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Nowak Aleksander
Gdansk University of Technology, Poland

THE RESEARCH ON EGNOS SYSTEM IN CONTEXT OF THE ABILITY TO DETERMINE THE SHIP'S HULL SPATIAL ORIENTATION

ABSTRACT

The European Geostationary Navigation Overlay Service (EGNOS) thanks to geostationary satellites covers an area of whole Europe, including Baltic and North Sea. It allows to fix the coordinates of object position with typical absolute accuracy of 1,5 m. Previous research have shown that relative accuracy is usually higher than absolute one [Nowak A., 2010, Nowak A., 2011], so probably it could be possible to use EGNOS to determine direction in space. The research described in the paper concerned relative accuracy of three homogeneous EGNOS receivers, in context of the ability to determine the ship's hull spatial orientation. Theoretical basis, the process of the experiment and the results of recorded data analysis were described. The research were conducted in the summer of 2014. Three homogenous Leica Viva series receivers were used. They were configured to receive a differential messages of the EGNOS system. Recorded data were analyzed in context of fixes relative accuracy. On the basis of achieved results, a conclusion about the possibility of construction the measurement system for the automatic determination of the ship's hull spatial orientation angles in real time was drawn. The further research directions were pointed out, too.

1. SYSTEM EGNOS – BASIC INFORMATION

The European Geostationary Navigation Overlay Service (EGNOS) is the first pan-European satellite navigation system. It augments the US GPS satellite navigation system and makes it suitable for safety critical applications such as flying aircraft or navigating ships through narrow channels. Consisting of three geostationary satellites and a network of ground stations, EGNOS achieves its aim by transmitting a signal containing information on the reliability and accuracy of the positioning signals sent out by GPS. It allows users in Europe and beyond to determine their position to within 1,5 meters [Felski A., Nowak A., 2013, www1].

EGNOS is a joint project of ESA, the European Commission and Eurocontrol, the European Organisation for the Safety of Air Navigation. It is Europe's first activity in the field of Global Navigation Satellite Systems (GNSS) and is a precursor to Galileo, the full civil global satellite navigation system under development in Europe. After the successful

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completion of its development, ownership of EGNOS was transferred to the European Commission on 1 April 2009. EGNOS operations are now managed by the European Commission through a contract with an operator based in France, the European Satellite Services Provider [www1].

The EGNOS system comprises two main segments: the Space Segment and the Ground Segment. His functional architecture is shown in fig. 1.

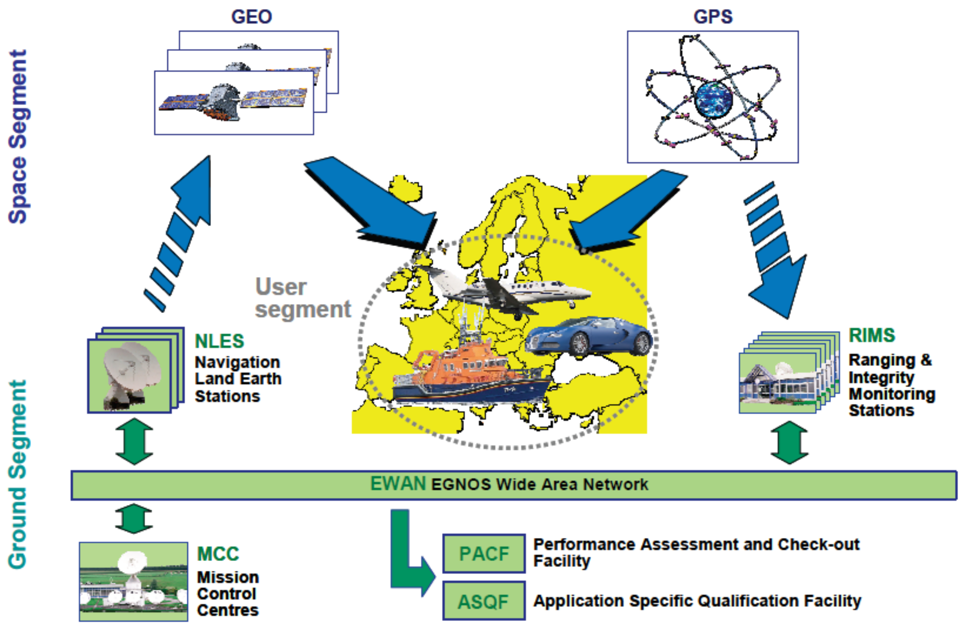

Fig.1. Functional architecture of EGNOS system [SDD OS, 2009]

The EGNOS Space Segment consists of 3 geostationary satellites (GEO) broadcasting corrections and integrity information for GPS satellites in the L1 frequency band (1575,42 MHz). The EGNOS Ground Segment comprises a network of:

- 34 Ranging Integrity Monitoring Stations (RIMS),
- 4 Mission Control Centers (MCC),
- 6 Navigation Land Earth Stations (NLES)
- EGNOS Wide Area Network (EWAN), which provides the communication network for all the components of the Ground Segment.

The locations of components listed above is presented in fig. 2.

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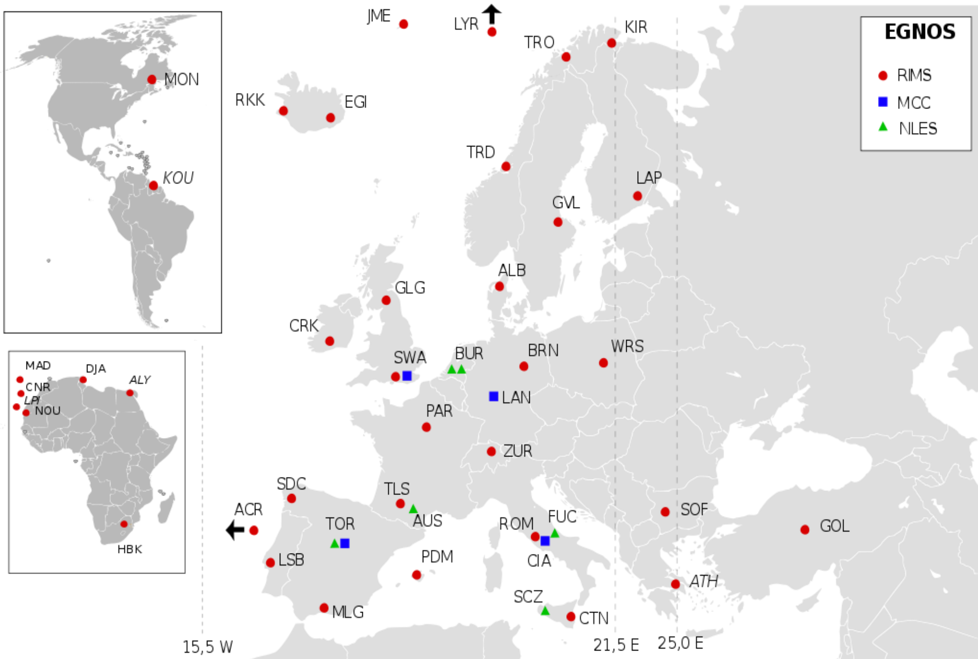

Fig.2. The location of the EGNOS Ground Segment components [www2]

EGNOS provides two services:

- **Open Service (OS)** – it has been available since 1 October 2009. In frame of it EGNOS positioning data are freely available in Europe through satellite signals to anyone equipped with an EGNOS-enabled GPS receiver [www1],
- **Safety of Live Service (SoL)** – it has been officially declared available for aviation on 02 March 2011. Space-based navigation signals have become usable for the safety-critical task of guiding aircraft - vertically as well as horizontally - during landing approaches [www1].

EGNOS seems to be attractive for users because of coverage area (see in fig. 3) and availability of low-cost receivers. EGNOS-enabled GPS receiver costs no more than GPS alone, because no additional module is needed to receive EGNOS transmission. Quite different situation is in case of other differential systems, where additional, very often expensive radio-modems are necessary. The absolute accuracy expected from EGNOS is depicted in fig. 3.

2. RELATIVE POSITIONING ACCURACY

Usually in navigational applications we consider absolute positioning accuracy understood as a measure how well the position solution confirms to “truth”. Truth is

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defined to be any specified user location where the position is known, within acceptable tolerances and with respect to an accepted coordinate system, such as World Geodetic System 1984 (WGS84) Earth-Centered, Earth-Fixed (ECEF) Coordinate System [SPS, 2001]. The absolute accuracy expected from the EGNOS is depicted in fig. 3.

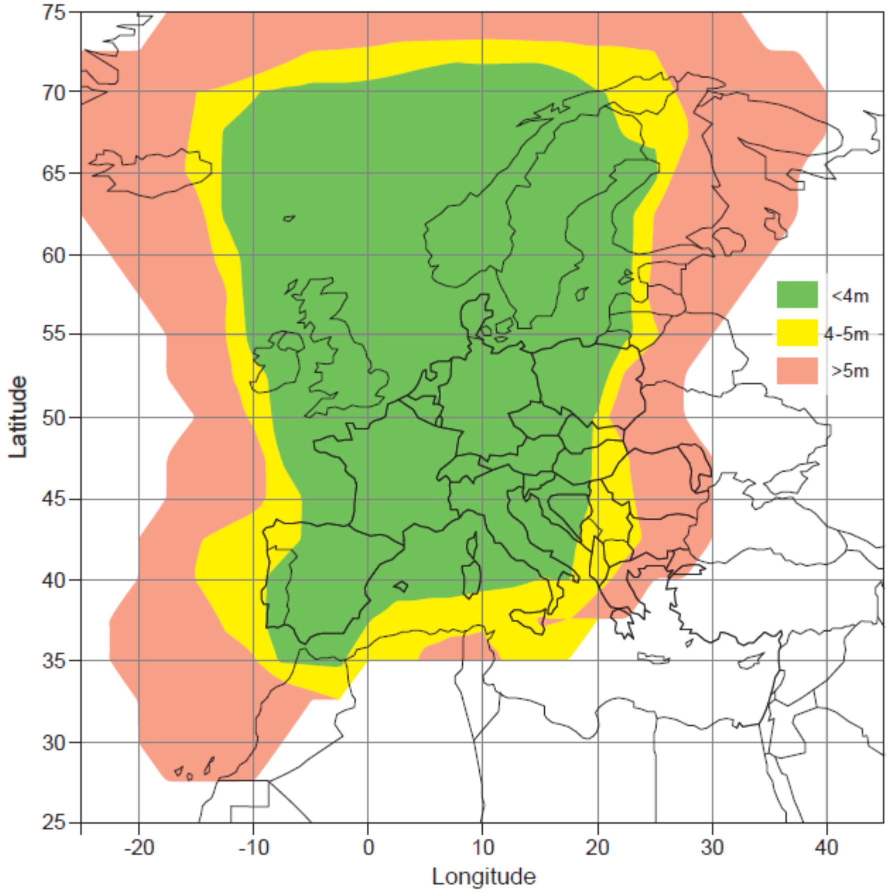

Fig.3. Absolute accuracy expected from EGNOS [SOL SDD, 2011]

The absolute accuracy is important, because it allows to estimate how far we are from navigational danger. But if we would like to determine direction with the use of two receivers, absolute accuracy is not so important as relative one understood as a measure, how precise one user is able to determine his location in relation to another one in case they are using the same positioning system at the same time. Of course high absolute accuracy results in high relative accuracy, but it is also possible to achieve high relative accuracy when the absolute one is low. The condition which has to be met is that the

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absolute fix errors of each receiver must have similar vectors (values and directions). Such situation is shown in fig. 4.

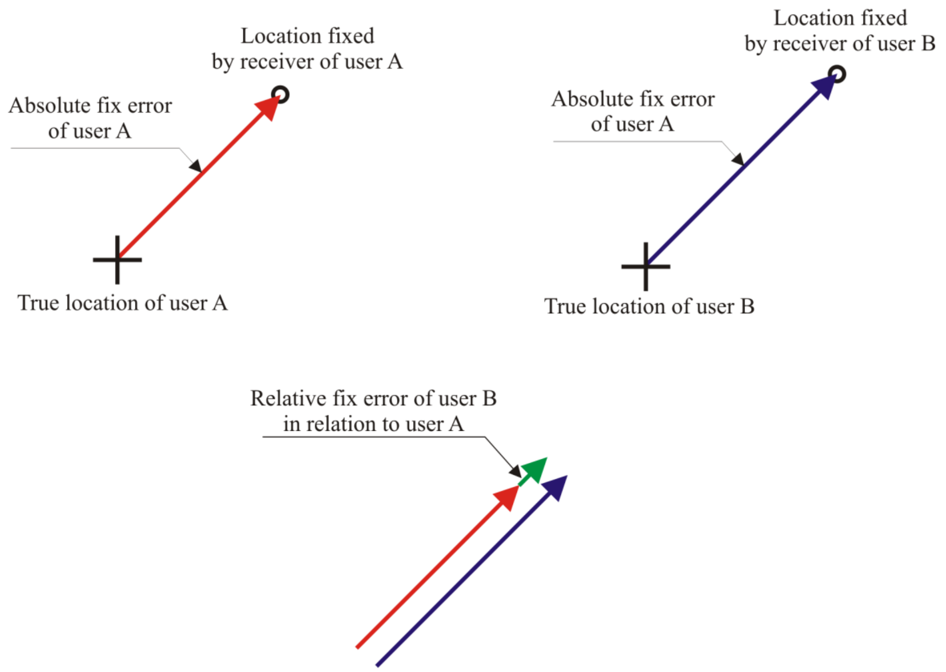

Fig. 4. The case of high relative fix accuracy in spite of low absolute one

High relative accuracy allows to determine direction in space on the basis of differences between coordinates of two receivers and spatial orientation of plane on the basis of fixes of three receivers. Of course accuracy of determination of spatial orientation angels is directly depended on precise of relative positioning. In order to increase relative fixing accuracy, probably homogenous receivers should be used. It can be assumed, that measurements errors connected with space segment and medium of satellite signal will be the same if receivers are close to each other. In such case only errors connected with the receives will affect relative accuracy of positioning. What is more, it can be expected, that high class receivers should have similar errors connected with their own noises. Thus, in the research three homogenous of highest class geodetic GNSS/EGNOS receivers were used.

3. THE EXPERIMENT

The main aim of the research was to prove the formulated hypothesis that three homogenous high class EGNOS receivers can be used to determination of ship's hull

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spatial orientation. To achieved it the measuring experiment described below was done. It should be underlined that obtained results based only on single point solutions, without any additional mathematical aid, like robust estimation. Thus, can be expected that further improvement of achieved relative fixes accuracy is possible.

3.1. THE COURSE OF THE EXPERIMENT

The experiment was carried out in Naval Academy of Gdynia. Three GNSS/EGNOS high class geodetic receivers were used. They were Leica Viva sets (shown in fig. 5) consist of:

- multi-frequency geodetic Leica Viva GS10 receiver,
- shockproof controller CS15 with VGA touchscreen,
- antenna AS10.

Receiver GS10 Controller CS15 Antenna AS10

Fig. 5. The Leica Viva sets

The basic parameters of Leica Viva GS10 receiver are presented in table 1.

Table 1. Basic parameters of Leica Viva GS10 receiver

Type of receiver	**GS10:** Multi-frequency, geodetic, GPS/GLONASS/GALILEO
Methods of measurements	**Methods of measurements:** static, fast static, kinematic on the fly; **Tracking frequencies:** L1/L2/L2C/L5/GIOVE_A/GIOVE_B/E1/E5a/E5b/ Alt_BOC/B1/B2/SBAS/WAAS/**EGNOS**/GAGAN/ MSAM/QZNSS
Technology of receiver	SmartTrack + GNSS, 120 channels
Interval of data recording	can be set by user from 0,05 do 300 seconds
Temperature of work	from -40°C to +70°C
Temperature od storage	-55°C do +85°C
Humidity	to 100%

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The three GNSS receivers were located as shown in fig.5. Distances between antennas of each of them (lengths of baselines) were measured in two ways:

- by tap measure,
- by 40 minutes GNSS static measurement campaign.

Because obtained results were very similar, thus coordinates fixed by GNSS static measurement were taken as "true" and on the basis of them the "true" mutual spatial orientation of three antennas was computed (angles between particular baselines, as shown in fig. 6 and table 2) . The antennas didn't move during the experiment, so the mutual spatial orientation was used as a measure of relative accuracy.

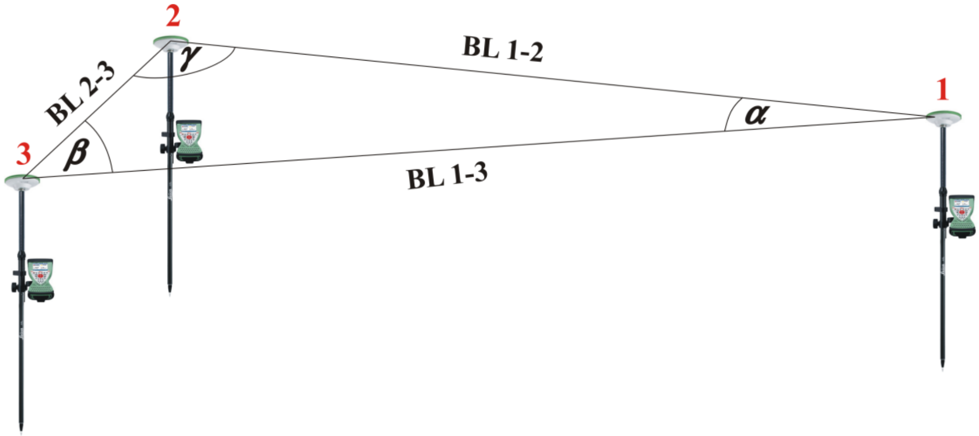

Fig. 6. The mutual spatial orientation of three GNSS antennas – baselines and angles between them

Table 2. True values of lengths of particular baselines and angles between them

Length of baseline **BL 1-2**	**20,958 m**
Length of baseline **BL 1-3**	**20,938 m**
Length of baseline **BL 2-3**	**4,258 m**
α - angle between BL 1-2 and BL 1-3	**11,67°**
β - angle between BL 1-3 and BL 2-3	**84,07°**
γ - angle between BL 1-2 and BL 2-3	**84,26°**

In the next step, the GNSS receivers were set in EGNOS mode and 3 hours measurement campaign was done. The fixes frequency was 1 Hz.

3.2. THE RESULTS OF THE EXPERIMENT

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Based on single point solutions of particular receivers the momentary mutual spatial orientation of three antennas was computed (angles between baselines). Then determined angles were compared with “true” values presented in table 2. The differences between them were errors, which are presented in fig. 7, 8 and 9. Root Mean Square (RMS) values of particular errors were used as a measure of spatial orientation accuracy, and are presented in table 3.

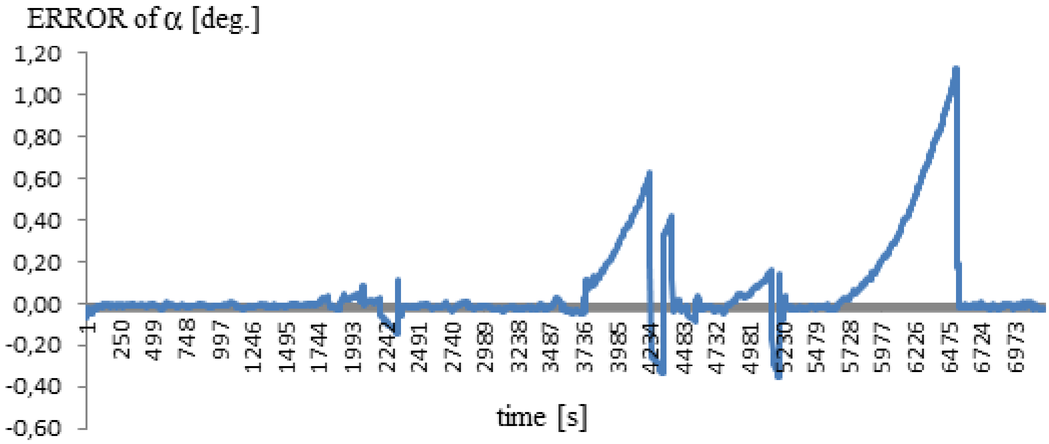

Fig. 7. Changes of errors of angle α determination during the experiment

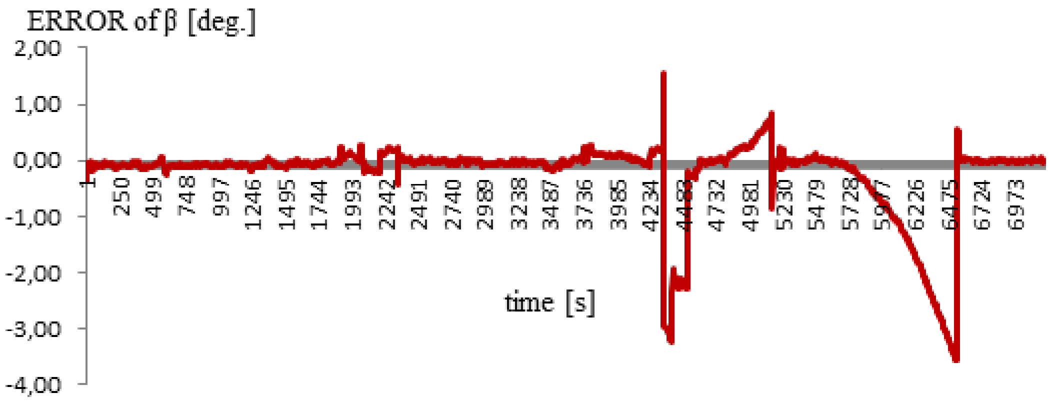

Fig. 8. Changes of errors of angle β determination during the experiment

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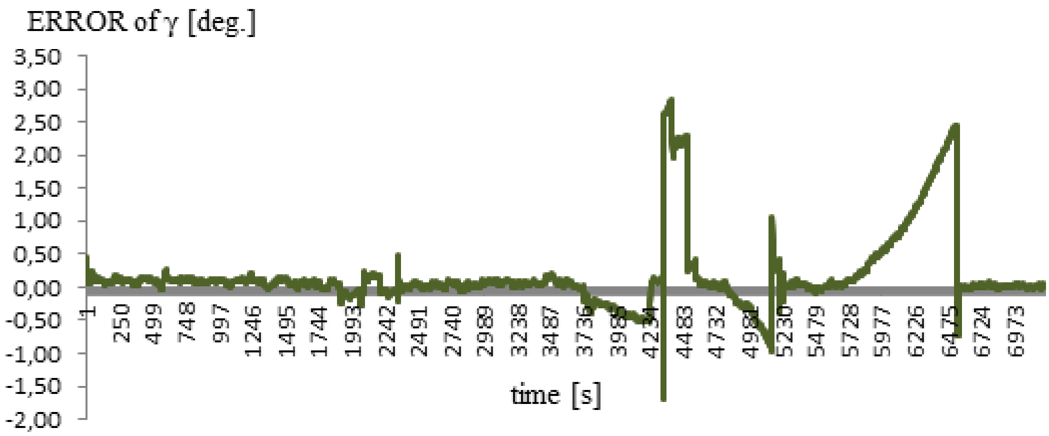

Fig. 9. Changes of errors of angle γ determination during the experiment

Table 3. RMS values of particular angels determination

RMS of angle α	**0,211°**
RMS of angle β	**0,590°**
RMS of angle γ	**0,734°**

CONCLUSIONS

The experiment shows that couple of homogenous high class EGNOS receivers achieve much more higher relative accuracy of fixes than absolute one. By analyzing the charts shown in fig. 8, 9, and 10, it can be noticed that the increase in the standard deviation (RMS) of particular angles determination is caused by temporary declines in relative accuracy. Thus, it requires a more thorough analysis of the recorded data in order to verify the reasons for this state of affairs.

Obtaining such high relative accuracy of positioning was undoubtedly possible thanks to application of high class homogenous geodetic receivers. The use of standard navigation receivers could not give as good results.

When it comes about the expected accuracy of determination of the ship's hull spatial orientation by three homogenous EGNOS receivers it should be mentioned, that it is strongly depended on distance between the antennas. As shown in table 3, angles β and γ were determined with over three times bigger errors than angle α. This inconvenience will be difficult to eliminate in real conditions, due to the physical dimensions of the ship's hull – length is always much bigger than width.

Further research will focus on the possibility of using cheaper navigation receivers and robust estimation account to improve the accuracy of determining the spatial orientation of the ship's hull by three EGNOS receivers.

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