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ON EGNOS MONITORING IN LOCAL CONDITIONS

Andrzej Felski[1]; Aleksander Nowak[2]
1) Naval Academy of Gdynia, Institute of Navigation and Hydrography, Smidowicza 69 str., Gdynia, Poland,
a.felski@amw.gdynia.pl
2) Technical University of Gdansk, Chair of Geodesy, Narutowicza 11/12 str., Gdansk, Poland,
aleksander.nowak@geodezja.pl.

ABSTRACT

Any SBAS system should deliver to the user corrections to pseudoranges as well as information about the system integrity. In theory, as soon as the system is permanently monitored by RIMS stations, it is impossible to deliver the fault information to the user. However many observations shows that accuracy of EGNOS service in the same time are different in different places, which shows the influence of local conditions on them. In addition evidences on possibilities in jamming or spoofing of GPS signals should be seriously taken into account. According to many sources of information, among them observations of authors, present accuracy of EGNOS service has better than declared. In fact EGNOS accuracy is about 1,5m (95%), but availability of the service happens still controversial and it has random character. According to reports essential differences as well as lack of correlation of this parameter in the different point of observations has been observed. So in author's opinion Local Monitoring of EGNOS service can contribute to better confidence of local users, especially in critical operations, like for example berthing of big ships or in landing operations with EGNOS procedures. An example of such system which works in real time has been elaborated in Polish Naval Academy and will be presented.

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1. INTRODUCTION

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 space geostationary segment 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. The ESA (European Space Agency) declares that the system allows users in Europe and beyond to determine their position to within 1.5 metres [Web-1].

The EGNOS Open Service has been available for free since 1 October 2009 to anyone equipped with an EGNOS-enabled GPS receiver. The EGNOS Safety of Live service 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 [Web-1].

Today there are three certified SBAS operational worldwide [Web-2] in fact working in with the same standards:

- Europe has the European Geostationary Navigation Overlay Service (EGNOS),
- The US has the Wide Area Augmentation System (WAAS), developed and operated by the Federal Aviation Administration (FAA), with an extension over Canada called CWAAS (Canadian WAAS),
- Japan has the Multi-functional Satellite Augmentation System (MSAS), developed and operated by Japan's Civil Aviation Bureau.

Two more systems are being developed for future certification by the International Civil Aviation Authority: Russia's System of Differential Correction and Monitoring (SDCM), under development by Roscosmos, and India's GPS and Geo-Augmented Navigation (GAGAN) system, under development by Indian Civil Aviation and India's ISRO space agency [Web-2].

2. DECLARED EGNOS PERFORMANCE IN POLAND

As it was mentioned before, we have in Poland different levels of declared EGNOS performance depending on which part of Poland we are talking about. Location of RIMS station (shown in fig. 1) clearly shows that in eastern part of Poland worse accuracy and availability of EGNOS services should be expected.

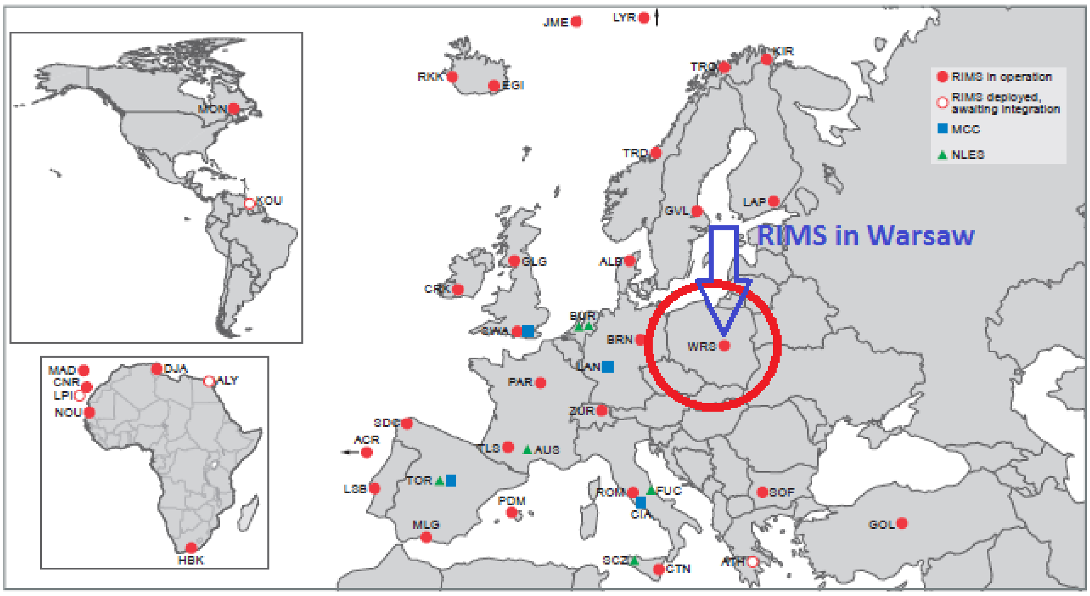


Fig. 1. EGNOS RIMS sites [EGNOS SOLSDD, 2011].

EGNOS Safety of Life Service Definition Document 2011 directly shows distribution of different levels of accuracy in Poland (fig. 2) but charts of EGNOS APV-I availability, continuity and SoL service continuity, seems to clearly justify researches concerning EGNOS performance in context of the system usefulness in polish harbour operations.

Table 1. contains EGNOS Safety of Life performance values and fig. 2-4 show problem of different EGNOS services performance in Poland.

Table 1 EGNOS Safety of Life Service performance values (EGNOS SOLSDD, 2011)

Parameter		**Performance**
Accuracy	Vertical	4 m (95%)
	Horizontal	3 m (95%)
Integrity	Integrity Risk	$2x10^{-7}$/approach
	Time To Alert	Less than 6 s
Availability		99.9% for NPA[1)] in all the ECAC[3)] 99% for APV-I[2)] in most ECAC
Continuity		For NPA: $<2x10^{-4}$ per hour in most of ECAC $<2x10^{-3}$ per hour in other areas For APV-I: $<1x10^{-4}$ per 15 s in the core of ECAC $5x10^{-4}$ per 15 s in most of ECAC $<10x10^{-3}$ per 15 s in other areas

1) NPA – Non-Precision Approach
2) APV – Approach with Vertical Guidance
3) ECAC - European Civil Aviation Conference

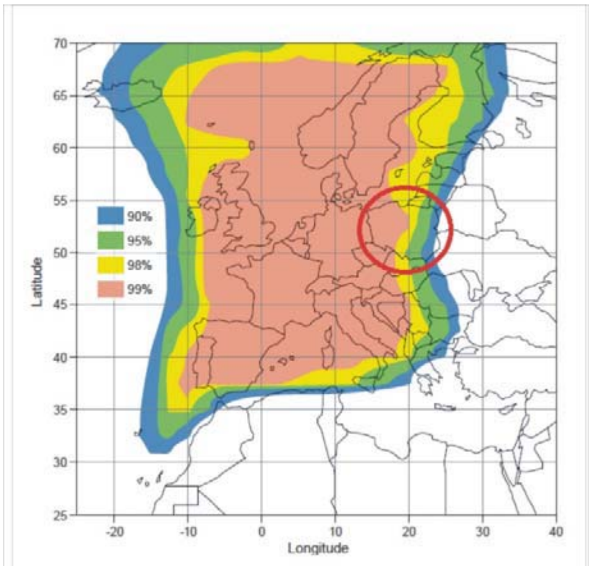


Fig. 2. EGNOS APV-I Availability [EGNOS SOLSDD, 2011]

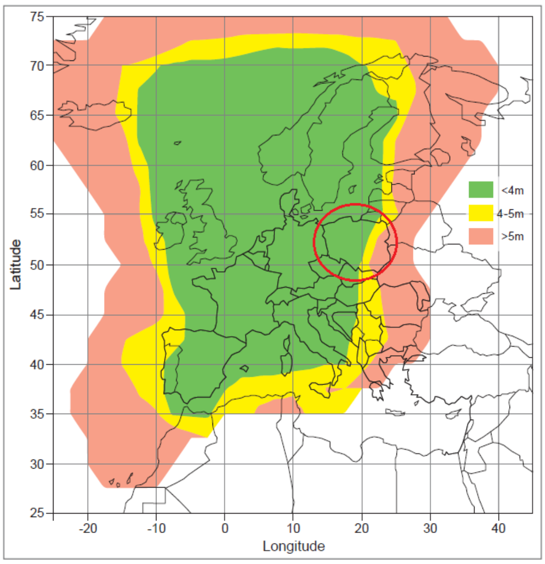
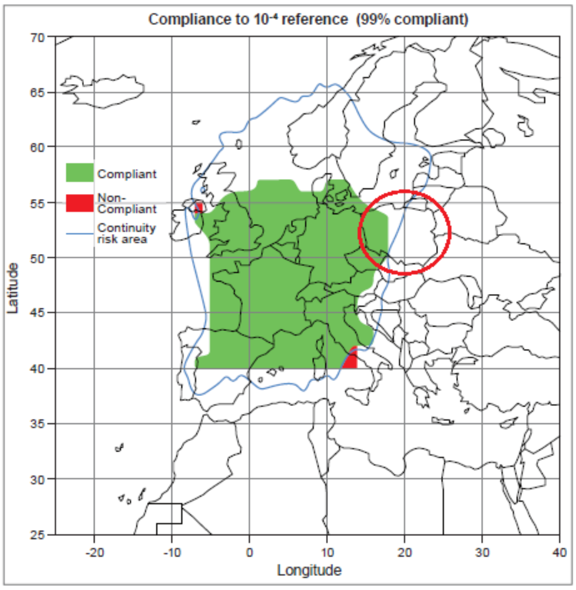
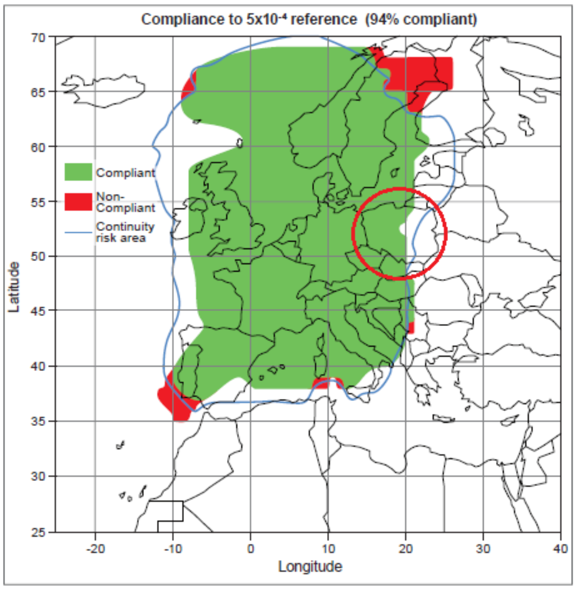


Fig. 3. APV-I accuracy expected from EGNOS [EGNOS SOLSDD, 2011]



Continuity Compliance to the 10^{-4} reference



Continuity Compliance to the $5x10^{-4}$ reference

Fig. 4. Continuity Compliance of EGNOS SoL Service [EGNOS SOLSDD, 2011]

3. DEDICATED AUTHOR'S SOFTWARE TO EGNOS SERVICES MONITORING

Dedicated author's software is called "EGNOS Forecaster". The software was built in Delphi XE as multithread application for 32-bit platform of Windows. It is based on single dialog form with fixed size (no resizable). The main task of application is monitoring EGNOS services current work and on this basis is forecasting reliability characteristics of its. The option of forecasting EGNOS behavior is based on the analysis of gathered data and uses the repeatability of the configuration of GPS satellites. Because of that appropriate work of the software demands two weeks observations at least. Shorter period could cause inadequate results of forecasting however monitoring function works correctly since first turn on. The main window of the software is shown in fig.7. The software could cooperate with every EGNOS receiver on condition that it is able to transmit at least GGA, ZDA and GSV messages in NMEA 0183 standard.

Forecast is calculated on the base of past EGNOS behaviour observations where MTBF – mean time between failures (mean time in state of work) and MTTR – mean time to repair (mean time in state of failure) are taken into consideration. State of work is defined as:

The current horizontal fix errors are lower than HAL (Horizontal Alert Limit) and current vertical error is lower than VAL (Vertical Alert Limit) and EGNOS corrections are available. In the other case, the system is in state of failure.

Horizontal and vertical errors are measured as distance between current position fixed by EGNOS receiver and true position (reference position) entered into the system. It is extremely important to enter accurate reference position. Otherwise the software will work incorrectly and the forecasts could significantly differ from reality. According to the algorithm only after two weeks of constant observations user obtains adequate forecast concerning estimated EGNOS availability and estimated mean time between failures (MTBF) for chosen values of HAL and VAL. The forecast is valid for next fifteen minutes. Longer period of observation causes more accurate forecasting but the last two preceding weeks are the most important (have the higher weight for the calculations). If user changes value of HAL or VAL the forecast will be recalculated. It allows to fit forecasting process to current navigational task.

Current observations are stored in data base and are used to forecast calculation and analyse EGNOS behaviour. User obtains information about system availability and MTBF in every 10 s. It contains calculated values for last hour (in fifteen minutes period) and forecast compatibility for last fifteen minutes (in numerical and graphical forms). It allows evaluating service quality if process of forecasting is going correctly.

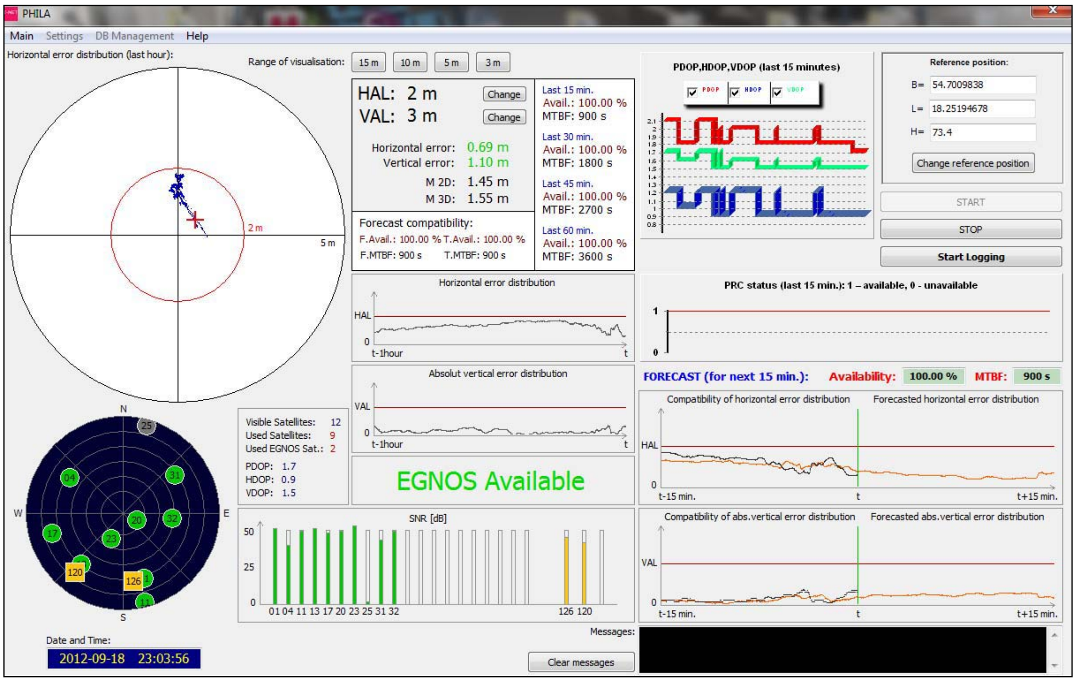


Fig. 5. The main window of EGNOS Forecaster software

The parts of main window of application which inform user about EGNOS availability, MTBF and forecast compatibility are shown in Fig. 6

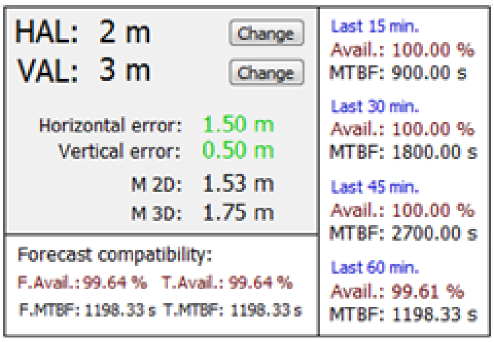


Fig. 6. Information about EGNOS availability, MTBF and forecast compatibility

Apart from forecasting functions the software realizes standard system monitoring tasks like:

- monitoring of current accuracy of service and presenting distribution of horizontal and vertical fix errors,
- monitoring number of visible and used satellites (including geostationary satellites transmitting EGNOS corrections) and presenting sky-plot,
- presenting signal to noise ratio values of visible satellites and information about availability of EGNOS corrections,
- monitoring and presenting values of Dilution of Precision (DOP) coefficients,
- allows to record current observations (coordinates of fixed position, DOP values, number of visible and used satellites, etc.),
- etc.

4. EXEMPLARY RESULTS OF OBSERVATIONS AND CONCLUSIONS

The observations were done for several weeks in monitoring station put out in Gdynia, located in Polish Naval Academy (see fig. 7). During this investigations the EGNOS Forecast software was cooperated with Hemisphere R110 GNSS Receiver.

Fig. 7. Monitoring Station in harbour of GDYNIA, located in Polish Naval Academy

Because of limited size of the paper exemplary results of observations are presented as general conclusions. They are:

a) Observed horizontal and vertical accuracy of the EGNOS was better than declared in EGNOS Safety of Life Service Definition Document 2011 (respectively 3 and 4 m for 95% level),
b) Observed SoL service availability was near 100% (only few gaps in EGNOS transmission shorter than 2 s),
c) Horizontal and vertical accuracy are timely better than declared in EGNOS SOLSDD 2011, thus it seems to possible using EGNOS to harbour operations which have stronger accuracy demands. For example observed horizontal accuracy for 95% level for 1 hour periods never exceeded 2.3 m and many times where better than 1.2 m,

d) Observed mean values of availability and MTBF for 1 hour periods for chosen thresholds of HAL were:
- for HAL = 2.0 m : Availability – 94,86%, MTBF – 876 s,
- for HAL = 1.5 m : Availability – 79,51%, MTBF – 298 s,
- for HAL = 1.0 m : Availability – 53,53%, MTBF – 91 s.

In authors' opinion the most important conclusion from above is that EGNOS can be used for the tasks where the accuracy better than declared in EGNOS SOLSSD is needed. The problem is, that it is available only for short periods and not regular, however it could be predicted. An example of such situation is presented on fig. 8, where the orange line represents forecasted horizontal error distribution for 30 minutes (past 15 and future 15) at the moment t. The black line shows measured horizontal error distribution in the past 15 minutes. It is easy to remark that both lines (predicted and real error distributions) are very similar. This similarity is interpreted as the prediction quality factor and basing on these information at the moment t we can expect accuracy of the system almost 3 times better than HAL. So it seems to be possible planning missions which need more accurate measurements basing on such approach. In presented version of software the forecast period is 15 minutes, but it is possible to modernise it into longer period. Such-like application of this software can be used in offshore or hydrography activities, when standard surveying equipment cannot be used because of the distances to the shore.

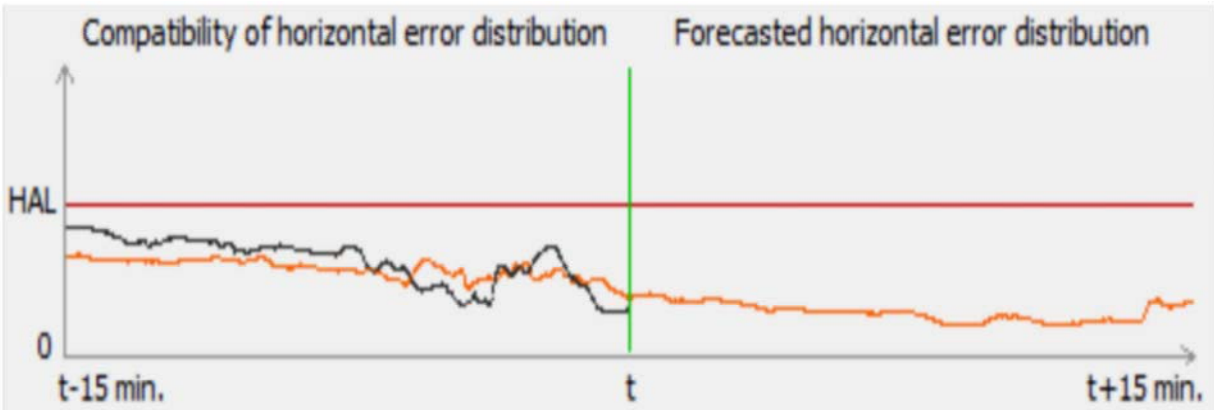


Fig. 8. An example of prediction window in the software.

Originally authors' idea of this kind of monitoring arises as the tool for airfields controllers to assure the supervision of EGNOS service during landing procedures. In this way any local distribution (natural or artificial – spoofing or jamming) can be discovered and controllers can react in the real time. It means at least to abort operation. This is the reason why 15 minutes is proposed for the forecasting window. However the similar approach is analysed be authors for big ships berthing operations in bed meteorological conditions. This is the truth, that in this case the prediction window should be longer, and at the moment this variant is analysed.

The presented results of observation are optimistic and open doors to further researches concerning usage EGNOS for precise navigational tasks. They show, that in spite of long term horizontal accuracy of the system in on the 2.5-3m (95%) level, timely is better than 1m, so precise forecasting of the system behaviour could significantly extend EGNOS applications.

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REFERENCES

EGNOS SOLSDD (2011), *EGNOS Safety of Life Service Definition Document*, European Commission, Directorate-General for Enterprise and Industry.

EGNOS SDDOS (2009), *EGNOS Service Definition Document Open Service*, European Commission Directorate-General for Energy and Transport.

EGNOS – A Cornerstone of Galileo (2007), SP-1303. ESA.

Federal Radionavigation Plan (2008), National Technical Information Service, Springfield. DOT-VNTSC-RITA-08-02/DoD-4650.5.

Felski A., Nowak A., Woźniak T. (2011), *Accuracy and Availability of EGNOS – Results of Observations*. Artificial Satellites vol. 46 no. 3/2011 pp. 111-118.

Męsikowski M., Nowak A., Oszczak B., Specht C. (2006), *EGNOS – Accuracy Performance in Poland*, Annual of Navigation, No 11/06, pp. 63-72

Web sites:

Web-1: http://www.esa.int/esaNA/egnos.html, consulted 01 September 2012.

Web-2: http://www.esa.int/esaNA/SEMNX8NXDXG_egnos_0.html, consulted 01 September 2012.

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