Experience of Use High-Precise Position Systems for Inland Waters

V Karetnikov¹, I Pashchenko¹, V Kozlov¹, A Butsanets¹

¹Department of Shipping on Inland Waterways, Admiral Makarov State University of Maritime and Inland Shipping, 5/7 Dvinskaya Str., Saint-Petersburg, 198035, Russia

Abstract. Real Time Kinematic (RTK) is a differential method of object positioning using GNSS in which code corrections are supplemented by phase ones and transmitted from a base station (with precisely known coordinates) to a movable receiver in real time [1]. Having a series of advantages over classical differential methods of object positioning the most essential of which is centimeter precision of positioning, the method has found wide use in various spheres. Networks providing RTK solutions in real time on a commercial basis, and also free of charge in certain countries within the frameworks of state geodetic networks cover considerable areas with a field of high-precision corrections.

1. Introduction

Currently in water transport there is enhanced interest in robotized self-contained above-water objects that function using unmanned technologies. Many problems can be solved using remotely controlled or automated robots [2, 3]. Robots enable surveys of a reservoir and dams [4] excluding human factor and reducing personnel costs. Above-water unmanned vessels assist in intelligence operations in shallow waters under conditions of limited visibility [5]. A bathymetric survey with the use of robots allows charts of shallow and protected areas to be prepared with a considerable reduction of costs of such operations [6-8]. Not of less importance is environmental monitoring, for instance, there are already unmanned vessels with automatic water sampling [9, 10].

Thus, it can be concluded that the use of unmanned vessels in operations is a sufficiently constructive solution allowing the efficiency and safety of operations to be increased.

The development of unmanned technologies is impossible without the development of remote control [4]. If the said technology is implemented there is no crew on board the vessel, and control is performed by the operator remotely. The operator receives data to take decisions aimed at ensuring safety of navigation from various data sensors located on board the vessel in real time. Here one should bear in mind that the introduction of unmanned vessels should not have negative effects on safety of navigation.

Data sensors should be very accurate and transmit data on the state of the vessel in time. The concept of the unmanned vessel implies a high level of automation. The larger the vessel, the more sensors it has.

As the vessel is significantly affected by external forces (wind, current, the heaving of the sea), one of the most important problems is the vessel’s positioning accuracy. The scientific publications discuss uses of RTK to prevent tsunamis [11], research aimed at increasing positioning accuracy [12, 13], there are no cases, however, of comparing popular (in the opinion of the employed experts) high-precision positioning systems already operating in the spheres of satellite navigation of inshore objects and flying vessels for their use in internal waterways.
2. Methods and Materials
In September 2018 the workgroup of the Scientific and Educational Center «Unmanned technologies in water transport» attempted an experiment to research whether it is possible to use RTK in practice for navigation in internal waterways.

In the course of the experiment it was planned:
- to establish the precision of determining the RTK position of a vessel proceeding on an area of inland waterways at working (safe speed);
- to determine the safety of the RTK solutions being received, as well as the actual number of failures and the re-initialization time of onboard RTK equipment, taking into account the specifics of the area of inland waterways selected for the experiment;
- to give a comparative characteristic of the data obtained through RTK on the position of the vessel with the reference data (the post-processed data were taken as the reference ones).

The experiment used the vessel (of project 3052) Viktor Shurpitsky (figure 1) the main characteristics of which are given in table 1. [14]. The vessel is a work vessel of the Neva-Ladoga region of waterways and navigation ensuring servicing and monitoring of navigation aids.

![Vessel «Viktor Shurpitsky»](image)

**Table 1. Basic characteristics of the vessel.**

| Characteristic                  | Dimension | Value  |
|--------------------------------|-----------|--------|
| Length overall                 | m         | 35.65  |
| Width overall                  | m         | 5.80   |
| Full height                    | m         | 2.60   |
| Draft (river/sea)              | m         | 1.51/1.48 |
| Displacement with % load       | t         | 157    |
| Power of propulsion machinery  | kW        | 2x200  |
| Crew                           | persons   | 10     |
| Freeboard, (river/sea)         | m         | 1.096/1.126 |
| Cruising capacity              | days      | 6      |

On top of the ship’s deckhouse two GNSS antennas and a radial system SA-2 (figure 2) were placed:

1. TW8829 Antenna GLONASS/GPS L1/L2 – an external active professional antenna to receive GPS L1/L2, GLONASS L1/L2 and SBAS (WAAS, EGNOS and MSAS) signals in the frequency band (L1 from 1.574 to 1.606 MHz and L2 1.215MHz-1.261MHz). It is part of the development kit NV08C-EVK-RTK-M
2. Geodetic antenna GPS/GLONASS L1/L2;
3. SA-2 Radial system (manufactured by the Russian company Design Bureau NAVIS)
The distances between the antennas were measured for subsequent bringing their centers of radiation into one point. The measurements were 90 cm by midship line and 66 cm between the antennas.

Geodetic antenna No.2 is connected to the receiver GLONASS/GPS JAVAD MAXOR (manufactured by the company JAVAD, U.S.) and was in the course of the experiment used jointly with the receiver for continuous recording using protocol BINR [15] of the data in RINEX format of the version 2.11. These data were later adjusted by the corrections, which allowed the coordinates to be determined with the accuracy 5 mm and these data to be accepted as the reference.

3. Results

The data on the ship’s position obtained with the use of antenna No.1 and the receiver NV08C-RTK-M (dual-frequency multisystem high-precision receiver GNSS to support navigation with centimeter precision using phase measurements GNSS GLONASS and GPS at the frequencies L1 and L2), for subsequent analysis and comparison were recorded using protocol NMEA [15] (figure 3). To evaluate and visualize the data obtained from the navigational receivers in real time, the software of Design Bureau Navis, «Storegis» was used (figure 4). The use of CY-2 enabled determination of the spatial angles of the ship’s orientation with the accuracy up to 0.2° per one meter of base.

The selection of the area and time for testing was one of the priority conditions for the conduct of the experiment. First, it was necessary to choose a place with strong additive noises. Depending on the properties the most widespread additive noises can be divided into three basic classes: fluctuation, concentrated, and pulse.
Of the greatest interest for our case is the last class, for it includes a subclass of pulse noises. Such noises are a regular or chaotic alternation of pulses that in a certain measure complicate the reception of a useful signal. An almost any noise lasting less than the duration of a signal element can act as a single noise. Despite an insignificant duration of action of separate pulse noises (usually $10^{-5} - 10^{-8}$ s), they are able to reduce the fidelity of the transmitted information significantly. This occurs due to the spectrum of such noise filling almost the entire frequency band of the receiver.

Pulse noises include:

- Industrial noise;
- Atmospheric noise;
- Electrization noise.

The said noises mostly occur due to the processes occurring in the Earth's atmosphere, and industrial activities. Thus, the water area in immediate proximity to the moorage wall of a shipbuilding or other large industrial facility can be the most constructive place for testing. In areas of the said objects there are much more sources of industrial noises than in a port area. The main source of the said noises will be electric arc welding, power components, electric motors, etc.

Besides, if possible, preference should be given to the time when there is precipitation, for under such conditions atmospheric noises are highly likely to occur.

Second, in choosing the area it is necessary to pay attention to the presence of a cross current. This will allow dynamic testing ensuring the misalignment angle between the midship line and the ship’s center-of-gravity path.

The time period from 26 September 2018 to 28 September 2018 was selected as the expected testing time. In the said period a rainy weather with double-layer cloud should be observed in the expected testing area, which is confirmed by the information presented in forecast charts with frontal analysis (figure 5). Such conditions may be considered as highly favorable for atmospheric noises to arise.

Figure 5. Forecast charts.

The suggested selection of place and time of the testing seems to be highly constructive, for it will allow simultaneous dynamic and static measurements to be taken in the complex jamming and situational environment, which is especially important taking into account the basic requirement for supporting safety of navigation.

A section of inland waterways of the Neva-Ladoga area of waterways and navigation 1,316–1,327 km was selected for conducting the experiment. The presence of shipbuilding yards (a potential source of industrial noises), ship traffic density (meeting ships and ships of opportunity as sources of cross-noise), a complex fairway and developed infrastructure have made this area the most interesting one for the conduct of this experiment.
4. Discussion

The complete coverage of the area with a cellular network enabled transmission of RTK corrections through Internet.

A base station (BS) located on the roof of the office building of Design Bureau Navis in Saint Petersburg (figure 6) the coordinates of which are precisely known through accumulation over long time and averaging of navigational information on its location, is connected to Internet. Through special software «NTRIP Caster» [15] a point of access was installed to transmit RTK corrections to the receiver in RTCM SC-104 format. The RTK receiver located on board the ship was connected to the BS point of access through the ship’s network of WiFi-router (in which Internet was accessed through a cellular modem).

Figure 6. BS location and ship’s route.

The initialization time of the onboard RTK receiver on the «NTRIP Caster» server of BS, the commencement of reception of RTK solutions and transition from floating solutions (RTK Float) to the fixed ones (RTK Fix) [16] was about 3-4 min. during the ship’s moorage. The age of the RTK correction is 1-2 sec.

Having recorded within 10 min. the navigational information for post-processing and the fixed solution, the RTK ship set to motion. Having performed a passage on the river Neva from 1,316 km to 1,327 km and back, having performed two Eight maneuvers (figure 7) and having safely passed in the closest proximity to the «Nevsky Shipbuilding Yard», the ship returned and got moored to the wharf.

5. Conclusion

In the course of the ship’s movement on the experiment’s route, short-time (2-3 sec.) losses of the fixed RTK solution were observed.

The positioning accuracy in RTK varied from 3-10 cm. There were no observed initialization failures of the onboard RTK receiver on the BS server.

According to the post-processed data and RTK solution graphs were constructed (figure 8), where the blue graph is navigational data accepted as reference, and the green graph is RTK solutions.

The performed experiment shows that, having solved a number of issues related to the specifics of operation of water transport:

- effects of pitching and rolling on the orientation of the GNSS antenna in space, inclusion into the antenna complex of a ship’s lean angle and differential sensors
- selection of the optimal way of transmitting RTK corrections to the onboard receivers (in absence of the coverage with a cellular network of an area of inland waterways, the use of satellite communications, etc.)
- to pay special attention to the electromagnetic protection of navigational information transmission channels for RTK under the effects of cross-noise, industrial noises on them [17]. Especially on areas of inland waterways passing near large cities and industrial areas
- creation of a network of base stations, as well as their control center in order to support a reliable field of high-precision RTK corrections
Using the already available developed infrastructure of inland waterways, it is possible to set up a new information and communication network of transmitting high-precision corrections of centimeter precision capable of supporting unmanned ship navigation in inland waterways of the Russian Federation.

References

[1] Rizos C 2009 Network RTK research and implementation—a geodetic perspective, *Position*. **1**(02) 144-50.
[2] Wróbel K, Montewka J, Kujala P 2018 System-theoretic approach to safety of remotely-controlled merchant vessel, *Ocean Eng.* **152** 334-45.
[3] Kondo M, Shoji R, Miyake K, Furuya T, Ohshima K, Shimizu E, Nakagawa M 2018 Monitor System for Remotely Small Vessel Navigating, *Int. Conf. Human Interface Manage. Info.* (Springer, Cham) 419-28.
[4] Hue N H, Huong D C, Thanh N H 2019 A Technical Solution to Improve the Existing River Dikes for both Flood Prevention and Transportation Purposes, *IOP Conf. Series: Mater. Sci. Eng.* **507**(1) 012012.
[5] Metcalfe B, Thomas B, Treloar A, Rymansaib Z, Hunter A, Wilson P 2017 A compact, low-cost unmanned surface vehicle for shallow inshore applications, *2017 Intel. Syst. Conf. (IntelliSys)* (IEEE) pp 961-8.
[6] Kitts C, Mahacek P, Adamek T, Rasal K, Howard V, Li S, Hulme S 2012 Field operation of a robotic small waterplane area twin hull boat for shallow-water bathymetric characterization, *J. field Robot.* **29**(6) 924-38.
[7] Jin J, Zhang J, Shao F, Lyu Z, Wang D 2018 A novel ocean bathymetry technology based on an unmanned surface vehicle, *Acta Oceanologica Sinica* **37**(9) 99-106.
[8] Karetnikov V, Ratner E, Ageeva A 2017 Introduction of the automated hydrographic survey systems for creation of electronic nautical charts of internal waterways in Southern Africa, *2017 IEEE AFRICON* (IEEE) pp 1479-84.
[9] Shuo J, Yonghui Z, Wen R, Kebin T 2017 The Unmanned Autonomous Cruise Ship for Water Quality Monitoring and Sampling, *2017 Int. Conf. Comput. Syst. Electronic. Control (ICCSEC)* (IEEE) pp 700-3.
[10] Chen Y J, Liu P X, Jiang B H, Zhang S X, Feng F 2018 Study on the application of water quality monitoring technology based on unmanned ship, *Desalination water treat.* **121** 311-5.
[11] Ohta Y, Kobayashi T, Tsushima H, Miura S, Hino R, Takasu T, Sato T 2012 Quasi real-time fault model estimation for near-field tsunami forecasting based on RTK-GPS analysis: Application to the 2011 Tohoku-Oki earthquake (Mw 9.0), *J. Geophysic. Res. Solid Earth* **117**(B2).
[12] Parkins A 2011 Increasing GNSS RTK availability with a new single-epoch batch partial ambiguity resolution algorithm, *GPS solutions* **15**(4) 391-402.
[13] Heinrich M, Sperl A, Mittmann U, Henkel P 2018 Reliable Multi-GNSS Real-Time Kinematic Positioning, *2018 Int. Symposium ELMAR* (IEEE) pp 103-8.

[14] Weber G, Dettmering D, Gebhard H, Kalafus R 2005 Networked transport of RTCM via internet protocol (Ntrip)-IP-streaming for real-time GNSS applications, *ION GNSS 18th Int. Technic. Meet. Satellite Division* pp. 13-6.

[15] Lenz E 2004 Networked transport of RTCM via internet protocol (NTRIP)–application and benefit in modern surveying systems, *FIG Working Week* pp. 22-7.

[16] Paziewski J 2016 Study on desirable ionospheric corrections accuracy for network-RTK positioning and its impact on time-to-fix and probability of successful single-epoch ambiguity resolution, *Adv. Space Res.* 57(4) 1098-111.

[17] Vishnevsky Yu G, Sikarev A A 2006 *Signal destruction fields and electromagnetic protection of information channels in automatic ship traffic control systems* (SPb: Sudostroyeniye) p 356.