EGNOS status and performance in the context of marine navigation requirements

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ABSTRACT: The current status of EGNOS (December 2006) is described as Initial Operations Phase and the EGNOS Open Service is just about to be formally declared as available for non-safety of life service. In meanwhile the EGNOS Signal in Space is provided almost in its nominal level and delivering, when available, the nominal system performance. New positioning technologies, such as EGNOS in Europe, create a new quality in marine navigation and bring further improvement of the maritime transport safety. It may be expected that very soon EGNOS will find significant interest among the maritime community serving as the augmentation system in the maritime transport applications of GNSS. The paper discusses the EGNOS status and the expected EGNOS performance in the context of marine navigation requirements. The system performance analysis is backed with the study of the various field tests results where the EGNOS positioning performance was verified by author in the experimental way.

1 EGNOS STATUS

European Geostationary Navigation Overlay Service (EGNOS) is designed to provide in Europe the regional augmentation to GPS and GLONASS systems. The main objective of the implementation such an augmentation is to improve the performance of existing satellite positioning systems in the context of accuracy, integrity, availability, and continuity.

The EGNOS will be available for users in the form of three services:

- The Open Service, consisting of provision of unrestricted access to the signal in space (SIS) without any guarantee of service.
- The Safety of Life (SoL) Service, consisting of the provision of access to the SIS with a guarantee of service regulated by a service-level agreement and by specific requirements on user terminal and the intended navigation operations.
- The Commercial Service, consisting of provision of controlled access to the SIS and data regulated by a commercial agreement.

On 28th of July 2005 EGNOS entered its Initial Operations Phase (IOP). The main objectives of the IOP are: to gradually increase operating efficiency and performance, and to ensure that appropriate resources are in place to guarantee the EGNOS operation. The IOP consists of three phases: rumping up, stabilization and qualification. Each phase was planned to last six months. The end of stabilisation phase supposed to be marked by Operations Definition Review (ODR) and at this stage EGNOS Open Service could be declared at the discretion of the authorising bodies (specifically the GNSS Supervisory Authority and European Commission). After the ODR the qualification phase to be conducted leading to Operation Qualification Review (OQR), at which point EGNOS will be capable of supporting safety-of-life operations. The IOP is conducted by ESA contractor called ESSP (European Satellite Service Provider), which is a consortium of European companies, lead by Alcatel Space. Following the OQR, the technical operation of the EGNOS should be directly controlled by the Galileo Concessionaire under formal management of the GNSS Supervisory Authority (Ventura-Traveset at el. 2006).

In spite of the established schedule, at the time of writing (March 2007) none of the official bodies did declared the EGNOS to be in its Open Service. The latest major system modifications took place in July 2006 when the EGNOS Test Bed (ESTB) operation was ceased and the full transition from ESTB to EGNOS was concluded. The actual EGNOS SIS status is as follows:

- The signal broadcast by the EGNOS satellites IOR-W (PRN 126) and AOR-E (PRN120) is used for EGNOS Initial Operations.
- The EGNOS ESA ARTEMIS satellite (PRN 124) is currently used by industry to perform various tests on the system.

Since July 2006 the operational EGNOS signal broadcast on PRN126 and PRN120, is using the MT0/2 and Band 9 of the Ionospoheric grid. The addition of MT0/2 into the system has a big significance in the development of EGNOS for users of non-safety of life services. MT0/2 will allow all receiver units, at their own risk, to process and use the corrections broadcast by EGNOS for multimodal non-safety of life applications. The provision of Ionospheric Band 9 should improve the EGNOS performance in the Northern European latitudes. The EGNOS signal on PRN124, currently used for testing, will broadcast in MT0/0 configuration (EGNOS website). At the moment it can be assumed that IOP phase will last till early 2008 when the SoL service will start finally. In meanwhile, the declaration of Open Service and Commercial Service opening can be expected during year 2007.

Together with resolving certain legal issues the technical infrastructure of EGNOS will evolve as well. The technical objectives of future EGNOS development include: extension system coverage to the North Africa region, implementation Message Type 0/2, enhancement of EGNOS RIMS to monitor GPS L1/L5, Galileo and GLONASS (EGNOS News 2006).

2 EGNOS AND MARITIME TRANSPORT REQUIREMENTS

In the maritime transport, the improvement of the performance parameters of the satellite positioning allows to extend the applicability of this method of positioning to operations with high safety requirements and in general improve the safety of navigation. The framework of maritime transport requirements for radionavigation systems performance is formed by two IMO resolutions: A.915(22) “Revised Maritime Policy and Requirements for a Future GNSS” and A.953(23) “World-Wide Radionavigation System”. First of those documents must be viewed as guidance for future developments of GNSS. Resolution A.915(22) is very valuable in the context of defining the operational requirements of various types of maritime operation but in general is addressed to the future satellite navigation systems such as: Galileo or the second generation GPS. EGNOS as the augmentation system of currently existing satellite systems has to be analyzed in the context of requirements set forth in the other document – IMO Resolution A.953(23).

This document gives the formal requirements for qualifying a radionavigation system as acceptable and safe enough for current needs of the maritime transport operations and in its general concept refers to existing systems showing the direction towards improvement of the actual performance and quality of positioning based on radionavigation services. The operational performance requirements for maritime radionavigation systems stated in the IMO Resolution A.953(23) are summarised in Table 1.

Table 1. Performance requirements for radionavigation systems according to IMO Resolution A.953(23) adopted 5th December 2003.

Parameter	Area of navigation		
	Harbour entrances, harbour approaches and coastal waters		
	High volume of traffic and/or a significant degree of risk	Low volume of traffic and/or a less degree of risk	Ocean waters
Position accuracy (horizontal, 95%)	≤ 10 metres	≤ 10 metres	≤ 100 metres
Coverage	adequate to provide position-fixing throughout this phase of navigation		Global
Update rate (computed and displayed position)	≤ 10 seconds	≤ 10 seconds	≤ 10 seconds
Update rate (if used for AIS, graphical display or direct control of ship)	≤ 2 seconds	≤ 2 seconds	≤ 2 seconds
Availability	≥ 99.8% (2 years period)	≥ 99.5% (2 years period)	≥ 99.8% (30 days period)
Continuity	≥ 99.97% (3 hours duration)	≥ 99.85% (3 hours duration)	NA
Time-to-alarm	10 seconds	10 seconds	as soon as practicable by Maritime Safety Information (MSI) systems.

The required operational performance of EGNOS is defined in the terms of the civil aviation needs and it is expected that EGNOS SIS (Signal in Space) will at least fulfil requirements of APV-II (Approach with Vertical Guidance) operation:

- position accuracy: horiz. – 16 m, vert. – 8 m;
- integrity: time-to-alarm – 6 s; integrity risk – $1 \div 2 \times 10^{-7}$/150 s; alarm limit – 20 m vert., 40 m horiz.;
- availability: 99.9% ÷ 99.999%;
- continuity risk: $1 \div 8 \times 10^{-6}$/15 s (equivalent of $0.72 \div 5.76 \times 10^{-3}$/3hours) – (highest requirement in maritime transport 3×10^{-2}/3hours).

Above aviation requirements are stricter in every aspect than those set forth in IMO Res. A.953(23). It is worth to explain that with GNSS or any its augmentation it is much easier to achieve the better horizontal position accuracy than vertical, so by complying to 8 meter vertical position accuracy requirement EGNOS has to bring the horizontal position accuracy well below 10 metres level. Additionally, the APV-II requirements describe expected EGNOS performance by some additional parameters, such as integrity risk and alarm limits, which are not stated in Res.A.953(23) but have been defined as the maritime transport requirements for future GNSS and set forth in IMO Res.A.915(22). In this context EGNOS potentially fulfils the maritime transport requirements not only as component of the current World-Wide Radio-navigation System (Res.A.953(23)) but as “Future GNSS” (Res.A.915(22)) as well.

The final performance of EGNOS in the aspect of integrity, continuity and availability will be achieved after the service reaches its full SoL (Safety–of-Life) application operability. So this is, why in the further part of paper the actual EGNOS performance in various areas is mainly characterized in the aspect of the positioning accuracy.

3 EGNOS PERFORMANCE ON THE POLISH COAST

When a new positioning system appears, it always raises questions about that how good is it and is it good enough for various applications. These questions become worthy to answer especially while talking about the Wide Area DGPS solution, which is highly dependent on the errors modelling over large areas. In this context, the verification of the EGNOS performance in various regions becomes the important issue. Along The Polish Coast, EGNOS may find many potential users serving as the augmentation of the positioning in the general and coastal navigation or during the port operations. This region, however, is located on the eastern edge of nominal EGNOS coverage and there is a possibility that the EGNOS accuracy in this region may be somehow degraded than that what is observed in the areas better covered by RIMS network.

Below the results of the tests of satellite positioning with using EGNOS signal are presented. The tests were conducted in the period after EGNOS had been declared to be in its Initial Operations Phase. In its main approach, the conducted experiments were focused on the verification of EGNOS performance in the context of maritime applications of the system. So this is why, the EGNOS accuracy is referred to maritime DGPS performance and the tests took place on the Polish Coast.

The results of conducted tests are presented in figures below. In Figures 1-3 the horizontal position error (HPE) or vertical position error (VPE) obtained during positioning for various systems (EGNOS, DGPS, GPS) or for different test sites (Gdynia; Dziwnów) is compared in several ways. Figure 1 presents and compares all-day position scatter plots. In Figure 2 the epoch-to-epoch HPE comparison of selected systems is given. The graphs included in Figure 2 show the distribution of points defined by two HPEs observed in the same time in two different receivers. The percentage of points located closer to one of two axes visualizes a quantity of epochs, while one receiver was giving less HPE than the other. Figure 3 summarizes the statistical parameters describing the accuracy of positioning observed with different systems or for different test sites during selected day periods and for whole day measurements. During tests, in both sites, the positioning was performed in static conditions with the antennas of the receivers located in known, precisely surveyed positions.

Having access to the EGNOS performance monitoring data, published on Internet, for Warsaw RIMS, the field measurements obtain in Gdynia could be referred to those, which were observed, at the same time, in the closest EGNOS monitoring station in Warsaw. The graph, presented in Figure 4 compares the EGNOS HPE observed during field tests in Gdynia to the EGNOS HPE logged during the same day in Warsaw RIMS.

Finally the Figure 5 gives the comparison of EGNOS performance parameters observed in various monitoring stations across Europe. This summary was based on information collected from ESA website. The sites chosen for analysis have been selected with the intension to compare the EGNOS performance in some extreme locations at the edge of the nominal service coverage (Tromso, Warsaw, Madrid) with those observations, which are obtained in the core of the service (Brussels, London). The Figure 5 compares the following performance parameters: Horizontal Position Error (HPE), Horizontal Protection Level (HPL), Vertical Position Error (VPE), Vertical Protection Level (VPL) and daily service availability for APV-I and APV-II operations. Protection Levels calculated within EGNOS describe the level of guarantee, which may be given by service that the positioning accuracy stays below the certain value. The data presented in the graph are the averages of the daily, 95% confidence level values of the each individual parameter logged at the end of every day in the period between 26th and 31st March 2007.

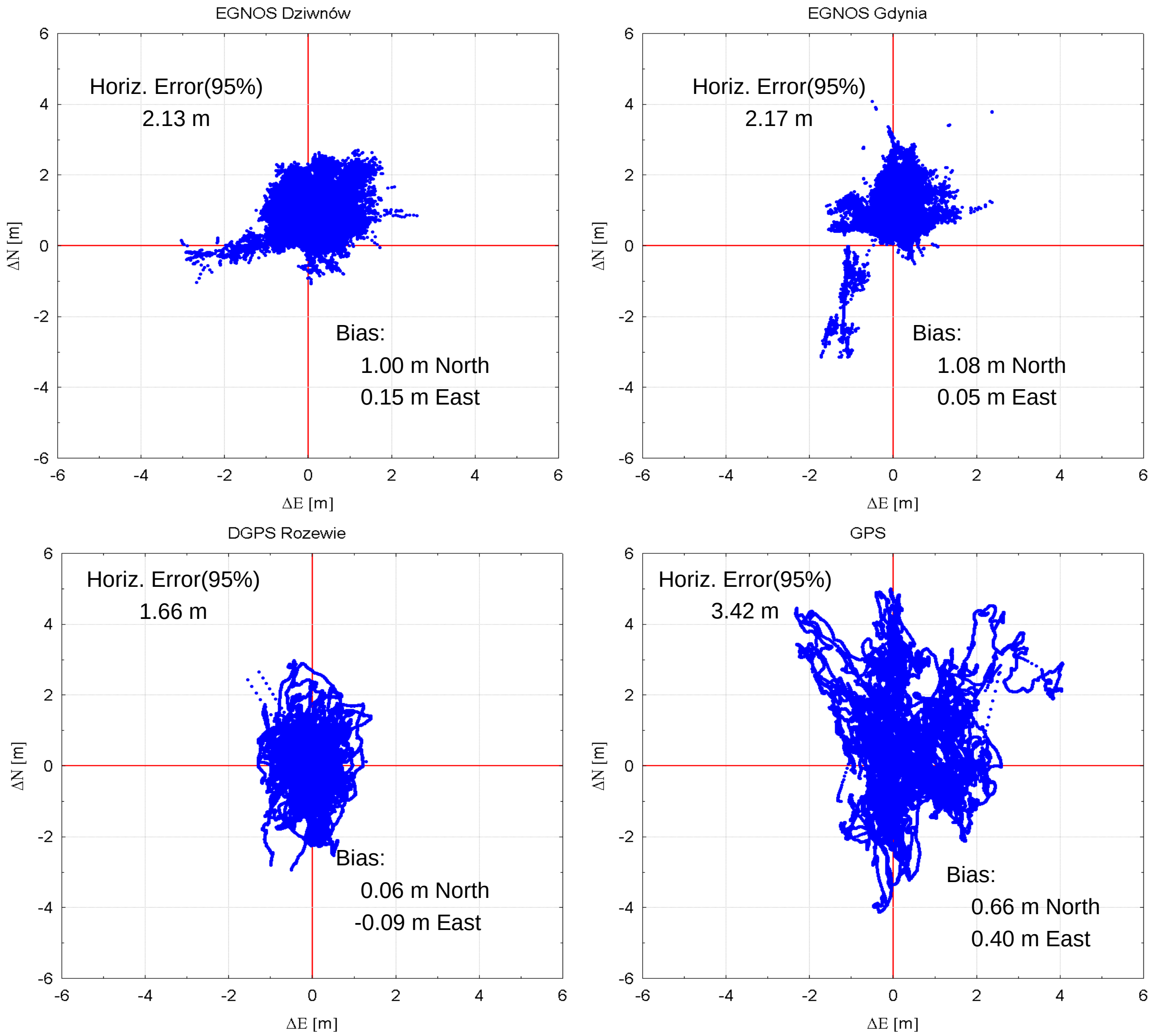

Fig. 1. Position scatter plots for GPS, EGNOS, DGPS observed during all-day measurements referred to “true” position

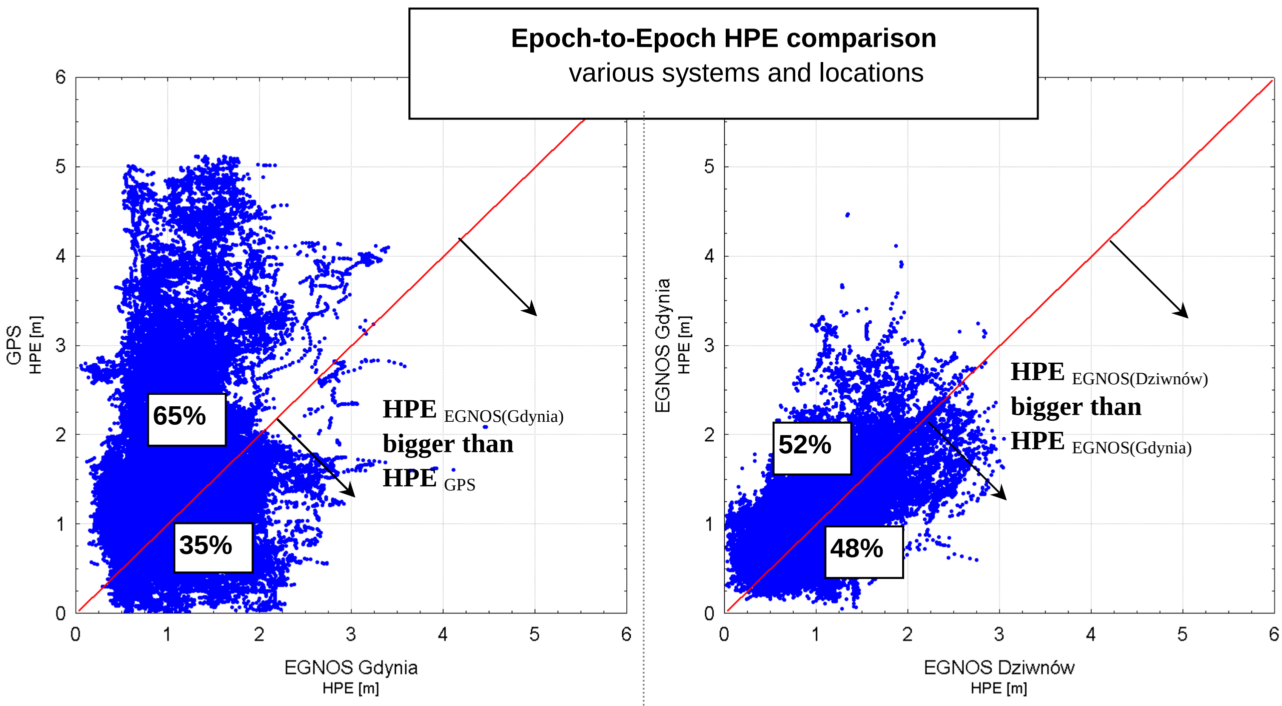

Fig. 2. Epoch-to-epoch comparison of HPE and VPE value between various methods of positioning or between various locations

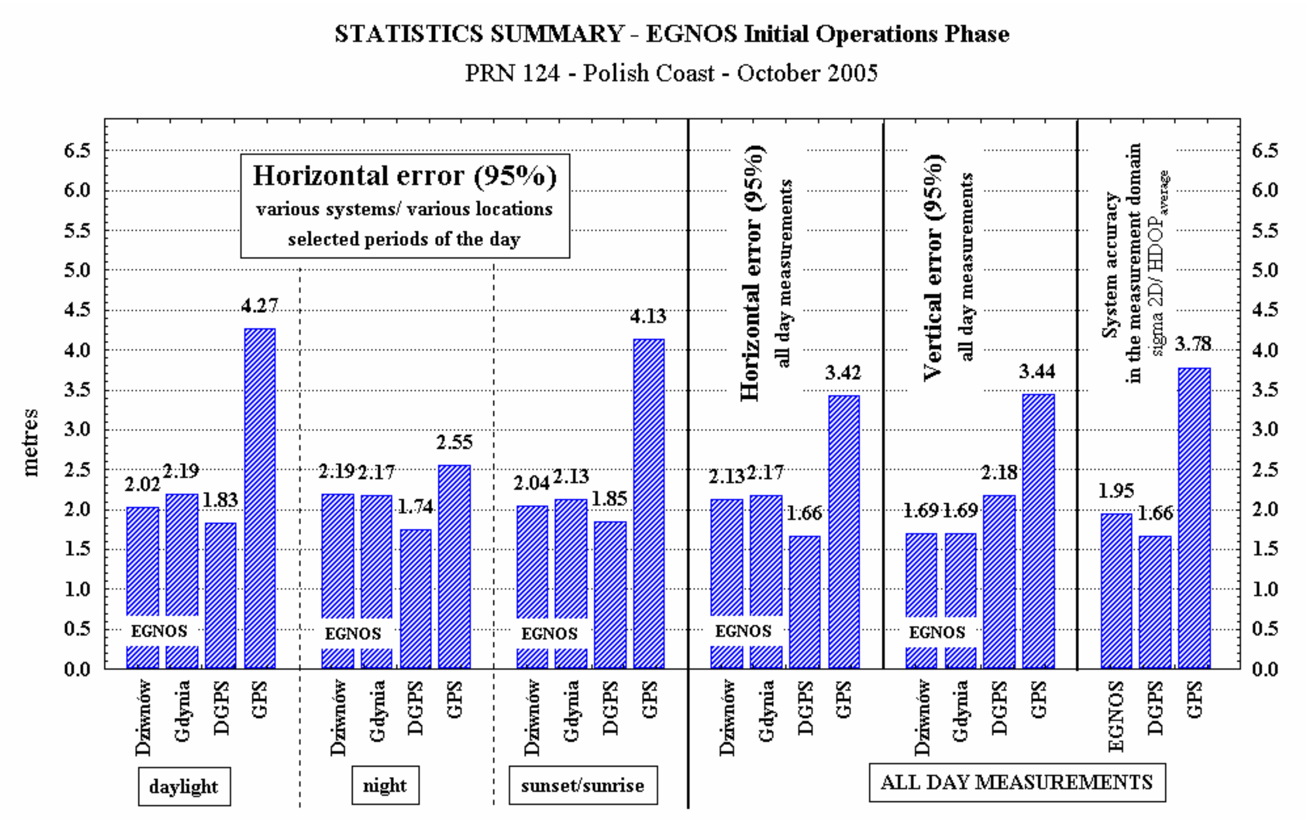

Fig. 3. Summary of position accuracy statistics obtained during experiment for various positioning methods, various locations and various periods of the day

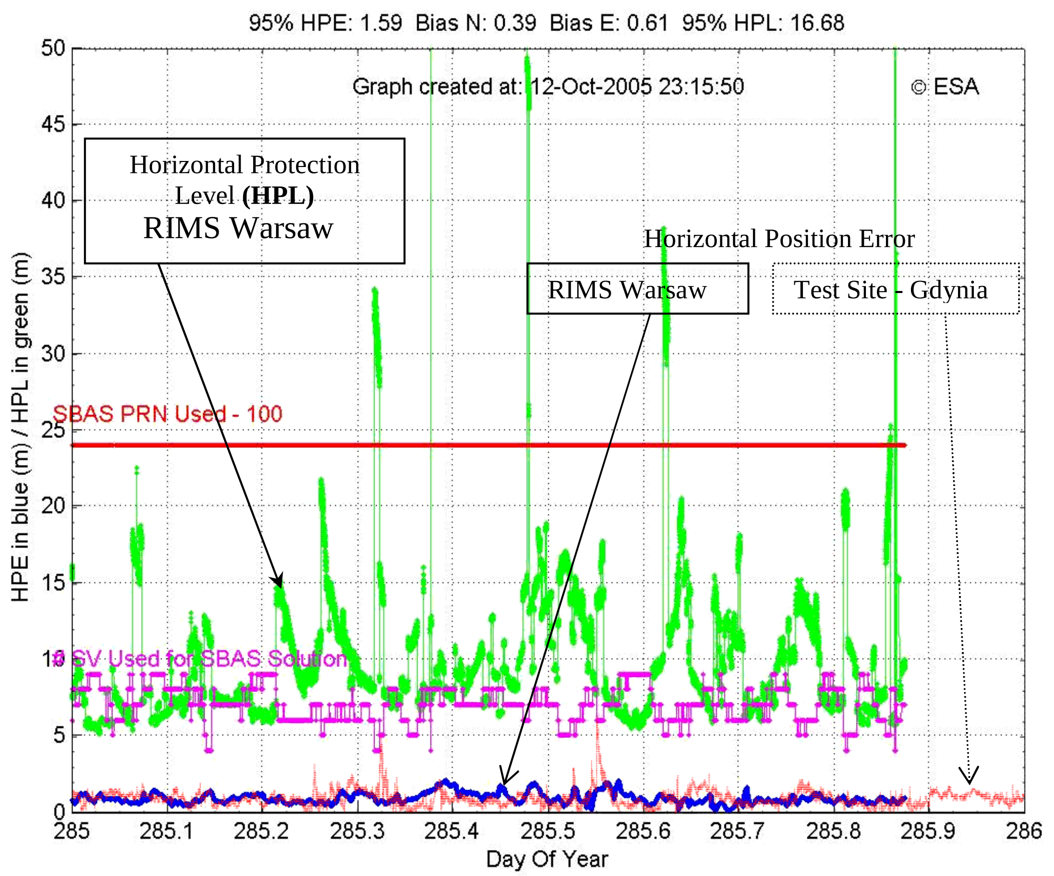

Fig. 4. EGNOS HPE observed in Gdynia compared to HPE and Horizontal Protection Level (HPL) logged, in the same time, in RIMS Warsaw – all day measurements (EGNOS website)

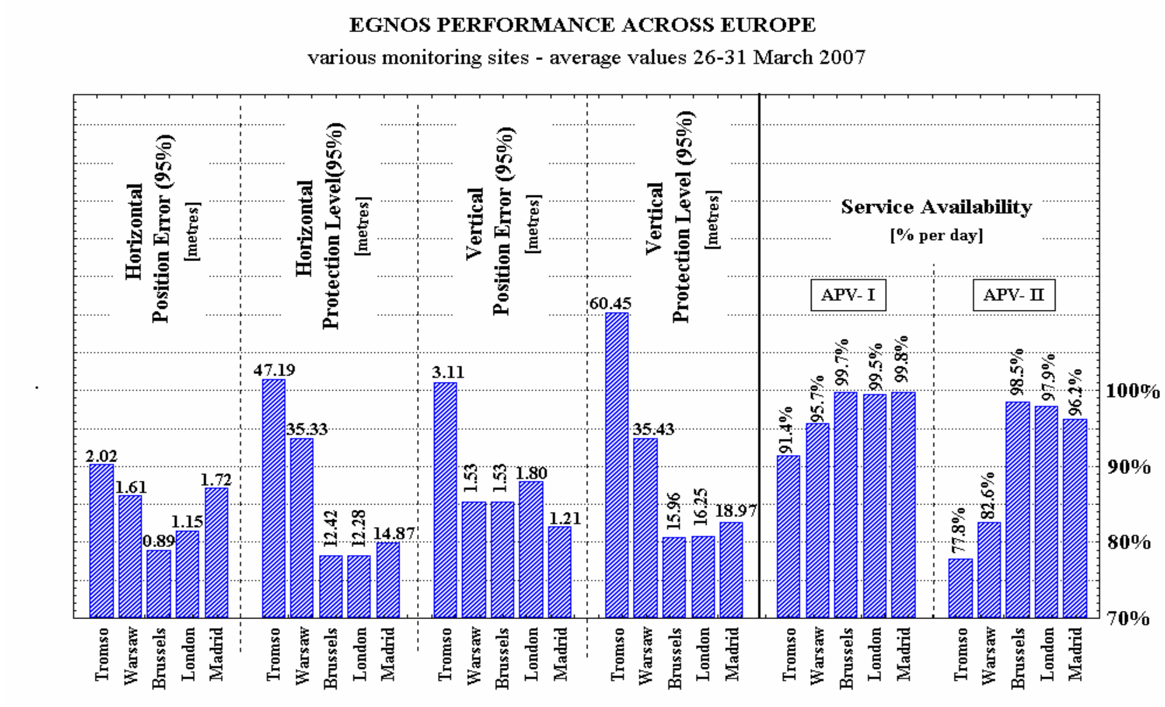

Fig. 5. EGNOS performance across Europe. Average daily values of HPE, HPL, VPE, VPL and APV availability observed in various EGNOS monitoring stations between 26sh and 31st March 2007(EGNOS website)

4 CONCLUSIONS

The horizontal EGNOS position accuracy in the area of experiment estimated during the all-day static test has reached the following values:

– horizontal error (95%) referred to true position – 2.13 to 2.17 meters;
– average position offset (bias) from true position – 1.1 meters to North;
– maximum single position HPE - not higher than 6 meters.

The performance of EGNOS is stable and at the same level during various day periods (daylight, night, sunrise, sunset) and the observed magnitude of the single HPEs and statistical errors in both test sites on the two edges of Polish Coast are similar.

The accuracy of EGNOS observed during field tests on the Polish Coast is worse than the accuracy obtained during the same time in the closest (~350 km away) RIMS station in Warsaw but the differences are not big (approx. 0.5m of horizontal error (95%)) and explainable by field nature of the tests conducted in Gdynia.

The EGNOS at the current stage of development delivers the comparable positioning accuracy as the maritime DGPS service. Slightly better absolute (referred to true position) accuracy of DGPS, expressed by lower values of 95% horizontal position error, can be considered as the result of lower offset (bias) of position estimates (lower offset of DGPS average position). This fact can be considered as the obvious advantage of Local Area DGPS over Wide Area DGPS, especially while close reference station is used (Rozewie ~40 km away).

The EGNOS performance may differ in various locations and may be degraded in the areas located at the edge of the nominal system coverage (Fig.5, Tromso and Warsaw). This service degradation is not so big in the context of positioning accuracy but exists mostly in the aspect of predictable service reliability (protection levels, availability).

Summarizing, it may be stated that the results of EGNOS Initial Operations Phase positioning presented in the paper show that this system is able to deliver users the service, which gives the comparable positioning accuracy as the maritime DGPS actually utilized in maritime transport. However, having in mind that EGNOS is providing to users the integrity channel and improves the satellite positioning availability, there are no doubts, that implementing EGNOS into the maritime transport applications is a good step towards the creation of the new quality of the navigational safety at sea.

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