Academic Journal of Engineering and Technology Science
ISSN 2616-5767 Vol. 2, Issue 2: 66-75, DOI: 10.25236/AJETS.020043

Study on Buoys for Trajectory Prediction Simulation of Maritime Drifting Objects

Weijiong Chen[1], Yuejiao Sun[2,*], Yu Liang[2], Zewei Han[1] and Junfang Su[1]

[1] *College of Ocean Science and Engineering, Shanghai Maritime University, Shanghai 201306, China*
[2] *Merchant Marine College, Shanghai Maritime University, Shanghai 201306, China*
[*] *Corresponding author e-mail: 2280534969@qq.com*

ABSTRACT. *In order to solve the problem of low efficiency and high cost which is caused by the poor accuracy of the drifting trajectory of the rescued object in maritime SAR ,this paper develops a AIS network communication buoy group for maritime search and rescue.Making full use of the data transmission and compilation functions of the micro control unit, the close-range information interaction function of AIS and the long-distance communication function of Beidou, we create a set of highly modular and low-cost maritime search and rescue buoys,which can realize the transition from 'Individual combat' to 'multi-soldier combat'. Experiments in key sea areas can supplement and correct the wind pressure drift coefficient, so that the prediction of drift trajectory is more accurate.*

KEYWORDS: *Maritime search and rescue, AIS networking, Buoy group, Prediction trajectory correction*

1. Introduction

As the developing of China's maritime economy and the increasing of ocean activities, maritime accidents also increase year by year.Once an accident occurs, the work of maritime search and rescue must be carried out immediately.Maritime search and rescue mainly consists of two parts: maritime search and maritime rescue [1]. Search is the most expensive, dangerous and complex task in the entire search and rescue process, which is usually the only way to discover and rescue survivors [2]. The main technical means used in maritime search is trajectory prediction.The trajectory prediction of objects to be searched has always been the research focus in the field of maritime search and rescue [3]. The technology has made great progress in the past few decades, but there are still some defects [4]. Since the leeway data comes from abroad, the leeway model will produce certain errors when applied to China's seas.

ISSN 2616-5767 Vol. 2, Issue 2: 66-75, DOI: 10.25236/AJETS.020043

Surface drifting buoys are widely used in the understanding and research of the ocean due to their advantages, such as small size, low cost and so on [5]. In order to improve the accuracy of the predicted trajectory, we need the surface drifting buoy with positioning function to carry out experiments on the key sea areas, then supplement and correct the wind pressure drift coefficient, so that the prediction of the drift trajectory is more accurate.With the continuous change of location and data transmission technology, it has been widely used in the field of buoys, but the development of surface drifting buoys is still not perfect [6]. Firstly, there are many drifting objects at sea. Different objects may cause differences in drift trajectories due to different factors such as shape, material, specifications, etc. Which leads that the development of buoys will be cumbersome.However, modularization will greatly shorten the development time [7]. Secondly,Secondly, most of the buoy communication relies on foreign satellites, and there are few buoys using the Beidou communication system.For example, the surface drifting buoys provided in literatures[8-15] use ARGOS, Iridium and other foreign satellites for communication. Only a small number of people such as the literatures [16-19] use the Beidou communication system.Excessive reliance on foreign satellites for communication not only leads to high cost of buoys, but also is not conducive to the safety of marine data in China.Then, the overall technical level of the buoys is still far from the foreign countries'. For example, the US Met-O company has been leading the oil spill tracking drifting buoy products and technology [12], but China is still in the development stage.Finally, the application of China's buoys in search and rescue is rare. At present, only Gao Ting, et al [16, 20, 15] have conducted research on search and rescue buoys.

Based on the current status of maritime search and rescue work and surface drifting buoys, the author developed an AIS network communication buoy group for maritime search and rescue, which adopts modular design and can provide users with a reliable, sample-guaranteed and targeted buoy in a short time.

2. Design of the buoy group

2.1 Overall design requirements

The buoy group consists of a main buoy and sub-buoys, and the number of sub-buoys is determined according to the needs of the user.The main buoy and sub-buoys are mainly composed of a buoy body, antennas, a positioning communication module, a battery, a weight block and the like.The buoy group adopts materials that are common on the market, which not only meets the requirements of buoys in harsh sea conditions, but also achieves the goal of reducing cost and being easy to promote.The specific design requirements are as follows:

(1) The sub-buoys send its own position and other information to the main buoy in time through AIS communication. The main buoy sums up the received information and its own information, then sends it to the Beidou receiver.The working diagram is shown in Figure 1;

ISSN 2616-5767 Vol. 2, Issue 2: 66-75, DOI: 10.25236/AJETS.020043

(2) In order to fully ensure the safety and watertightness of the buoy group, two layers of sealing rings are added at the joint of the tube and top cover to achieve a good sealing effect;

(3) In order to ensure pressure resistance and corrosion resistance, the buoy tube is made of PE material (as shown in Table 1). For the main buoy, the bottom cover is made of a PE cover that is matched with the tube, and the top cover is made of anti-corrosion aluminum alloy (Fig. 2). , and then add the acrylic plate (Fig. 3); for the sub-buoy, both the bottom cover and the top cover select are the same of the main buoy's bottom cover, using a hot melt process to connect;

(4) The power supply adopts No. 5 rechargeable lithium battery, which guarantees continuous operation for 10 days to complete the search and rescue experiment.

(5) The core circuit board should be integrated with the communication modules. If there is a shared circuit, it is necessary to ensure that various communication modes work normally, and the current communication module is detected and fed back in time;

(6) Four identical copper studs are used to connect the battery compartment with the hardware module to ensure that the internal modules are stable;

(7) The weight is located at the bottom of the buoy tube, which can adjust the center of gravity to meet the stability requirements;

(8) Single person can easily pick up and be easy to lay.

Table 1 PE pipe part specification size table

Nominal pressure	0.6MPa	0.8MPa	1.0MPa	1.25MPa	1.6MPa	Each meter can be customized (m)
Standard size ratio	SDR26	SDR21	SDR17	SDR13.6	SDR11	
Nominal outer diameter (mm)	Wall thickness (mm)	Wall thickness	Wall thickness	Wall thickness	Wall thickness	
75	2.9	3.6	4.5	5.6	6.8	6.9.12
90	3.5	4.3	5.4	6.7	8.2	6.9.12
110	4.2	5.3	6.6	8.1	10.0	6.9.12

ISSN 2616-5767 Vol. 2, Issue 2: 66-75, DOI: 10.25236/AJETS.020043

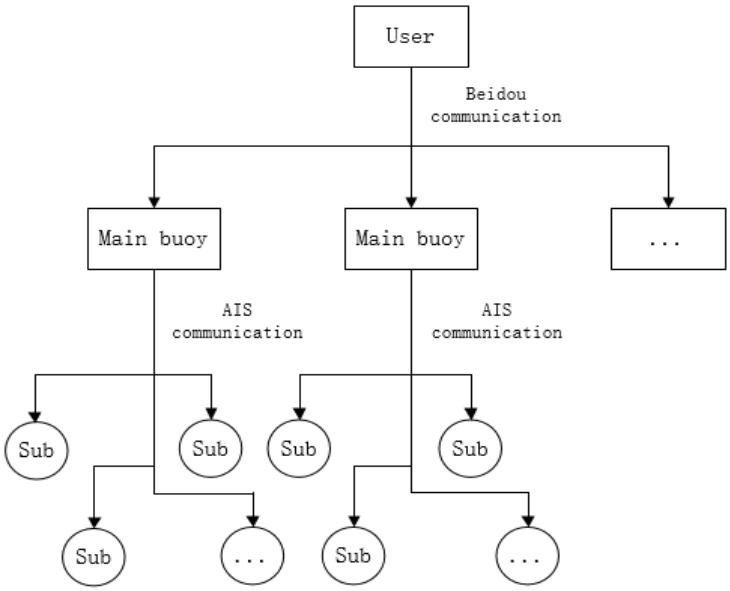


Figure. 1 Schematic diagram of the buoy group work

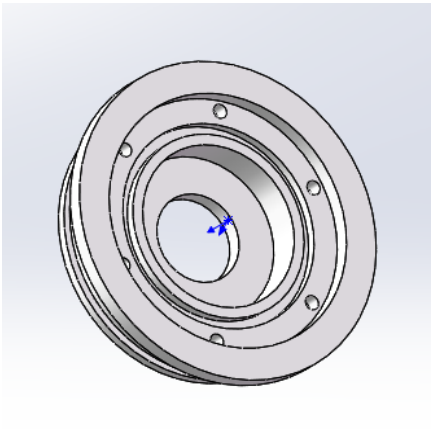


Figure. 2 aluminum alloy top cover

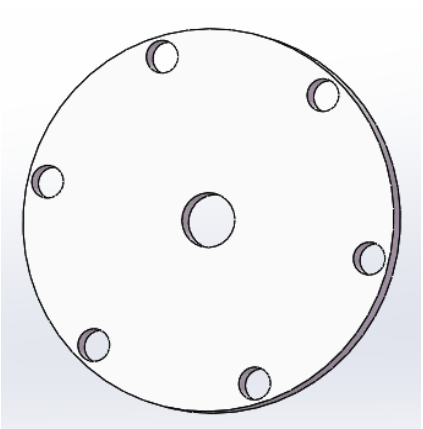


Figure. 3 Acrylic sheet

2.2 Buoy group shape design

The buoy group is generally designed in the shape of a cylinder. By adjusting the weight of the bottom, the inclination of the buoy in the water can be changed. The main technical parameters:

ISSN 2616-5767 Vol. 2, Issue 2: 66-75, DOI: 10.25236/AJETS.020043

The buoy group is generally designed in the shape of a cylinder. By adjusting the weight of the bottom, the inclination of the buoy in the water can be changed. The main technical parameters of the main buoy and sub-buoys:

The buoy height is 500mm, the outer diameter of the buoy body is 110mm, the wall thickness is 6.6mm, and the nominal pressure is 1.0Mpa;

The buoy weighs 3kg;

Angled to the water surface at 30° (adjustable).

The cylindrical buoy body has good wave-floating property, drifts with the wind and waves at sea and can realize the trajectory simulation of the drift target.The outer surface of the buoy is coated with paint, which is similar to the color of sea water, so it is not easy to be salvaged by other unrelated people. The attitude of a single buoy in seawater is shown in Figure 4.

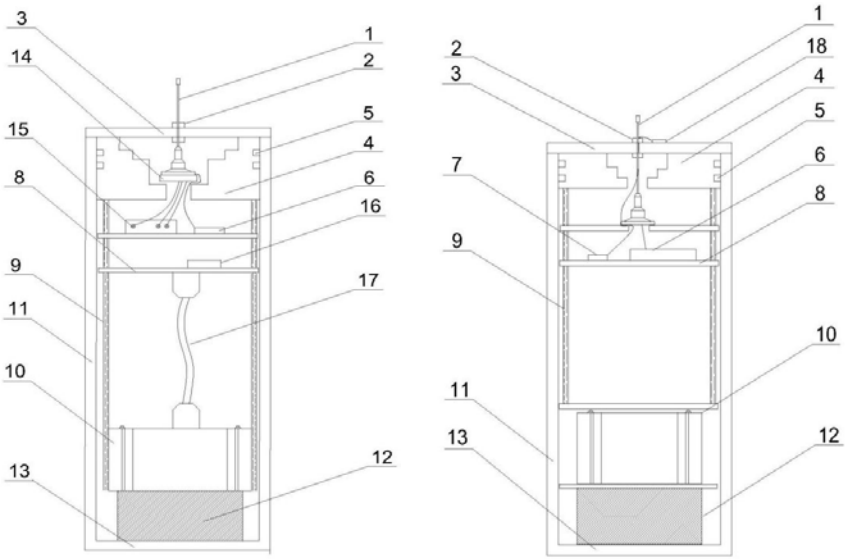
Figure. 4 Status of a single buoy in sea water

2.3 Structure design of the buoy group

The main buoy adopts a separate structural design, and the sub-buoy adopts an integrated structural design.The buoy body is equipped with antennas, a positioning communication module, a battery and a weight block from top to bottom. The battery and the communication positioning module are connected by copper studs, which is advantageous for fixing the position of the internal components and improving the impact resistance.The main buoy positioning communication module is obtained by integrating the Beidou module, the AIS module and the micro control unit; the sub-buoy positioning communication module is obtained by integrating the AIS communication module, the GPS module and the power supply unit.

The buoy group construction can be seen in Figure 5:

ISSN 2616-5767 Vol. 2, Issue 2: 66-75, DOI: 10.25236/AJETS.020043



(a) Main buoy plan *(b) Sub-buoy Plan*

Figure. 5 1.AIS antenna; 2.Waterproof joint; 3.Acrylic sheet; 4.Top cover; 5. Sealing ring; 6.AIS module; 7.GPS module; 8. Circuit board; 9. Copper stud; 10. Power module; 11. Buoy cylinder; 12. Counterweight; 13. Bottom cover; 14. Beidou antenna; 15. Beidou module; 16. Micro control unit; 17. Watertight connector; 18. GPS antenna.

2.4 Design of buoy group communication module

According to the design requirements, select hardwares.The specific models are shown in Table 2.

Table 2 Main hardware models

Buoy category	Module	Specific model	Operating Voltage (V)	Size (cm)
Main buoy	Beidou module	ATGM332D	DC+5V;DC+12V (Amplifier)	5.5*6
	AIS module	DYA420	3.5V~4.2V	4.9*3.2
	MCU	STM32F103ZET6	2 V~3.6 V	3*3
Sub-buoy	AIS module	DYA420	3.5V~4.2V	4.9*3.2
	GPS	NEO-7N UBLOX	3.3V~5V	2.8*4
	MCU	STM32F103ZET6	2 V~3.6 V	3*3

Several aspects of the communication module to consider:

Circuit board: ① the position and size of all components on the whole circuit board and the coordination or interference between the various components; b. the

ISSN 2616-5767 Vol. 2, Issue 2: 66-75, DOI: 10.25236/AJETS.020043

size of the entire circuit board, the position of the circuit board in the entire buoy, the fixed way, the supply of electricity and its distribution.

Hardware integration: a. AIS module and Beidou module have some requirements on the layout, and the module needs to meet these requirements to work normally; b. For the main buoy, not only a circuit board but also two communication modules must be considered at the same time. It is necessary to ensure that the two communication modes work normally; c. If there is a shared circuit, the shared circuit is required to ensure that each hardware can work normally, and the currently used communication module is detected and can feed back.

Program: a. AIS data and Beidou data protocol and decoding; b. Elimination of invalid data; c. Work flow when multiple communication methods are integrated into one module; d. When debugging, the two communication modes are debugged separately.If the debugging is successful, perform the second debugging until it is working normally.

3. Development of buoys

3.1 Development process of buoys

In order to ensure the sealing of the buoy, the aluminum alloy top cover and the acrylic plate are tightly connected with 6 bolts, and two O-rings are added at the joint of the lid.The buoy group is powered by a rechargeable lithium battery pack.The battery pack is located above the weight block, which solves the power supply problem, increases the weight, and improves the stability of the buoy group.

The Beidou positioning communication module adopted by the main buoy integrates RDSS RF transceiver chip, power amplifier chip and baseband circuit, which can realize BDS&GPS combined positioning work.The module has high integration, low power consumption, and is compatible with receiving RDSS and BDS/GPS satellite navigation signals, realizing high-precision positioning and speed measurement of the mobile carrier.The buoy uses the GPS module to receive data, and the theoretical accuracy can reach 2.5 meters. The Beidou II module sends data and the transmission success rate is 100%.The data is sent out at a frequency of 2 minutes/time, and analyzed at the receiving end.

The AIS communication module used by the main buoy and sub-buoys has a stable transmission frequency and high receiving sensitivity. The transmission content such as the device MMSI number, ship name, size, etc. can be designed by the user.The module has high integration and small volume, and the data is sent out at a frequency of 2 minutes/time. The theoretical accuracy of the communication distance can reach 30 nautical miles.

The working process of the buoy group is shown in Figure 6:

ISSN 2616-5767 Vol. 2, Issue 2: 66-75, DOI: 10.25236/AJETS.020043

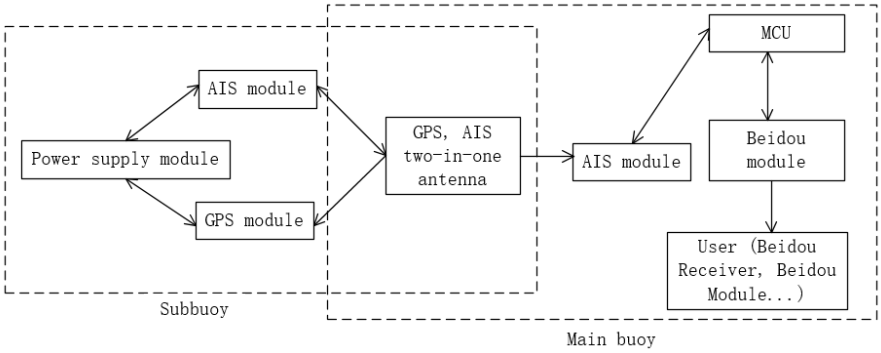


Figure. 6 The working mode diagram of main buoy and sub-buoys

The circuit of the buoy group is designed according to the design principles that each communication module does not interfere with each other and the board is as small as possible.

3.2 Hardware Testing

In order to verify whether the buoy group can achieve the expected function, the hardware test is performed on a single main buoy and a single sub-buoy. The test results are shown in Figure 8 below:

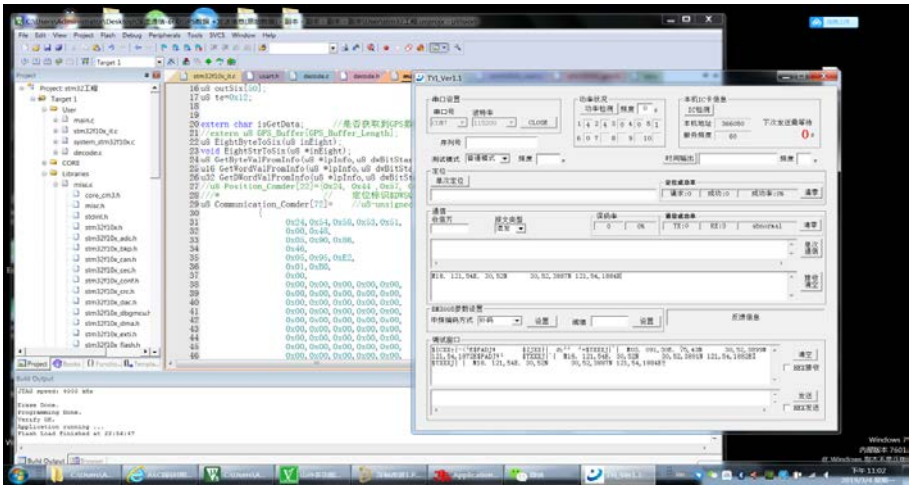


Figure. 7 main buoy, sub-buoy positioning debug data

ISSN 2616-5767 Vol. 2, Issue 2: 66-75, DOI: 10.25236/AJETS.020043

From the data sent back, the buoy group works properly and achieves our desired goals.

4. Summary and outlook

The above test results show that the buoy group can work normally and achieve the expected results.But buoys have room for improvement. The next step is to experiment in key areas and optimize buoys.

This paper introduces the design process and development of a marine AIS networking communication buoy group.The buoy group has a high degree of modularity, use Beidou satellite to communicate and adopt the "multi-combat combat" mode .Which can not only reduce the time for scientific research institutions to develop similar products and save costs, but also contribute to the safety of marine data in China.However, there is still much room for development in the maritime AIS network communication buoy group:

Extend the application object. The cylindrical buoy we developed is only for marine drowning personnel. There are many targets in maritime search and rescue. If objects are different, the results of drift are different.

Optimize the startup method. The water-immersed sensor is used as the starting device of the buoy. Once the water-immersed sensor starts working, the buoy enters the working mode from the standby mode.So the buoy can automatically start.

Expand the measurement elements. The developed buoys are now only capable of transmitting location information and have no monitoring capabilities for other elements of the ocean. Later, the functions of the buoy can be extended, such as adding a water temperature sensor, a wave sensor, a water quality sensor, and the like.

Add water sails. The sail can increase the flexibility of passive control and facilitate the movement of the buoy [21].

References

[1] Liu Lei. Risk Analysis and Avoidance of Maritime Search and Rescue. Pearl River Water Transport, 2017 (17): 72-73.
[2] Xing Shengwei. Global optimization model and simulation study of sea stereo search [D]. Dalian: Dalian Maritime University, 2012.
[3] Wu Xiang. Research on methods to improve the probability of successful search in maritime search and rescue [D]. 2016.
[4] Hackett B, Breivik Ø, Wettre C. FORECASTING THE DRIFT OF OBJECTS AND SUBSTANCES IN THE OCEAN [C]. Eric P. Chassignet, Jacques Verron. Ocean Weather Forecasting: An Integrated View of Oceanography. Germany: Springer, 2006: 507-523.
[5] Lumpkin R, Özgökmen T, Centurioni L. Advances in the Application of Surface Drifters [EB/OL]. (2016-8-22) [2018-5-12] www.annualreviews.org.

ISSN 2616-5767 Vol. 2, Issue 2: 66-75, DOI: 10.25236/AJETS.020043

[6] Yu Lizhong, Shan Guanglin. Surface drifting buoy and its tracking technology [J]. Ocean Technology, 1997 (2): 1-11.
[7] Breivik Ø, Allen A A, Maisondieu C, et al. Advances in search and rescue at sea [J]. Ocean Dynamics, 2013, 63: 83-88.
[8] Yang Yuewen, Shang Hongmei. Method for real-time tracking and monitoring of oil spill on the sea with surface drifting buoys [J]. Ocean Technology, 2007, 26 (2): 17-19.
[9] Li Wenbin, Zhang Shaoyong, Shang Hongmei, et al. Design of surface drifting buoy based on new generation Argos satellite system [J]. Ocean Technology, 2011, 30 (1): 1-5.
[10] Zhang Xiansheng, Tan Qiulin, Ding Liqiong, et al. Design of Beacon Based on Iridium System [J]. Journal of Computer Measurement and Control, 2013, 21 (10): 2804-2807.
[11] Zhao Ping. Oil spill tracking and positioning buoy device: China, CN101407249A [P]. 2008-11-25 [2018-4-21].
[12] Yang Rui, Gu Qun. Oil spill tracking buoy based on Beidou satellite [J]. Journal of Shanghai Maritime University, 2014, 35 (3): 23-27.
[13] Xu Mingchang. A fishery tracking buoy satellite positioning anti-theft device: China, CN107831507A [P]. 2017-10-24 [2018-4-25].
[14] Yin Cailing, He Haixing, Xue Rui, et al. Development of intelligent positioning buoy system for underwater high-speed target positioning [C] // Chinese Acoustics Society. Proceedings of 2016 National Acoustics Conference. Wuhan: Chinese Acoustics Society, 2016: 351 -354.
[15] Yu Lin, Song Jun, Zhou Kai. A drifting buoy device for search and rescue training: China, CN205680345U [P]. 2016-02-29 [2018-4-25].
[16] Gao Ting, Chen Hongwu, Zhang Shuai. Design of Alarm Terminal for Water Falling Personnel Based on Beidou Positioning [J]. Computer Engineering and Design. 2013, 34 (10): 3470-3474.
[17] Xu Chun, Cui Xuejie, Liu Chenglong. A drifting buoy: China, CN203767030 [P]. 2014-8-13 [2018-4-21].
[18] KONG Weiqi, YANG Zhiyong, MA Shangchang. Design and Implementation of Meteorological and Hydrological Drifting Buoy Based on Beidou Communication System [J]. Modern Electronic Technology, 2017, 40 (19): 160-163.
[19] Huang Xu, Zhang Wenwei, Wang Gang, et al. Communication control method for ocean surface drifting buoy based on Beidou satellite: China, CN107797119A [P]. 2017-09-05 [2018-4-25].
[20] Pei Liang, Sun Jinwei, Miao Bin, et al. A simulated humanoid drifting buoy for maritime search and rescue training: China, CN203149981U [P]. 2013-04-03 [2018-4-25].
[21] Subbaraya S, Breitenmoser A, Molchanov A, et al. Design of Lagrangian Drifters for Ocean Monitoring [J]. IEEE ROBOTICS & AUTOMATION MAGAZINE, 2016, 3: 2-13.