



Validation of the EGNOS system in flight tests

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ABSTRACT

Paper present results of the HEDGE project, which was conducted in 2010-2012 to verify EGNOS parameters during air operations in general aviation. Stakeholders participated in that project were: scientific research centers, government agencies, aircraft operator and local small airfield. Aircraft operator involved in a project performed the EGNOS system installation on the aircraft and on the airfield, using plan for technical solution developed in the second phase of the project, and as result of that in next phases of project performed test and certification flights. Additionally aircraft operator is allowed to train new and current pilots, which will fully realize plan for preparing all the pilots to be familiarized with EGNOS System, and if so, this system will be widely and commonly used in aviation/air force. All demonstration, testing and certification flights will be in participation of scientific research center and government agency, which will guarantee the test procedure correctness in accordance to flight safety regulations and rules for new equipment on board aircrafts.

KEYWORDS: NPA, GNSS, EGNOS

1. Introduction

Article presents example of experimental implementation the EGNOS (European Geostationary Navigation Overlay Service) system to APV-I (Approach Procedures with Vertical guidance) operations, which was conducted in Poland in framework of the HEDGE project and according to ICAO requirements in Annex 10. It is worth notice, than till 18 October 2013 in Europe 79 airports implemented EGNOS-based procedures[1]. Aim of the project was to establish a certification process of EGNOS as SBAS (Satellite Based Augmentation System) in general aviation. It required analyses of accuracy, integrity, continuity and availability of SIS (Signal in Space) form European Satellite Services Provider (ESSP). However, besides reliance upon ESSP's signals, EASA and EUROCONTROL recommended use a local monitoring stations, in order to check and compare quality of parameters from country area with relation to those from EGNOS. During HEDGE project, parameters were delivered by stations from three cities: Warszawa, Kraków and Rzeszów. Thus, project exploited the excellent accuracy performance of EGNOS to analyze the implementation of GLS (GNSS Landing System) approaches

(Cat I - like approached using SBAS, with a decision height of 200 ft). Location of the EGNOS monitoring station, located near Polish-Ukrainian border, being also at the east border of planned EGNOS coverage for ECAC (European Civil Aviation Conference) states was very useful for SIS tests in this area.

2. Crucial signals and parameters

According to current EGNOS programme schedule, the project activities were carried out with EGNOS system v3, which is developed. Therefore, the project allowed demonstrate feasibility of the EGNOS certifiable version for civil applications. Planned demonstration and trials will be provided on 21 Polish airports chosen based on SIS analysis and EGNOS operational coverage in Poland. For creating and testing software and making other documentations a ESA standards like ECSS-E-40, ECSS-Q-80B were used.

Receiver Septentrio, PEGASUS program and SPAN were essential elements. The PEGASUS (Prototype EGNOS and GBAS Analysis System Using SAPPHERE) is a prototype which allows analysis of GNSS data collected from different SBAS and GBAS (Ground Based Augmentation System) systems and using only algorithms contained in the published standards. The tool has been developed in the frame of the GNSS-1 operational validation activity defined in the EUROCONTROL SBAS project and aims to be a first step forward the development of a standard processing and analysing tool to be used for the future EGNOS operational validation. PEGASUS was designed to facilitate the output data handling and interchange. The tool provides several functionalities such as computation of position and GNSS systems attributes like accuracy, reliability, and availability simulating MOPS-compliant receivers, computation of trajectory errors, prediction of accuracy and availability with the required integrity and simulation of GBAS Ground Station processing algorithms. Since June 2003 the GBAS Modular Analysis and Research System (MARS) is integrated in PEGASUS in order to support GBAS data processing needs and activities. The GBAS MARS allows to collect and evaluate relevant data and provide required results and is able to assist Air Traffic Service Providers to aid site approval and obtain operational approval of a GBAS installation for supporting CAT-I precision approach conditions at an airport from their respective safety regulation authorities.



Fig.1. Visualization of postprocessing data (RTK/INS) gathered during the fly over the Mielec airport and GPS/GPRS device for real time monitoring as a second monitoring system on airplane Piper PA-34 Seneca II

The Synchronized Position Attitude Navigation (SPAN) system is NovAtel's Global Navigation Satellite System - Inertial Navigation System (GNSS/INS) solution for applications requiring continuous position, velocity and attitude information (fig. 1). Using Inertial Measurement Unit (IMU) data in addition to GNSS, SPAN provides a high rate position, velocity and attitude solution which seamlessly bridges GNSS outages. The tight integration of the IMU to the

receiver core improves GNSS performance by enabling faster signal reacquisition and quicker return to fixed integer status after a loss of GNSS signals.

2. Main assumptions

The accomplishment of international programme required adopting the following assumptions:

- Final Approach of GNSS landing with “Overlines” method;
- Accomplish of the RNAV (Random Navigation) GNSS Approach Procedures;
- Certification of the GNSS receivers (on board);
- Test flights - checking assumed solutions;
- Operational of EGNOS System;
- Test flights in frames of programs;
- Collecting indispensable materials and drawing up documents, necessary to do the certification;
- Certification of the GNSS approach in Poland

Project HEDGE is collaborative EU project, which aims are:

- develop the helicopter SOAP (SBAS Offshore Approach Procedure) procedure (and necessary avionics) and then to successfully demonstrate it to the user community;
- develop helicopter PINS (Point in Space) procedures for mountain rescue and HEMS (Helicopter Emergency Medical Services), and to then successfully demonstrate them to the user community;
- demonstrate EGNOS (European Geostationary Navigation Overlay Service) APV (approach with vertical guidance) approaches to general aviation in Spain, Poland;
- (OPTION) To complete EGNOS data gathering that shows the performance of EGNOS.

The new GNS 430 W (already WAAS enabled) receiver in the Seneca airplane is applied during experiments, because:

- already WAAS enabled;
- then use an experimental data card from Garmin to enable EGNOS;
- perform the necessary tests in the laboratory to validate that the receiver is able to work properly with the broadcasted EGNOS SIS at the time the demonstrations will be performed.

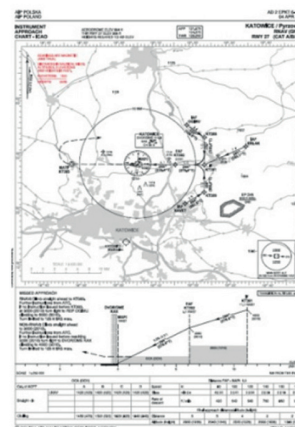


Fig.2. Example: RNAV GNSS for Katowice – Pyrzowice Airport

3. Flight validation

The following guidelines were taken into consideration for conducting the flight validation activities:

- The validation was carried out in daylight hours under VMC (Visual Meteorological Conditions)
- The Final Approach Segment has to be flown ½ scale down, at least once
- All segments of the approach were flown at least once (segments common to the LNAV approaches were already flown during the LNAV validation flights)
- The Missed Approach segment was flown
- A test database containing the RNAV IFP was used
- There was one pilot acting as FVP, and one observer assisting the FVP in the validation process observing the 'out of cockpit' environment
- The aircraft used during the flight validation had the appropriate performance capabilities for which the IFP was designed.
- The FV was conducted with a Piper Seneca II aircraft. The aircraft is equipped with the appropriate RNAV equipment for conducting LPV operations: a Garmin GNS 430W connected with other required avionics (antenna, CDI/VDI). The complete set allows flying during all phases of flight, from en-route to precision approach down to LPV minima.

The IFP to be validated, designed by Pildo and PANSA, was coded inside a test database produced by Jeppesen and Garmin. The pilots inserted the FV plan inside the FMS-like Garmin device and conducted the trials in the relevant navigation mode using the GPS/SBAS guidance. Guidance during the entire flight, including aircraft positioning, was provided by the CDI/VDI fed by the GNS 430W.

In order to record continuous data and monitor the EGNOS during the campaign, a flight data recording and monitoring system was installed on the aircraft. The system (standalone platform) included an U-blox Antaris 4 GPS/SBAS receiver.

The receiver was installed at Katowice airport. The main objective was to collect GPS L1/L2 and EGNOS data, for the later post-processing allowing evaluating the local performance of the system. The automatic reports regarding the performance of the signal are included in the Annex D. This information has been provided by PANSA.

Before the flight trials, the local APV-1 availability in the area was simulated using a predictive RAIM algorithm developed by Pildo Labs. The analysis was performed at the ARP, considering also the following conditions:

- No digital terrain model was used to simulate the local conditions of the area (useful in some environments to take into account the masking caused by a mountainous environment);
- The GPS almanac was downloaded from the U.S. Coast Guard Navigation Center website;
- The simulation was carried out for a 12 hours dataset (from 9:00h to 21:00h), with samples every 5 minutes.

The obtained result is of a 100% APV-1 availability at the threshold coordinates. The estimated horizontal and vertical errors were also estimated. These simulations ensured that the EGNOS would enable an APV-1 level of service at Katowice during the whole day.

The data analysis focuses on the data recorded during the flights. The next figures show the trajectories flown during the approaches. The approaches are drawn jointly with the tested paths (yellow lines). The following figures present the flight trajectories of the demonstrations together with the waypoints and runway threshold. It can be seen how the aircraft successfully accomplished the operations up to the OCA/H values, when either a missed approach or a landing was conducted. In the profile views, the next reference altitudes have been plotted:

- 5000 ft, which is the minimum altitude to fly the initial segments of both approaches;
- 1235 ft, which is the CAT A LPV minima (OCA) of the procedures; and
- 991 ft, which is the elevation of RWY 27 THR



Fig.3. Plan view of the flight demonstrations

4. Flight deviations

To have a clearer picture of the deviations presented to the pilot during approaches, horizontal and vertical deviations have been computed with respect to the desired flight path. The results are presented in the figures inside this section.

The distances in the vertical axis represent the horizontal or vertical Flight Technical Error (FTE) in meters. The FTE is provided as guidance information to the pilot during the flight, while the NSE and TSE can only be determined using truth reference after post-processing the data. Figures located below show the deviations of the a/c during the intermediate and final approach segments, while the figures located in the right side offer a zoom of the deviations during the FAS.

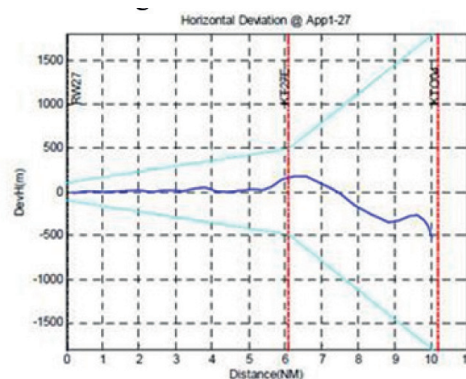


Fig.4a. Horizontal deviations

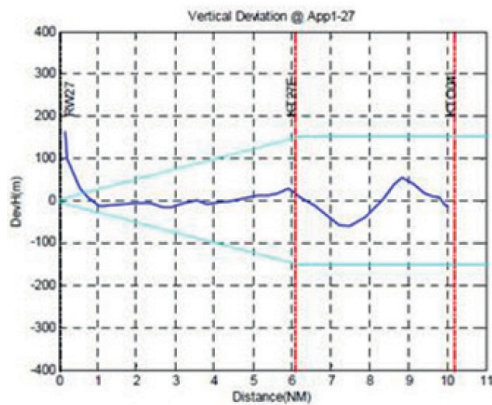


Fig.4b. Vertical deviations

The FSD (Full Scale Deflection) of the CDI/VDI is also plotted in the figures (cyan color) when contained in the figure limits, both in the horizontal and the vertical domain. These curves indicate the value of the deviations that the aircraft would have had with respect to the approach path if the CDI/VDI needles had been totally deflected. The curves have been calculated using in-house developed tools, in accordance to MOPS RTCA DO-229D. As can be seen, the FSDs are not constant, and they change between linear and angular along the approach, following the requirements laid down in the MOPS.

WARSAWA HORIZONTAL ACCURACY

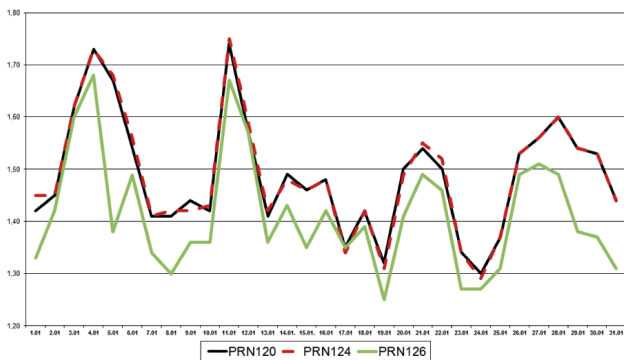


Fig.5. Horizontal accuracy at Warszawa station in January 2012

In order to obtain better performances, conducted analysis of availability, continuity, horizontal and vertical accuracy, as well as vertical and horizontal integrity was conducted on the data from the EGNOS Data Access Service/EGNOS Data Collection Network gathered in January-April 2012. Signals were provided by three satellites: PRN120, PRN124, PRN126. PRN126 and PRN124 was several times temporary switched off. Signals were delivered to three stations in Poland: Kraków, Rzeszów, Warszawa.

During research station in Kraków was temporary switched off (April, March) because of some technical problems. Figures 5-8 illustrated some of chosen performances. At all station horizontal and vertical integrity misleading information equals 0.

KRAKÓW HORIZONTAL ACCURACY

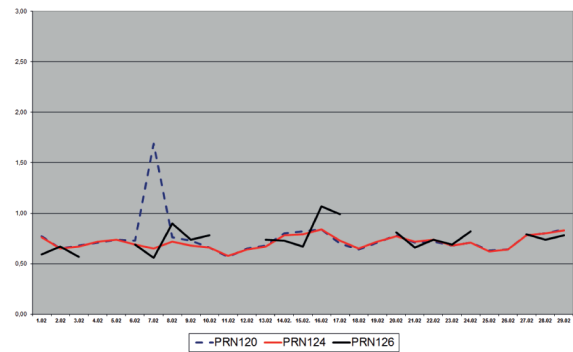


Fig.6. Horizontal accuracy at Kraków station in February 2012

RZESZÓW APV1 AVAILABILITY [%]

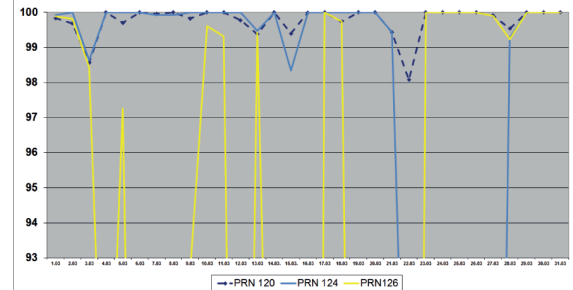


Fig.7. AVP-I Availability at Rzeszów station in March 2012

WARSAWA VERTICAL ACCURACY

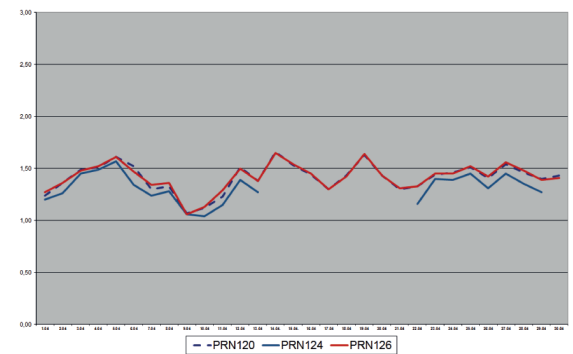


Fig.8. Vertical accuracy at Warszawa station in April 2012

Analysis performances of EGNOS shown, that horizontal accuracy average reached 0,51-1,6 m, vertical 1-1,51 m. Availability did not reach value below 96%.

5. Conclusion

The HEDGE project was being carried out in years 2010–2012, carrying air tests out and results which served for expressing conclusions were being collected.

The LPV flight procedures for Katowice provide tangible operational benefits for the airport operators in case of ILS inactive. EGNOS system was capable providing excellent aircraft guidance,

appreciated by the pilots. Vertical and horizontal accuracy reached 0,5-1,6 m, while availability was almost 100% .

The main outcomes of the validation of the new GNSS procedure are as follows:

- The EGNOS availability performance APV-I was fully achieved during all the approaches;
- The coding of the procedure for SBAS is satisfactory;
- The horizontal and vertical sensibility of the CDI was successfully tested.
- The procedure is safe from the obstacle clearance point of view (it has been flown ½ scale down the nominal glide path without identifying potential obstacles). No significant obstacles were found when overflying the surroundings of the airport either.
- The flyability of the procedure was correct.

The ground and flight validation performed are successful. It is nevertheless highly recommended to perform a deep obstacle assessment before moving forward towards the publication of the procedure in the AIP.

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