIS navigation mark management, AIS data sharing, and provide assistance for maritime supervision and law enforcement, public security departments to combat crime, and more.

The MMSI code of a certain AIS beacon is fixed and unchanged, but the MMSI code on each AIS beacon light equipment is adjustable. The integrated navigation beacon device with AIS module can be connected via Bluetooth through a mobile app, and staff can set a unique MMSI code for a certain AIS navigation beacon through their mobile phones. After the setup is completed, signal detection is required. In addition to using ship borne AIS equipment at the dock or at sea, there are also flexible handheld testers. Taking the NAT-200 AIS tester as an example, this

device can detect Class A and Class B AIS, AIS-SART, as well as AIS navigation marks or AIS base stations. The working channels are AIS1 (161.975MHz), AIS2 (162.025MHz), and DSC (156.525MHz) channels, which comply with the ITU-R M.1371-4 international standard and can store up to 10 test data times. A complete measurement cycle takes 10 minutes. When measuring the signal returned by AIS navigation marks, it generally does not exceed 3 minutes, and the shortest one only takes a dozen seconds. Before the physical AIS navigation mark is set up and before and after the installation of ship borne AIS equipment, AIS information verification can be performed through handheld devices. Figure 4 shows several display interfaces of the handheld tester in use, and the richness of information and the intelligence of the device need to be improved.

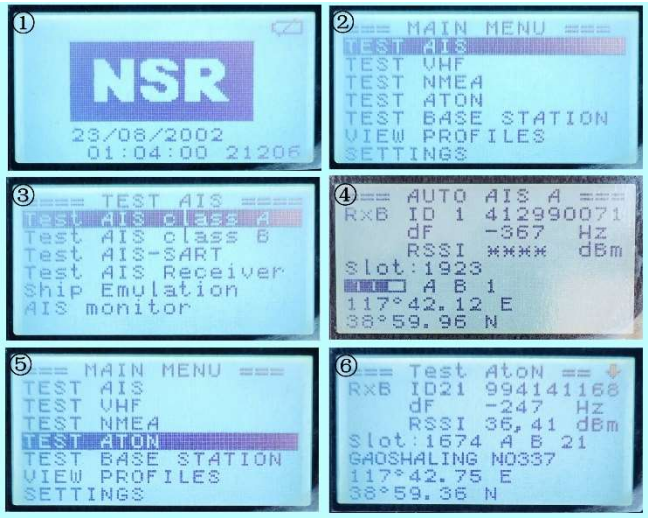

Figure 4. Testing the Display Interface of Different AIS Devices

6. Current Situation Description and Analysis

In terms of the use of AIS navigation equipment, previous split AIS equipment had a longer receiving distance. Taking the East Light Beacon AIS at Tianjin Lingang Grain and Oil Terminal as an example, thanks to the stable supply of mains electricity, high power of split equipment, and higher installation position, the signal of split light station AIS equipment can be received by ship borne AIS equipment 10 nautical miles away. However, the integrated navigation beacon installed on the buoy can only supply a portion of the electrical energy to the AIS module. Due to the supply of electrical energy, power, and installation location of the equipment, the distance at which the ship's onboard equipment first receives the AIS navigation beacon signal is not ideal (although the information will continue to be displayed on the equipment after receiving it). Further optimization of the equipment structure is the next direction for efforts.

From the perspective of remote management of AIS navigation marks, the navigation support operation management system can provide feedback on the current and voltage of AIS equipment modules. Taking buoy 223 in the Dagusha Channel as an example, there are a total of 17 pieces of AIS current and voltage feedback in a month, and about 1 piece is returned every 2 days. However, there are as many as 632 pieces of current and voltage feedback for navigation mark lights, and about 21 pieces every day. Managers can intuitively judge the health status of navigation mark lights by the changes in day and night current and voltage, and deal with abnormal situations of navigation mark lights in the first time. To determine whether the AIS module is healthy, it takes some time to rely solely on the navigation support operation management system. Although the VDL monitoring system cannot query the current and voltage status of AIS devices, the system collects information through AIS base stations. It can

not only display virtual AIS navigation marks, but also the feedback time interval of physical AIS navigation marks is basically stable at around 3 minutes.

With the improvement of VDL monitoring system, abnormal AIS navigation marks can be quickly detected, such as false AIS navigation marks, repeated MMSI codes, abnormal message broadcast frequency, abnormal message MMSI codes, etc. False AIS ship stations, abnormal ship station broadcasts, multiple codes on one ship, etc. can also be detected in a timely manner and analyzed at any time. Various non-standard AIS information inputs have also surfaced. Behind these problems, the lack of effective supervision is an important factor.

Although the Maritime Safety Administration of the People's Republic of China issued the "Guidelines for the Application of Automatic Identification System (AIS) Navigation Marks" on May 1, 2018, which stipulated the classification, message, parameter configuration, and display symbols of AIS navigation marks, provided recommended standard specifications for the naming of AIS navigation marks, and divided the MID involved in the maritime MMSI code into three major maritime areas, there is still a phenomenon of inconsistent and non-standard naming of AIS navigation marks, and arbitrary naming of virtual AIS navigation marks[2]. Some setting units name physical AIS navigation marks as light floating AIS responders, which is easy for crew members to misunderstand; In addition, some ship equipment is outdated and does not display AIS navigation mark information according to international standards, or it can be displayed but the display symbols are not modified in a timely manner, which can easily cause confusion. In addition, the performance of AIS physical navigation mark equipment currently available in China varies greatly, and stability needs to be improved. There is also no industry regulatory mechanism or effective performance testing platform, and the effectiveness of the equipment cannot be objectively evaluated. Whether the performance of the equipment meets international standards, whether it meets the requirements of the International Association of Navigation Marks and the International Maritime Organization, and whether the settings of various parameters are reasonable, these issues still need further consideration.

7. Conclusion

The informatization and intelligence of the shipping industry is the future development trend. The International Maritime Organization (IMO) and the The International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) have repeatedly expressed and emphasized the concept of "E-Navigation". With the construction and development of China's maritime e-navigation system, AIS navigation marks, as an important component, will be further applied and promoted. Although the development of AIS navigation marks still faces various difficulties, the advantages and development prospects of AIS navigation marks cannot be denied. I believe that in the near future, with the development of AIS navigation mark technology and the gradual improvement of various related standards, the navigation assistance efficiency of AIS navigation marks will be better stimulated, AIS navigation marks will better serve the shipping industry, and the concept of E-navigation will gradually be realized.

References

[1] Guo Xiaofei Research on AIS Navigation Mark Application Management Ship Electronic Engineering General Issue 264th, 2016 Issue 6

[2] Nianwei, Wu Yixin How to Strengthen Navigation Mark Management Based on AIS Technology [J]. People's Transportation,2020,(02):66+68.

[3] Zheng Junfang AIS Frontier Technologies and Applications [C]//Journal of Guangzhou Maritime University, Volume 22, 2014 (Total Issue 57) Naval War College;,2014:12-13+18.