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Abstract. *A research of European Geostationary Navigation Overlay Service (EGNOS) performance was conducted with a help of a satellite navigation receiver, working in the mode of receiving differential corrections. The goal of the research was to define the operation characteristics of EGNOS in central Ukraine, without a ground station. We have estimated the key system parameters, such as: accuracy, availability, continuity and integrity. Using the data recorded by our receiver and PEGASUS software to process it, this article illustrates the current state of EGNOS in Kiev. The research was conducted in static, while having the coordinates of the receiving station calculated in centimeter accuracy. The research was performed under the UKRAINE project, detailed information about the project is given under Acknowledgments header.*

Keywords: accuracy; availability; continuity; integrity; satellite navigation.

1. Introduction

EGNOS – European Geostationary Navigation Overlay Service is a system of space functional augmentation type SBAS (Satellite Based Augmentation System) intended to improve performance of GNSS (Global Navigation Satellite System) systems, specifically GPS and GALILEO, on the territory of Europe.

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.

EGNOS is a joint project of European Space Agency (ESA), the European Commission and Eurocontrol, the European Organization for the Safety of Air Navigation. It is Europe’s first activity in the field of GNSS and is a precursor to Galileo, the full global satellite navigation system under development in Europe.

After the successful 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.

Starting from October 1 2009, EGNOS Open Service provides signal transmission on a satellite navigation receiver with EGNOS option. EGNOS Safety of Life service has become available from March 2nd 2011. General SBAS requirements are listed in [1].

Introduction of EGNOS in Ukraine will be beneficial not only for the aviation sphere, which is an important part of our country development, but also for monitoring ground traffic, creating efficient agriculture solution, free and accurate mapping, different maritime and other location based services.

As our primary concern is aeronavigation, the key benefits for GNSS users are:

– improvement of the accuracy of receiver location to about one meter;

– integrity data which validates the signals transmitted by GNSS satellites along with alerts in near real time;

– accurate and reliable synchronization with Universal Time Coordinated (UTC).

The measurement elements of EGNOS ground segment are RIMSs (Ranging and Integrity Monitoring Station), which send raw data streams to the Central Processing Facilities of each Mission Control Center in addition to the generic interface data.

The closest active RIMSs are located in Warsaw (Poland), Sofia (Bulgaria) and Konya (Turkey).

RIMS installation is planned. Currently EGNOS providers are seeking appropriate location for segment installation.

2. Aim of the work

The aim of this work is experimental estimation of EGNOS system performance quality in Ukraine (Kyiv particularly).

The experimental data includes positional information received from GPS and corrections received from EGNOS geostationary satellites.

The received messages are processed by PEGASUS software. Using the results conclusions are made if the characteristics of the navigational system fit to the safety requirements of the aviation users.

As part of the activities of the EUROCONTROL GNSS Program, the SBAS and GBAS Projects aim at the operational validation of the Space Based Augmentation Systems (SBAS) and Ground Based Augmentation Systems (GBAS) respectively. To support both the SBAS and the GBAS projects and to provide them with adequate tools for their respective data evaluation campaigns, a dedicated Tools Development activity has been put in place within the GNSS Program. One of the major tools developed is known as PEGASUS. This tool is presently being used to analyze the performance of the European experimental SBAS known as the EGNOS System Test-Bed (ESTB). The tool is being used by the SBAS Project and has been delivered to various European partners who are using it for their data evaluations campaigns for both, static and dynamic measurement.

The measurement is done in static mode, the coordinates of the receiving station were measured and considered as the basic point.

In the research we used GPS satellites and geostationary 120 and 126 satellites, which transmit the messages with corrections. We also received messages from GLONASS satellites, but they have no corrections available from the EGNOS system and therefore are excluded from the experiment.

The primary focus was on these characteristics:

– accuracy;
– availability of ionospheric corrections;
– integrity information;
– continuity of data;
– overall availability of service.

The experiments started from 2008, even before EGNOS official launch, and ran up to 2014.

3. Research results

The research of 13th January 2014 is given as an example to show the results.

The horizontal 95 percentile accuracy of APV-1 category is 2.19 m and vertical 95 percentile accuracy is 1.92 m. The horizontal 95 percentile accuracy of LPV-200 category is 2.19 m and vertical 95 percentile accuracy is 1.92 m. These measurements were defined statistically and fit to the requirements for accuracy listed by ICAO for given categories.

Accuracy in horizontal plane (fig. 1) is displayed as the deviations on North-South and East-West from the basic point.

The map of availability of the atmosphere piercing points is displayed on (fig. 2). Coordinates of Kiev are 30° 30' east 50° 27' north. Availiability for piercing points: 90-100 % for sattelites to the west, decreasing somewhat to the south and north, rapid fall to 40-50 % for satellites to the east.

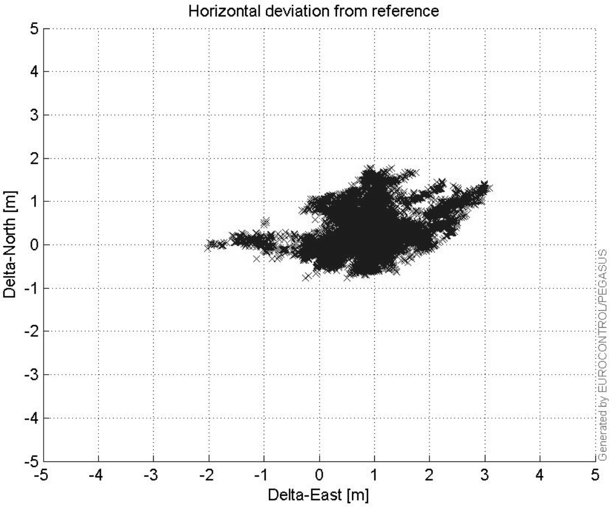

Fig. 1. Accuracy in horizontal plane

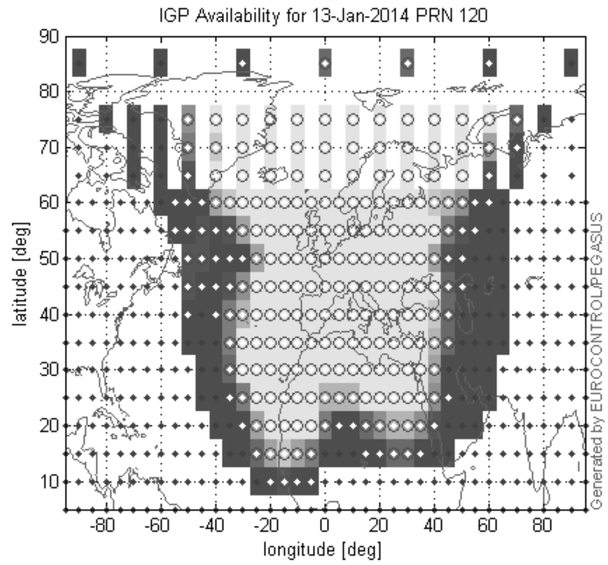

Fig. 2. Availability of piercing points of ionosphere

The GPS system's errors or malfunctions may, depending on the satellite geometry, have serious repercussions for user safety if not detected in time and restrict significantly the range of possible applications. For further reading consider [2].

The integrity requirements are given in Table 1. The requirements for LPV were issued separately as part of WAAS standards. EGNOS broadcasts an integrity signal giving users the capacity to calculate a confidence interval, alerting them when a GPS satellite malfunctions and is not be used for an application where safety is a factor. The data produced and transmitted by EGNOS thus includes estimates of GPS satellite orbit and clock errors and estimates of errors due to GPS signals crossing the ionosphere. These parameters enable users to evaluate a limit from its position error.

Table 1. ICAO SARPs high level integrity requirements

Typical operation	TTA	Integrity	Horizontal alert limit	Vertical alert limit
NPA	10 s	$1\text{-}10^{-7}$/h	0.3 NM	N/A
APV I	10 s	$1\text{-}2\text{x}10^{-7}$ per app	40.0 m	50 m
APV II	6 s	$1\text{-}2\text{x}10^{-7}$ per app	40.0 m	20 m
CAT I	6 s	$1\text{-}2\text{x}10^{-7}$ per app	40.0 m	15-10 m

NOTE: TTA – time-to-alarm; app – approach; SARPs – Standards And Recommended Practices

Four parameters characterize integrity:
– alarm limit;
– protection level;
– integrity risk;
– Time To Alarm (TTA).

If the positioning error exceeds the stated protection level, an alarm must be transmitted to the user. That alarm must be received by the user within the Time To Alarm limit. The probability of an alarm not being transmitted to the user within the time limit must be lower than the integrity risk.

In practice, since the actual position error is unknown to the user, estimates of these errors called "Protection Levels" (XPL, X designating the horizontal H or vertical V component) are compared to the alarm limits. A civil aviation approach procedure corresponding to an alarm level XAL will be authorized only if the XPL protection level is less than XAL.

More extensive information about requirements is available in [1] and information about protection levels is available in [3].

To summarize integrity information in this work we used the Stanford diagram. The measurements, which correspond to typical operations of APV-1, LPV-200 and CAT-1 for horizontal and vertical planes are shown on (fig. 3) and (fig. 4), on horizontal axis precision errors are plotted for horizontal (hpe) and vertical (vpe) planes, on the vertical axes we have alarm limits for horizontal (hpl) and vertical planes (vpl) respectfully. The color scale allows to estimate the number of points(therefore number of epochs). In current paper it is given in greyscale.

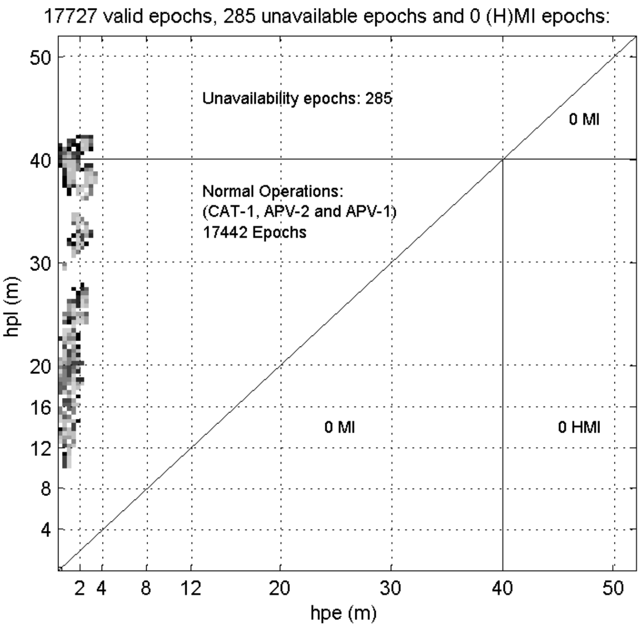

Fig. 3. Horisontal Stanford diagram

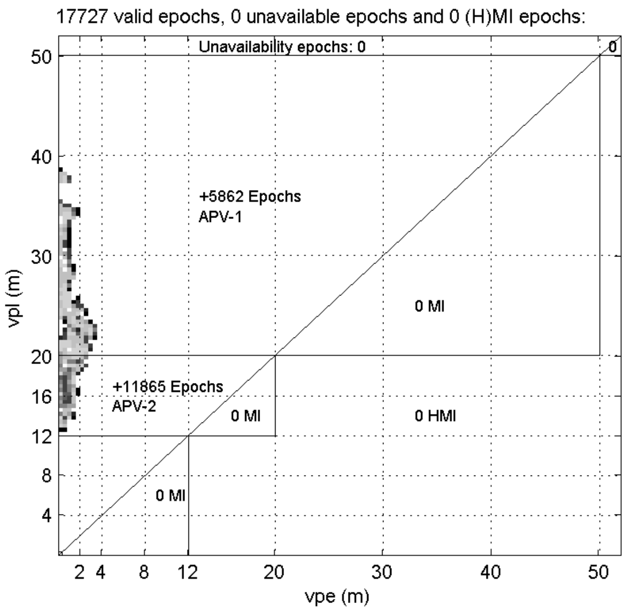

Fig. 4. Vertical Stanford diagram

From 17727 valid epochs on (fig. 3). 17442 epochs are fit for safety critical operations, 285 epochs are unavailiable. From 17727 valid epochs on (fig. 4). 5862 epochs are fit for APV-1 only, 11865 for APV-2 and also can be used for APV-1, 0 epochs for CAT-1. No epochs exceed the alarm limit of 50 m.There are no integrity events, therefore we have no integrity information failures in the form of misleading information, we can say that GPS and EGNOS had no integrity malfunctions during that period.

The most problematic parameter for Ukraine is continuity which is good but not exactly stable and still not good enougph for safety critical operations.

Availability emphasizes the operational economy of the navigation system. It is computed as the fraction of time the EGNOS system is providing position fixes to the specified level of accuracy, integrity and continuity.

In the research APV-1 is available 98.392 % and LPV-200 – 98.313 % of total time, still these characteristics do not fit to the standards listed in ICAO documents. Safety critical operations require 99.9999999 % availability.

4. Conclusions

The results state quite good signal quality of EGNOS in Kiev, but still it cannot be used for any safety critical operations until a RIMS station is placed. EGNOS has come a long path to its current state and is unlikely to get better performance without the installation of RIMS and significant changes in aviation sphere of Ukraine.

5. Acknowledgments

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Представлені результати досліджень роботи системи EGNOS в Україні. Проаналізовані точність, неперервність, доступність, цілісність цієї системи і на їх основі зроблені висновки про необхідність створення наземного доповнення для EGNOS в Україні.

Ключові слова: доступність; неперервність; супутникова навігація; точність; цілісність;

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Представлены результаты исследований работы системы EGNOS в Украине. Проанализированы точность, непрерывность, доступность, целостность данной системы и на их основе сделаны выводы о необходимости создания наземного дополнения для EGNOS в Украине.

Ключевые слова: доступность; непрерывность; спутниковая навигация точность; целостность;

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