Problem of positioning for maritime navigation and hydrography purposes, seen from the categories of the position error point of view, seems to have been solved on a global scale. Differential GPS, based on LF/MF reference stations, from 90-ties is the most popular radionavigation system for hydrography at the open sea. EGNOS - the first European satellite navigation system is a joint project of the European Space Agency, Eurocontrol, European Commission represents the first step towards Galileo – autonomous navigation satellite system of the 2nd generation (GNSS-2). The system Operational Readiness Review (ORR), took place in June 2005 and resumed of more than eight years of studies, work. The Initial Operations Phase have therefore started in July 2005 as an effect of successful negotiations between ESA and European Satellite Services Provider. Presented paper reports final results of the long-term static measuring campaigns, which were done before the EGNOS System Test Bed (ESTB) ending. Two-week accuracy analyses were done and the position error statistic distributions of system were also compared with the classical DGPS based on LF/MF reference station.

INTRODUCTION

The International Hydrographic Organisation (IHO) has issued Standards for hydrographic surveys (S44) since 1957. These are the standards used by most producers of hydrographic data. S44 4th Edition classifies surveys into four different types (four 'intended uses') [5]:

- Special Order - for specific critical areas with minimum under keel clearance and where bottom characteristics are potentially hazardous to vessels (generally less than 40m), such as harbours, berthing areas, and associated critical channels with minimum under keel clearances.
- Order 1 – for harbours, harbour approach channels, recommended tracks, inland navigation channels, and coastal areas of high commercial traffic density (less than
100m), such as harbours, harbour approach channels, recommended tracks and some coastal areas with depths up to 100 m.

- Order 2 – for areas with depths less than 200m not covered by Special Order and Order 1.
- Order 3 – for areas not covered by Special Order, and Orders 1 and 2 and in water depths in excess of 200m.

Summary of minimum standards for positioning in hydrographic surveys, according to [5] is presented in Tab. 1.

Tab.1 IHO S-44 - Summary of Minimum Positioning Standards for Hydrographic Surveys [5]

<table>
<thead>
<tr>
<th>ORDER</th>
<th>Special</th>
<th>Order 1</th>
<th>Order 2</th>
<th>Order 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal Accuracy (95% Conf. Level)</td>
<td>2 m</td>
<td>5 m + 5% depth</td>
<td>20 m + 5% depth</td>
<td>150 m + 5% depth</td>
</tr>
<tr>
<td>Fixed aids to navigation and features significant to navigation</td>
<td>2 m</td>
<td>2 m</td>
<td>5 m</td>
<td>5 m</td>
</tr>
<tr>
<td>Natura Coastline</td>
<td>10 m</td>
<td>20 m</td>
<td>20 m</td>
<td>20 m</td>
</tr>
<tr>
<td>Mean position of features</td>
<td>10 m</td>
<td>10 m</td>
<td>20 m</td>
<td>20 m</td>
</tr>
<tr>
<td>Topographical features</td>
<td>10 m</td>
<td>20 m</td>
<td>20 m</td>
<td>20 m</td>
</tr>
</tbody>
</table>

Global Positioning System Standard Performances [4], even after Selective Availability turning off (2nd May 2000), could not be accepted for many professional applications in hydrographic surveying. Especially air requirements require high integrity and reliability indexes could be fulfill only based on local or regional augmentation services. These techniques improve GPS data providing additional information from complementary systems, thereby augmenting both accuracy and quality performances. Land-based GPS differential services have been started in the beginning of 90-ties, in XXth century and covered almost all sea restricted areas in the world. Medium frequency transmission of the pseudorange corrections (PRC’s) and integrity information allow to archive no more than 5 m (p=0.95) accuracies in the range of 100 Nm from DGPS Reference Stations. In Europe, The European Tripartite Group (composed of the EC, ESA and Eurcontrol) is in the process of developing the European Geostationary Navigation Overlay Service (EGNOS), which covers the European Civil Aviation Conference (ECAC) region. The Paper presents the comparison analyse of DGPS and EGNOS application possibilities in hydrography, in the accuracy aspect.

1. SYSTEM DGPS LF/MF

DGPS reference stations are being used to broadcast differential GPS corrections to marine users. The corrections can increase GPS accuracy up to 2 m. (p=0.95) and allows to fulfill all navigation requirements in coastal navigation and hydrographic surveying. Idea of Polish DGPS system was started by Polish Hydrographic Office in 1993. In december of 1994 technical equipment consisted of the two DGPS reference stations (MX-9112) with local
monitoring and Control station was bought in Magnavox. With installation (in 1995) Naval Academy in Gdynia started investigation project for determining the role of DGPS in Polish Radionavigation Plan. The researches focus on coverage, availability, accuracy and integrity of system. National DGPS system consists of two separated subsystems controlled by control stations located in Gdynia and Szczecin. Architecture of the system has been separated on two parts because Polish coastline is being legislative divided between three independent Maritime Offices.

In the last years Polish DGPS system was modernized. In 1998 the old T – type antenna (ERP=0.4) of DGPS reference station Rozewie was replaced by a new more efficiency system and later (in 2001) the same thing was done on the second reference station Dziwnow.

2. EGNOS

EGNOS was designed for three types of services called:

- GEO Ranging (R-GEO): Transmission of GPS-like signals from three GEO satellites will augment the number of navigation satellites available to users. It allows improve the system geometry and accuracies.
- GNSS Integrity Channel (GIC): Broadcasting of integrity information will increase the availability of the EGNOS safe-navigation service to the level required for civil-aviation in non-precision approach.
- Wide-Area Differential (WAD): Broadcasting of differential GPS pseudorange corrections will increase the EGNOS navigation service performance - mainly its accuracy - to the level required for precision approaches down to CAT-I landings.

The coverage area serviced by EGNOS is the European Civil Aviation Conference (ECAC) Service Area (Fig. 2), comprising the Flight Instrument Regions (FIR) under the responsibility of ECAC member states (most European countries, Turkey, the North Sea, and the eastern part of the Atlantic Ocean).
EGNOS provides continuous services. Its infrastructure consists of:

- Four - Mission Control Centers (MCC): London-Swanwick (UK), Frankfurt-Lagen (Germany) Madrid-Torrejon (Spain) and Roma-Ciampino (Italy).
- Thirty four - Range and Integrity Monitoring Stations (RIMS) located all over the world.
- Six - Navigation Land Earth Station (NLES)
  a. Inmarsat (AOR-E): Goonhilly (UK), Tolouse (France),
  b. Inmarsat (IOR): Raisting (Germany), Fucino (Italy),
  c. ESA Artemis: Scanzano (Italy), Madrid-Torrejon (Spain).
- Two Support Processing Facilities Station: Torrejon, Toulouse.
- EGNOS Wide Area Network – EWAN with a main server in Amsterdam (Nederland).
3. CAMPAIGN AND RESULTS

The measurement campaign focuses on establishing horizontal and vertical accuracies of the EGNOS system in the long term observation, to compare the accuracies between EGNOS and LF/MF DGPS and compare final results with expected values from ESTB [4]. Reference points for receivers (EGNOS and DGPS) were set in the Port of Gdynia. Campaign took two weeks. The accuracies statistics were calculated based on Mathcad software. Lower figure presents scatter plots of the position solution for EGNOS and parallel working DGPS.

![Scatter plots](image)

Fig. 4 Scatter plots relative to average position (500.000 fixes/plot)

Archived horizontal accuracy presents table no 2.

<table>
<thead>
<tr>
<th>Fix number</th>
<th>DGPS</th>
<th>EGNOS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>rms (p=0.65) [m]</td>
<td>2rms (p=0.95) [m]</td>
</tr>
<tr>
<td>000001-500.000</td>
<td>0.8824</td>
<td>1.7649</td>
</tr>
<tr>
<td>500.001-999.999</td>
<td>0.8566</td>
<td>1.7133</td>
</tr>
<tr>
<td>1.000.000-1.500.000</td>
<td>0.8335</td>
<td>1.6670</td>
</tr>
<tr>
<td>1.500.001-2.000.000</td>
<td>0.8615</td>
<td>1.7230</td>
</tr>
<tr>
<td>Σ</td>
<td>0.8587</td>
<td>1.7174</td>
</tr>
</tbody>
</table>

The same analyses were done relate to vertical position error performance (fig. 5).
Fig.5 Vertical position error performance histogram (left-EGNOS, right-DGPS)

Tab.3 Statistical vertical accuracy results of DGPS and EGNOS campaign

<table>
<thead>
<tr>
<th></th>
<th>DGPS</th>
<th></th>
<th></th>
<th>EGNOS</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fix</td>
<td>rms (p=0.65)</td>
<td>2rms (p=0.95)</td>
<td>95 % of</td>
<td>Fix</td>
<td>rms (p=0.65)</td>
</tr>
<tr>
<td></td>
<td>number</td>
<td>[m]</td>
<td>[m]</td>
<td>population</td>
<td>number</td>
<td>[m]</td>
</tr>
<tr>
<td></td>
<td>2.000.000</td>
<td>1.4332</td>
<td>2.8665</td>
<td>2.8009</td>
<td>1.700.000</td>
<td>6.2108</td>
</tr>
</tbody>
</table>

4. SUMMARY

Final results have shown significant differences between EGNOS statistics calculated in two methods: when Gaussian distribution of errors were assumed and sorting of individuals errors to find the element which value is upper that 95 % of population. The measurements proved than many individual fixes error had a large values. Archived accuracies were significant differ than Estimated ESTB horizontal accuracy performances. During EGNOS system campaign the large position errors occurred, calculated EGNOS vertical accuracies shown 12.4 m (p=0.95). Classical DGPS LF/MF horizontal and vertical accuracies were lower than 2-3 m. As a summary we can conclude that EGNOS could not fulfill accuracy requirement of the hydrographic special order, where DGPS archive required accuracy.

REFERENCES