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Signal monitoring as a part of maintenance of navigation support system in civil aviation

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ABSTRACT
This paper gives an overview on some chosen aspects of monitoring signal in case of system performing abilities. Nowadays, in civil aviation, there is a focus mainly on satellite systems which are often called the future of navigation. Global Navigation Satellite System (GNSS) is not able to operationally work without any support system. One of them is EGNOS (European Geostationary Navigation Overlay Service).

KEYWORDS: navigation, monitoring, satellite system, aviation

1. Introduction

Maintenance of a positioning or navigational system consists of many tasks. One of them may be monitoring of signal. Nowadays, in civil aviation, there is a focus mainly on satellite systems which are often called the future of navigation. Global Navigation Satellite System (GNSS) is not able to operationally work without any support system. One of them is EGNOS (European Geostationary Navigation Overlay Service). Known as a satellite-based augmentation system (SBAS), EGNOS provides both correction and integrity information about the GPS system, delivering opportunities for Europeans to use the more accurate positioning data for improving existing services or developing a wide range of new services [3]. EGNOS also provides verification of the system's integrity, which relates to the trust that can be placed in the correctness of the location information supplied by the navigation system. In addition, it provides timely warnings when the system or its data should not be used for navigation. Integrity is a feature which meets the demands of safety-critical applications in sectors such as aviation and maritime, where lives might be endangered if the location signals are incorrect [4].

2. Architecture of EGNOS

The European Geostationary Navigation Overlay Service (EGNOS) was developed by the European Space Agency, the European Commission and EUROCONTROL. In the structure of satellite system, EGNOS may be find as follows [4]:

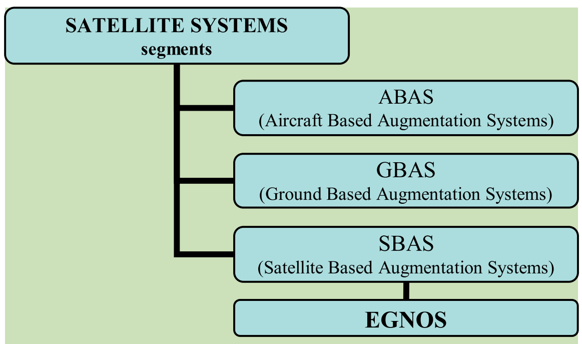

Fig.1. Satellite systems segments

The EGNOS system consists of three geostationary satellites and a network of ground stations. The system started its initial operations in July 2005, with accuracy better than two metres and availability above 99%; it was certified for use in safety of life applications in March 2011 [1]. According to specifications, horizontal position accuracy given by EGNOS should be better than seven metres. In practice, the horizontal position accuracy is at around metre level. An EGNOS Data Access Service became available in July 2012. Similar service is provided in North America by the Wide Area Augmentation System (WAAS), and in Asia, notably Japan, by the Multi-functional Satellite Augmentation System (MSAS). EGNOS is very similar to WAAS and fully interoperable with WAAS i.e. aircraft equipped with a WAAS-enabled receiver are able to use EGNOS. EGNOS is also interoperable with the Japanese MSAS. The table below shows EGNOS satellite segment structure.

Table 1. EGNOS satellite segment structure

Satellite Name	PRN Number	Satellite Location (Longitude)	NMEA Number (Gamin receivers)
Inmarsat-3 AOR-E	PRN 120	15.5° W	33
ESA-Artemis	PRN 124	21.5° E	37
Inmarsat-3 IOR-W	PRN 126	25.0°E	39

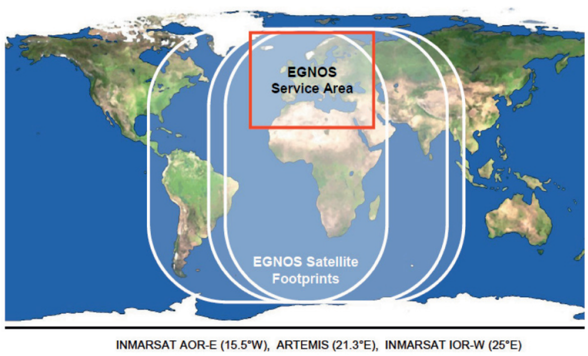

Fig.2. EGNOS cover area

More than 40 ground stations are linked together to create EGNOS network which consists:

- 39 RIMS (Ranging and Integrity Monitoring Stations): receiving signals from US GPS satellites,
- 4 MCC (Mission Control Centers): data processing and differential corrections counting,
- 6 NLES (Navigation Land Earth Stations): accuracy and reliability data sending to three geostationary satellite transponders to allow end-user devices to receive them.

The services currently being provided by EGNOS are:

- EGNOS Safety of Life Service (SoL) This service is intended for applications where human life could be in danger if the positioning system does not meet integrity requirements,
- EGNOS Open Service (OS). Applications that have not the safety requirements met by the EGNOS SoL service, are considered to be Open Service applications [5],
- EGNOS Data Access Service (EDAS): this is the provision of EGNOS data through the internet. It is important to point out that the service provided by EGNOS is dependent on the receiver at the user side [5].

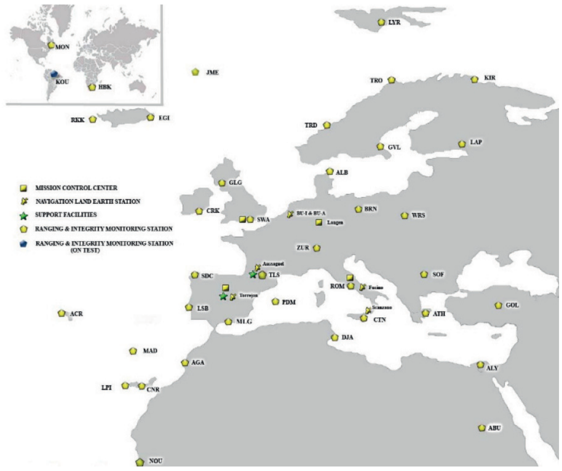

Fig.3. EGNOS ground stations

3. EGNOS performances

EGNOS performances are measured in terms of four parameters: accuracy, integrity, continuity and availability. ICAO documents give specific definitions of these parameters:

- Accuracy: GNSS position error is the difference between the estimated position and the actual position. For an estimated position at a specific location, the probability should be at least 95 per cent that the position error is within the accuracy requirement.
- Integrity: is a measure of the trust which can be placed in the correctness of the information supplied by the total system. Integrity includes the ability of a system to provide timely and valid warnings to the user (alerts) when the system must not be used for the intended operation (or phase of flight).
- Continuity: is the capability of the system to perform its function without unscheduled interruptions during the intended operation. It relates to the capability of the navigation system to provide a navigation output with the specified accuracy and integrity during the approach, assuming that it was available at the start of the operation.
- Availability: is characterised by the portion of time the system is to be used for navigation during which reliable navigation information is presented to the crew, autopilot, or other system managing the flight of the aircraft [1].

When referring to EGNOS performances, it is usual to consider those attainable by an error free receiver using all the GPS satellites in view at location and with no multipath effects. This is necessary to provide a valid reference as the actual performances will depend in any case of the type of receiver, number of satellites used (usually less than all in view at location) and the local multipath effects [2].

The EGNOS Signal in Space is being broadcast from two satellites for redundancy purposes only. This redundancy ensures that although during the normal operation of the system a low number of discontinuity events can be expected, the simultaneous outage of both satellites is extremely remote. This redundancy mitigates as well the masking effects of one of the GEOS by obstacles or other sources [2].

Nominal performances: Vertical accuracy is improved from 15 meters to 4 meters. Horizontal accuracy is improved from 10 meters to 3 meters. Observed performances: Vertical accuracy is improved from 4-5 meters to around 2 meters. Horizontal accuracy is improved from 2-3 meters to around 1 meter. On top, EGNOS includes an integrity function i.e. a warning in case of an issue with the system, emitted within 6 seconds of the malfunction and repeated.

EGNOS qualifies as a navigation service under the Single European Sky (SES) Regulations. As a consequence, the provision of the service by the EGNOS Service Provider (ESSP) is subject to certification and the system subject to an EU Declaration of Verification. This supervision was performed by the French national supervisory authority (DSAC). The European Aviation Safety Agency (EASA) will take over the continued compliance monitoring of EGNOS.

EGNOS is a key technical enabler to the SESAR operational concept. EGNOS will contribute to the achievement of the objectives of the Single European Sky policy. In particular, it will contribute to de-fragment the provision of navigation services thanks to its pan-European nature and will facilitate enhanced navigation performances, in line with the SES ATM Master Plan.

4. Monitoring EGNOS signal

Thanks to EGNOS User Support from European Space Agency we can observe signal in space status and other service performances which show us how EGNOS works [7,8]. Actually, EGNOS has two working geostationary satellites and one which is being tested. These are:

- PRN 120, NAME AOR-E, POSITION 15.5°W, OPERATOR Inmarsat,
- PRN 124 (TEST), NAME ARTEMIS, POSITION 21.5°E, OPERATOR ESA,
- PRN 126, NAME IND-W, POSITION 25.0°E, OPERATOR Inmarsat.

Website allows to see monitoring status from satellites, as shown below (PRN 120).

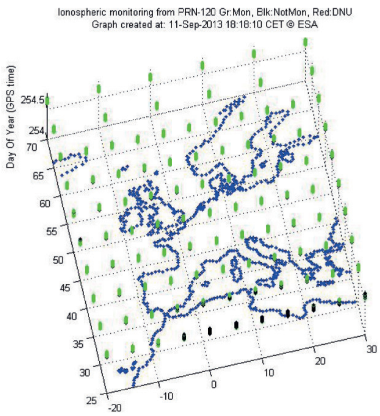

Fig.4. Ionospheric monitoring status from PRN 120

For needs of this article – two RIMS stations were taken to compare performance of EGNOS in its working area.

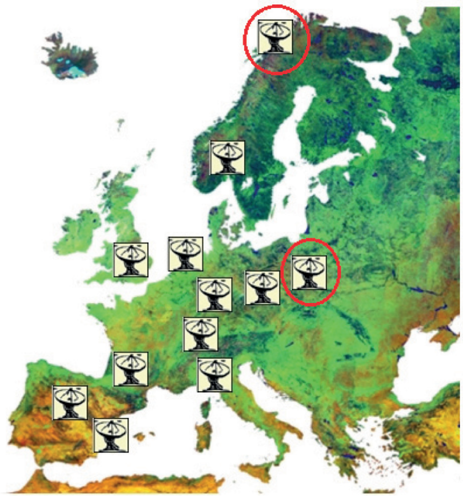

Fig.5. RIMS station chosen for the article

At first, we took Warsaw, Poland (WRS) during 26.12.2013. It is possible to observe parameters such as:

- HPL – horizontal protection level,
- HPE – horizontal position error,
- VPL – vertical protection level,
- VPE – vertical position error.

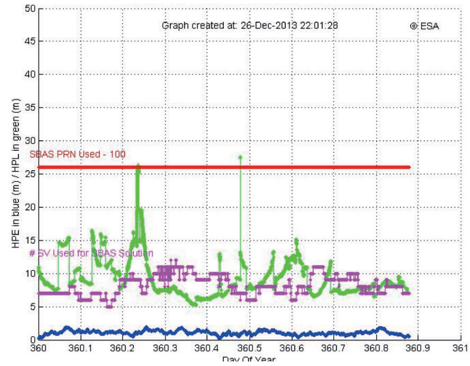

Fig.6. HPE/HPL parameters observed in WRS station during 26.12.2013

Worth noticing is that error statistics are around 1 – 2 meters. The biggest deviations were noticed at the points of 360,2 and 360,5 day of year.

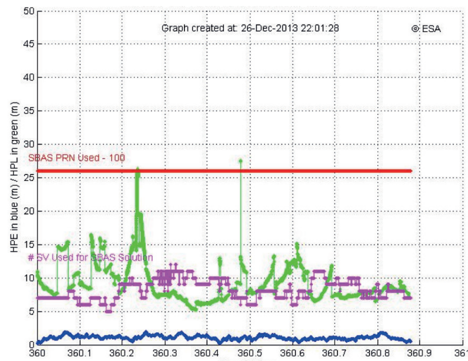

Fig.7. VPE/VPL parameters observed in WRS station during 26.12.2013

Error for vertical parameter is usually less then 1 meter. Below there are also horizontal (HNE) and vertical (VNE) accuracy of measured position which can be seen from both satellites. Here only PRN 120 will be shown, time chosen is 26.11.2013 – 26.12.2013, also WRS station. Fortunately, HNE is around 1 m and VNE, no more than 2 m.

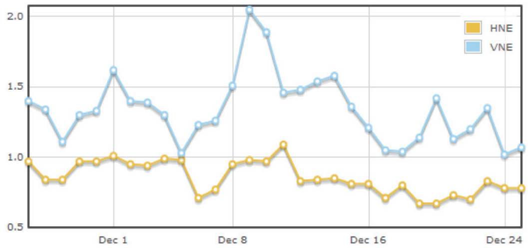

Fig.8. Horizontal (HNE) and vertical (VNE) accuracy of measured position

Second RIMS station is Tromsoe (TRO) in Norway. Parameters HPL, VPL, HPE and VPE will be shown for 31.10.2013.

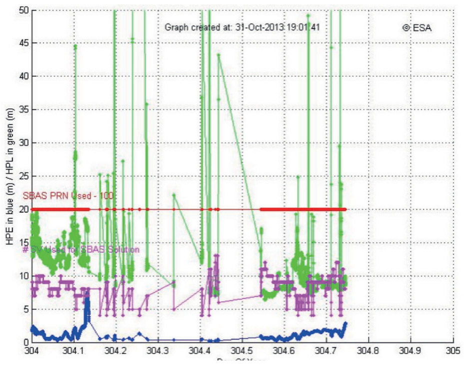

Fig.9. HPE/HPL parameters observed in TRO station during 31.10.2013

Worth noticing is that error statistics are once between 5-10 meters. There are big deviations noticed all the time. It is important that the TRO station is at the edge area of EGNOS performance. Even bigger deviations are for vertical parameters. Error gets to 25 m.

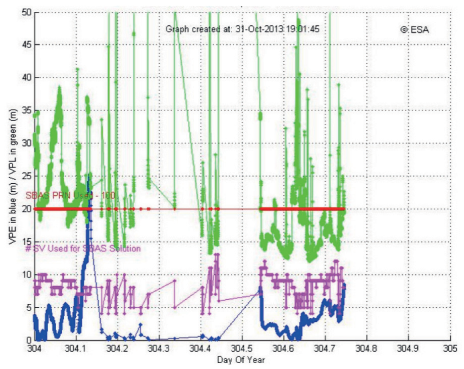

Fig.10. VPE/VPL parameters observed in TRO station during 31.10.2013

Horizontal (HNE) and vertical (VNE) accuracy of measured position which can be seen from both satellites, here again only PRN 120 will be shown, time chosen is 26.11.2013 – 26.12.2013 for TRO station.

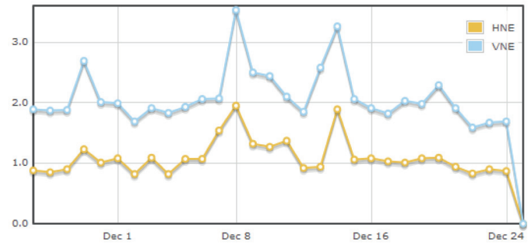

Fig.11. Horizontal (HNE) and vertical (VNE) accuracy of measured position

5. Conclusion

The EGNOS system is such a developed solution that does not require additional infrastructure at the airport where the approach procedure will be performed with its use [9]. Element that may limit ability to use the system may be the failure of fulfillment of one of the four criteria that are placed in front of satellite systems, however, if full coverage of the airport area is provided, the system gives a continuous and reliable signal – the system can be with no major financial outlays installed and can assist landing without additional configuration.

To check the signal quality of the system it is worth to install a device that will monitor its operation at the airport [6]. The EGNOS system compared to other currently used is resistant to weather conditions, it can be also used to operate flights even in zero visibility. It should also be noted that the approach using EGNOS are ecological and economical [10].

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