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EGNOS – ACCURACY PERFORMANCE IN POLAND

ABSTRACT

EGNOS – the first European satellite navigation system is a join project of the European Space Agency, Eurocontrol, European Commission and represents the fist step to 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, works, leaded by ESA and an industrial consortium with Alcatel Space as the Prime Contractor. The Initial Operations Phase has therefore started in July 2005 as an effect of successful negotiations between ESA and European Satellite Services Provider. During the last years many different test, trials and measurement campaigns have been done in positioning, navigation, time services and other application for improving different characteristics of EGNOS [4, 5]. Some of them were also realised in Poland [1, 2] and observed accuracy confirm high system performances. Poland is at the edge of the system coverage then the system disturbances could be more probable than in the central part of the Europe.

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

Global Positioning System Standard Performances [6], even after Selective Availability turning off (2nd May 2000), could not be accepted for many professional applications in navigation. 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. This solution couldn't be applicable in air navigation because of its local nature, then National Aviation Administrations made an effort to improve safety of navigation of a flight in all phases even in areas not presently covered by traditional navigation systems (oceans, remote regions etc.) then:

− 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;

− in the United States, where the Federal Aviaiton Administration (FAA) leads the development of the Wide Area Augmentation System (WAAS) covering US Continental Part (CONUS) and also Canada region (CWAAS);

− in the Japan, Japanese Civil Aviation Beareau realized the MTSAT Satellite Based Augmentation System (MSAS), which is designated for Japan Flight Instrumental Region (FIR).

The coverage area serviced by EGNOS is the European Civil Aviation Conference (ECAC) Service Area (fig. 1), 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).
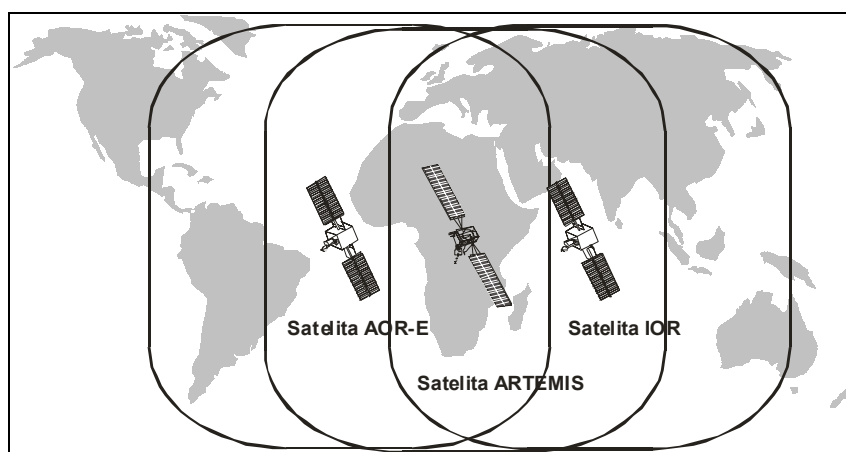

Fig. 1. Coverage of EGNOS system

EGNOS was designed for three types of services called:

1. 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.
2. 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.
3. 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.

EGNOS has the potential to benefit the main Policy areas of the EU and impacts on certain of the technical and user benefits analysed. In summary these benefits are [5]:

1. Provides critical GPS integrity information.
2. Improves the existing services performance specification by GPS augmentation.
3. Aids and supports EU policies including:
   a. Technical Innovation: SME's and innovation in industry are supported through improved knowledge and development potential.
   b. Space: creates the environment for potential new services and user.
   c. Transport: Support to applications relating to Transport such as the Trans European Transport Network, the balance of growth and the environment.
   d. Improved competitiveness in the global marketplace of navigation and LBS.
4. Supports Lisbon Strategy policies relating to internal markets, crisis management.
5. Some user vulnerabilities may be improved.
6. Provides additional satellites that create observables.
7. Potential use of L-band spectrum and geostationary satellites will influence harmonisation and rationalisation initiatives.
8. Gives Regional Coverage.

EGNOS – STATUS AND FUTURE

EGNOS provides continuous services. Its infrastructure consists of:

1. Three – geostationary satellites (Inmarsat III [PRN120] – AOR-E – 15.5º W, Inmarsat III – IOR [PRN126] – 64º E and ESA Artemis [PRN124] – 21.5º E).

2. Four – Mission Control Centers (MCC): London-Swanwick (UK), Frankfurt--Lagen (Germany) Madrid-Torrejon (Spain) and Roma-Ciampino (Italy).

3. Thirty four – Range and Integrity Monitoring Stations (RIMS) located all over the word.

4. 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).

5. Two Support Processing Facilities Station: Torrejon, Toulouse.

6. EGNOS Wide Area Network – EWAN with a main server in Amsterdam (Nederland).

Ranging and Integrity Monitoring Stations receive and collect dates transmitted from GPS satellites then sent it, every second, to the processing facilities, which are responsible for augmented GPS information generation. Processing and computing of the EGNOS information to be broadcast to the users is supported by the four-times redundant Master Control Centers. They compute position of each RIMS and made an error analyses between true and calculated pseudorange measurements (fig. 2).
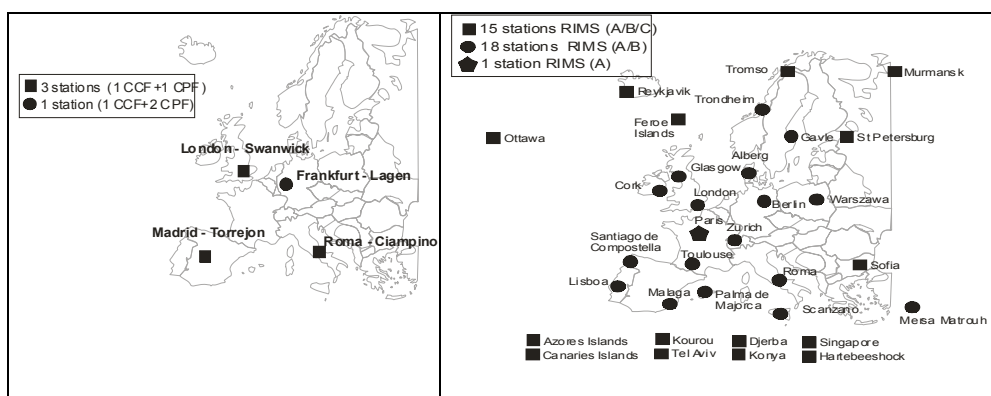

Fig. 2. EGNOS: MCC and RIMS structure

Transmission of the corrected information I realized via three geostationary satellites supported by Navigation Land Earth Stations. EGNOS uses the same frequency (L1 1575.42 MHz) and ranging codes as GPS, but has a different data message format (fig. 3). Sixteen different message types have so far been defined

to broadcast integrity data and WAD corrections. The message schedule follows a 6-second duty cycle. This is structured both to prioritize the 6-second integrity time-to-alarm and to minimize the time for EGNOS initialization.
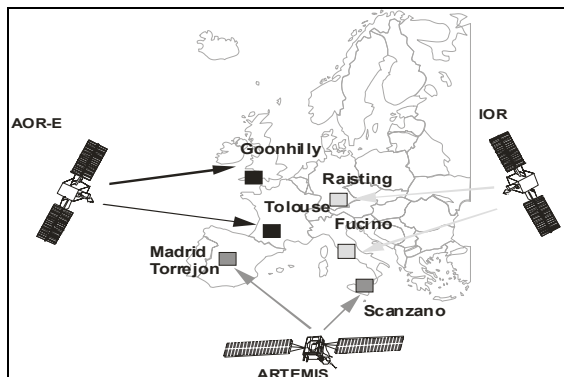

Fig. 3. EGNOS: NLES structure

In June 2005, ESA launched an EGNOS Evolution definition phase to establish a viable plan implemented in the 2006-2010 time frame. These concept include [4]:

1. The EGNOS Data Access System (EDAS) – which will provide on-line interface between users and multimodal Service Providers (in 2006).
2. The Regional Extension Module (REM) where extended coverage plan will be realized. The potential areas for REM are North Africa, Middle East and Eastern Europe (2007 – 2008).
3. The ESA Alert Interface via EGNOS (ALIVE) relates to identify ways to inform people about natural disasters based on dedicated EGNOS messages (2008 – 2009).
4. The Multi-constellation Regional System (MRS) will provide augmented service for: GPS (L5) Galileo and Glonass (2010 – 2011).

ACURACY PERFORMANCE

The Operational Readiness Review confirmed that EGNOS performances fully met system assumptions in accuracy, availability and integrity. Archived accuracy reached 1 – 2 m, during the campaign realised in nine main European cities [5]. The measured availability were also optimistic and reached 99.94 % for APV-1 and

more than 95% for AVP-2. The integrity test based on 20 mln samples confirmed that not a single 'misleading information' event was observed at any location in Europe [5].
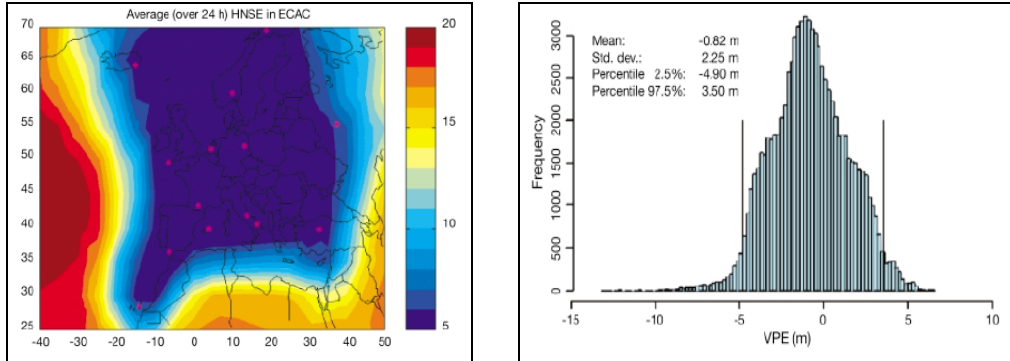

Fig. 4. Estimated ESTB horizontal accuracy (2-sigma value) performances (left)
and Typical ESTB vertical-position error histogram [4]

CAMPAIGN

The measurement campaign focuses on:

1. Establish horizontal and vertical accuracies of the EGNOS system in the long term observation.
2. Based on parallel DGPS measurements to compare the accuracies between EGNOS and LF/MF DGPS.
3. Compare final results with expected values form ESTB [4].

Reference points for receivers (EGNOS and DGPS) were set in the Port of Gdynia (fig. 5). The main minimal requirements for the campaign were determine as:

− session length – 2 weeks (approx. up to 2 mln position solutions);
− L1, code measurements;
− elevation > 5 deg;
− SS/SNR 40/19;
− PDOP < 10 deg;
− HDOP < 6 deg;
− recording standard – NMEA-0183 (GGA every 1 sec).

Fig. 5. Antennas Location

Campaign took two week between 10 – 23.03.2005. The accuracies statistics were calculated based on Mathcad software. Lower figure presents scatter plots of the position solution for EGNOS and parallel working DGPS.
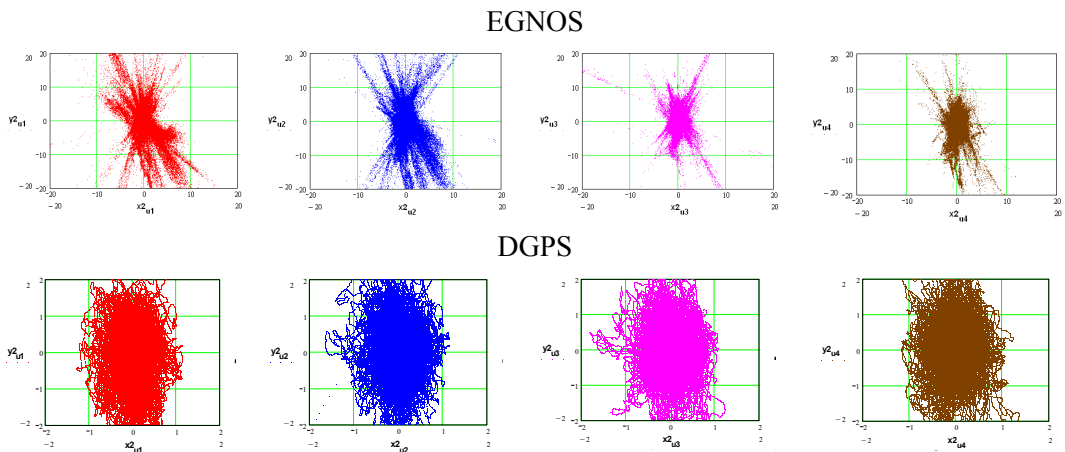
EGNOS

DGPS

Fig. 6. Scatter plots relative to average position (500.000 fixes/plot)

Archived horizontal accuracy presents table 1.

Table 1. Horizontal accuracy of DGPS and EGNOS systems

	DGPS				EGNOS		
Fix number	rms (p=0.65) [m]	2rms (p = 0.95) [m]	95% of population [m]	Fix number	rms (p=0.65) [m]	2rms (p = 0.95) [m]	95% of population [m]
000001 – 500.000	0.8824	1.7649	1.6171	000001 – 500.000	4.6205	9.2411	9.3202
500.001 – 999.999	0.8566	1.7133	1.6146	500.001 – 999.999	4.1557	8.3114	7.4831
1.000.000 – 1.500.000	0.8335	1.6670	1.5562	1.000.000 – 1.500.000	1.8219	3.6439	3.1172
1.500.001 – 2.000.000	0.8615	1.7230	1.6084	1500001 – 1.700.000	3.5034	7.0069	5.9393
∑	**0.8587**	**1.7174**	**1.6021**	∑	**3.7120**	**7.4240**	**6.6970**

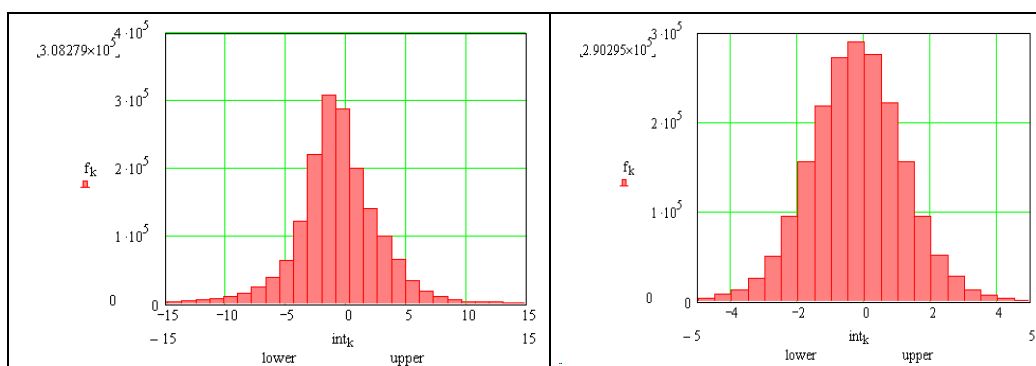The same analyses were done relate to vertical position error performance (fig. 7).

Fig. 7. Vertical position error performance histogram (left-EGNOS, right-DGPS)

Table 2. Vertical accuracy of DGPS and EGNOS systems

	DGPS				EGNOS		
Fix number	rms (p = 0.65) [m]	2rms (p = 0.95) [m]	95% of population [m]	Fix number	rms (p = 0.65) [m]	2rms (p = 0.95) [m]	9% of population [m]
2.000.000	1.4332	2.8665	2.8009	1.700.000	6.2108	12.4216	6.9754

Final results has shown significant differences between EGNOS statistics calculated in two methods:

1. Gaussian distribution of errors were assumed.
2. 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 value. Lower figure presents those position errors which values were upper than 95% of population. Different curves relates to three periods of campaign (each represents 500.000 fixes).
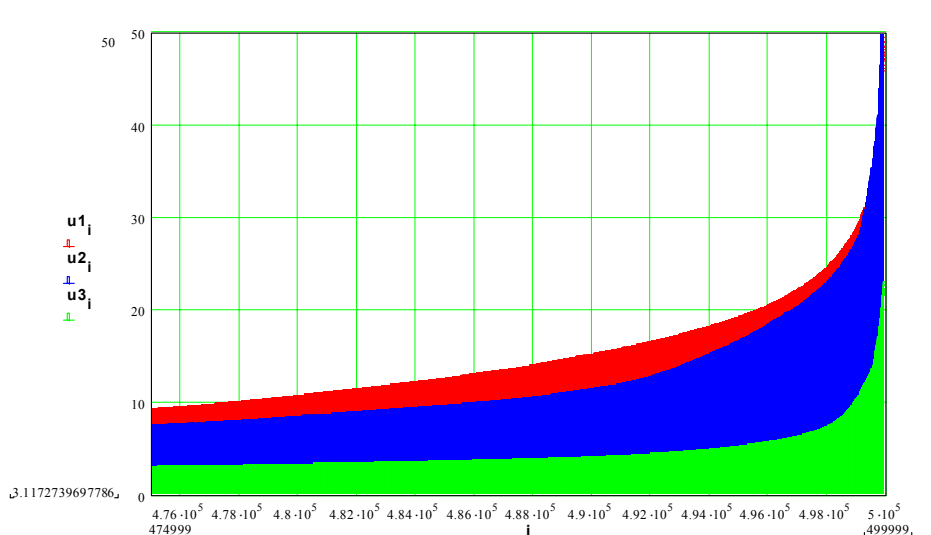

Fig. 8. Position errors which values were upper than 95% of population for three periods of campaign: u_1, u_2, u_3 (each represents 500.000 fixes). Value i related to sorted fix number

CONCLUSIONS

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. The measurements have shown:

1. Archived accuracies were significant differ than Estimated ESTB horizontal accuracy performances.

2. During EGNOS system campaign the large position errors occurred.
3. Calculated EGNOS vertical accuracies shown 12.4216 m (p = 0.95).
4. Classical DGPS LF/MF horizontal and vertical accuracies were lower than 3 m.

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