Navigation system for unmanned vessels using a navigation buoy

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Abstract. Nowadays the floating aids to navigation are being actively developed for remote control of the buoy location. The modern technical level allows building a buoy with the functions of monitoring the environment and transmitting the received information to coastal services. This task is becoming more urgent in connection with the development of unmanned vessels. The paper considers the results of field tests of an operating navigation buoy with special navigation equipment. The buoy is designed for information support during field tests of unmanned vessels and water transport facilities in the test water area in the Volga-Baltic basin of the inland waterways of the Russia Federation. Full-scale tests of special navigation equipment were carried out in accordance with the developed program and test procedure. The tests included the validation of the receipt of data from special navigation equipment to an external server via LTE mobile networks, assessment of the accuracy of positioning by means of navigation equipment, assessment of the percentage of data loss during transmission and validation of data visualization on an interactive map displayed in an Internet browser.

1. Introduction

The need to develop autonomous floating aids to navigation with the possibility of information support is explained by many factors. Such factors include the need for monitoring the meteorological situation, forecasting waves etc. As an example, it is possible to cite the development of buoy flooding warning systems using Wi-Fi communication via chip STM32F407 [1] method of fairway buoy based on passive underwater acoustic positioning [2], intelligent buoys under the ice [3] and others. A general disadvantage of existing floating aids to navigation is the impossibility of remote monitoring of changes in the location of the buoy under the influence of wind and wave loads, the absence of any feedback from shore services or nearby vessels, which requires a mandatory line of sight of the buoy to ensure safe navigation.

In order to solve this problem, a new model of a navigation buoy was created. It can be used to ensure the safety of navigation, including autonomous and unmanned surface vessels. The purpose of the paper is to analyze the operability of the operating model of the navigation buoy in terms of software and hardware, as well as to estimate the parameters that are impossible or difficult to evaluate without carrying out field tests. The test location is the test water area in the Volga-Baltic basin of the inland waterways of the Russian Federation.
2. Methods and Materials
The created operating model of a technical facility with special floating aid to navigation is necessary for information support for carrying out full-scale tests of unmanned vessels and water vehicles in the test water area. An important feature of the developed system of aids to navigation is the continuous registration of all measured indicators and their display at a remote workplace. The applied approach allowed refusing a set of time sections of information and providing independent and continuous information support for full-scale tests, which fully complied with the requirements of IMO MSC.1/Circ. 1604 Interim guidelines for mass trials dated June 14, 2019, in terms of the creation of a reliable infrastructure to ensure safety, security and environmental safety of testing.

The created operating model of the technical means of the special aids to navigation has most of the functions that the test vessels and automated control systems supposedly possess. At the same time, the control method is not so important for both on-board technical means and remote control infrastructure.

During the creation of a test sample, the need to ensure the prevention of any incidents, prompt response to emergencies and warnings was taken into account. Therefore, the period for updating navigation information, including at the operator's workplace, does not exceed 5 seconds and data are recorded from all devices every second. The main and backup communication and data exchange systems were implemented and tested. For communication, 4G LTE and high-speed Wi-Fi technologies were used, including Long-Range (LR) technology. It is planned to deploy a seamless information exchange network.

The existing experience of Admiral Makarov State University of Maritime and Inland Shipping, as well as the results of work [4–7] allowed formulating detailed technical requirements, both for the technical device and for a special floating aid to navigation, which were considered during the development of the sketch of the devices. To create a working model, a modular principle of assembly and testing of individual components was applied.

3. Results
After the assembly, the model of technical means was placed (Figure 1) on the upper glass of the body of the floating aid to navigation RB-3 using metal brackets, while the antennas were removed to the uppermost position.

![Figure 1. Assembling the technical device on the upper glass of special floating aids to navigation barriers RB-3](image)
takes no more than 5 minutes. Its main purpose is to write an encryption key into the device, which is unique for each technical aid to navigation.

![Figure 2. Presetting the technical device before installation on the hull of a special navigation barriers RB-3](image)

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Figure 3 shows assembled special floating aid to navigation. A crane attachment is connected to the eyelets for placing the buoy on test water area. The batteries are located in an internal waterproof compartment. The information sensor is embedded in a special compartment that allows connecting with the external environment and preventing water from entering the inner compartment.

![Figure 3. Assembled special floating aids to navigation](image)

Figure 3. Assembled special floating aids to navigation

After the launch of the operating model of the technical means with a special floating aid to navigation, the anchor was laid (Figure 4). The size and length of the anchor chain and anchors were used in accordance with the requirements for the safety of navigation on inland waterways. A cement anchor was preferred, although a cast iron anchor was acceptable. The anchor chain was connected to the anchor through a swivel block.

The anchor was laid in the lower border of the site No. 2 of the “Drone” test water area. Thus, a dedicated navigational safety device was placed in the test area. The special aid to navigation retained its vertical landing despite the fact that in this area the river flow rate reached significant values, which
was clearly seen from the deviation of the milestone that enclosed the test water area from the vertical plane (Fig. 4).

![Special floating aids to navigation on water area “Drone”, site 2 on the Neva river](image)

**Figure 4.** Special floating aids to navigation on water area “Drone”, site 2 on the Neva river

The technical means, installed on special aids to navigation, was assembled and activated after being loaded aboard the conditional vessel “Puteyskiy 16”. The activation of the means of communication of the technical aids was accompanied by the activation of the simulator of navigation fire. A powerful red LED was used as a simulator of navigation light, which was regulated by a controller of a technical facility. The navigation light simulator was programmed for flashing mode. However, it is necessary to note that the mode of the simulator of navigation light can be easily changed.

The positioning data and information from the sensor began to flow to the remote workplace after the activation of the device. Figure 5 shows the screenshot of the screen of the remote workstation. The yellow buoys show the locations of the milestones enclosing the perimeter of site No. 2 of the Drone test water area. The red point located downstream of the pair of milestones enclosing the lower boundary of the test water area shows the momentary location generated by the consumer navigation equipment, which is a part of the technical means located on a special aid to navigation. The special software of the remote workstation allows several modes of operation, including the mode of displaying the trajectory (history) of movement (Figure 6).

![Display of the momentary location generated by the navigation equipment of a consumer of technical means](image)

**Figure 5.** Display of the momentary location generated by the navigation equipment of a consumer of technical means
4. Discussion
In order to verify the input of data from a technical device of a special aids to navigation to an external server over LTE mobile networks, sequential requests were made via the http protocol, a get request was used, log files were verified on the external server, AWStat statistics were used, Apache server errors were verified (error_log ). No errors were found. The assessment of the accuracy of the determination of the location of the aid to navigation using the developed technical device was carried out by recording data on the location of the device determined by GNSS signals for 1 hour (≈3000 measurements). At the same time two devices were used, with different GNSS receivers, separated by 15 meters apart. Mathematical processing showed that the accuracy of the determination of the location of a technical device with 95 % availability was 12 meters (receiver A – U-Blox NEO-6) and 6 meters (receiver B – U-Blox NEO-7), which corresponded to the declared technical characteristics of receivers with standard antenna.

5. Conclusion
According to the results of field tests, it became possible to draw the following conclusions. The proposed navigation buoy had the ability to quickly communicate with ships via Wi-Fi broadband wireless communication channels. In addition, the device provided a more accurate positioning of the buoy, since it achieved an accuracy of tens of centimeters through the use of RTK corrections. The navigation device continuously recorded the waves of water (using the integrated 9-axis 3D position sensor), which allowed providing the approaching vessels with additional information about the navigation situation in digital form using special signals from the LED emitter. In the future, the navigation buoy can be used as a navigation barrier in real conditions [8–10], including for unmanned or autonomous surface vessels.

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