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THE EUROPEAN SBAS: THE ALTERNATIVE EQUIVALENT TO INSTRUMENT LANDING SYSTEM

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Abstract:
This work contains information on the European Satellite-Based Augmentation System that provides regional satellite-based augmentation services. This report presents an overview of the EGNOS, its main functions and advantages, composition and parameters, and the investigation of the state of EGNOS Approach with Vertical guidance.

Keywords: *Satellite-Based Augmentation System, European Geostationary Navigation Overlay Service, European Satellite Services Provider, Approach Procedure with Vertical Guidance, Integrity Event, Availability, Continuity Risk, Accuracy*

1. Introduction

The Global Positioning System is a space-based satellite navigation system that provides location and time information in all weather conditions, anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites. [1] [2]

The accuracy and confidence level of the information obtained from an independent GNSS (Global Navigation Satellite System) does not satisfy the high level of reliability necessary for the determination of the user location. Therefore, wide-area differential systems SBAS (Space Based Augmentation System) are used to improve the accuracy in determining the coordinates of the objects.

Currently fully functional SBAS are:

EGNOS (European Geostationary Navigation Overlay Service), operated by the European Space Agency;

WAAS (Wide Area Augmentation System), operated by the United States Federal Aviation Administration;

MSAS (Multi-functional Satellite Augmentation System), proposed by Japan.

SBAS in the process of development are:

GAGAN (GPS Aided Geo Augmented Navigation), operationalized by India;

SDCM (System for Differential Correction and Monitoring), proposed by Russia;

WAGE (Wide Area GPS Enhancement), operated by the United States Department of Defense for use by military and authorized receivers;

CWAAS (Canadian Wide Area Augmentation System);

SNAS (Satellite Navigation Augmentation System), proposed by China;

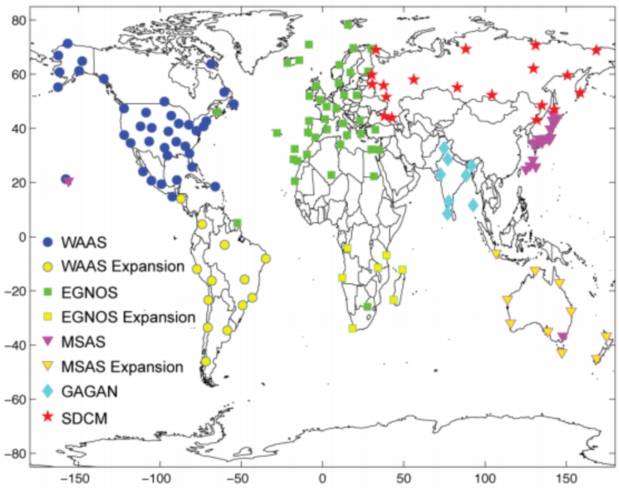

Fig. 1
Areas of action of
WAAS, EGNOS, MSAS, GAGAN and SDCM

Starfix DGPS System and OmniSTAR system (a commercial systems), operated by Fugro;

StarFire (a commercial navigation system), operated by John Deere. [3] [4] [5]

2. The European SBAS: description and main functions

EGNOS, the European Geostationary Navigation Overlay Service, is the European SBAS and has been deployed to provide regional satellite-based augmentation services to aviation, maritime and land-based users in Europe.

EGNOS provides a cost effective alternative equivalent to ILS CAT I, offering similar performance yet without the need for infrastructure installation and maintenance. It is a very valuable navigation aid mainly to small and medium-size airports, increasing safety and accessibility to those aerodromes. [6]

EGNOS helps to increase passenger safety thanks to allowing instrument approach procedures that are safer than non-precision approaches. For airlines it helps to make fewer delays, diversions and cancellations due to bad weather conditions or poor visibility at airports that are not equipped with ground-based navigation aids. For such airports EGNOS increases capacity as separation between aircrafts can be reduced; increases accessibility as planes can land even in bad weather/poor visibility conditions; reduces costs compared to the installation and maintenance of ground-based navigation aids as EGNOS only requires an approach procedures for the runway. [7]

The European Satellite Services Provider (ESSP-SAS) is the central coordinator and the end-to-end responsible of the EGNOS operation and service provision. ESSP is organizing on a yearly basis the EGNOS Service Provision Workshop for EGNOS users and stakeholders, the perfect place to receive updated information on the EGNOS system and services, implementation information and success stories and to collect feedback from users and interchange ideas and experiences among EGNOS users in different domains.

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 at a stake if the positioning system does not meet stringent integrity requirements.

EGNOS Data Access Service (EDAS). This is the provision of EGNOS data through the Internet.

EGNOS Open Service (OS). Applications that have not met the safety requirements by the EGNOS SoL service are considered to be Open Service applications. [8] [9] [10]

3. The European SBAS: composition and parameters

EGNOS is divided into four functional segments.

Ground segment. It is composed of the following stations/centers which are mainly distributed in Europe and are interconnected through a land network:

Thirty nine Ranging and Integrity Monitoring Stations (RIMS) receive the satellite signals and send this information to the MCC centers. The EGNOS extension program envisages the deployment of 7 additional RIMS.

Four Master Control Centers (MCC) receive the information from the RIMS stations and generate correction messages to improve satellite signal accuracy and information messages on the status of the satellites (integrity). The MCC acts as the “brain” of the EGNOS system.

Six Navigation Land Earth Stations (NLES) receive the correction messages from the CPFs for the upload of the data stream to the geostationary satellites and the generation of the GPS-like signal. This data is then transmitted to the European users via the geostationary Satellites.

Two auxiliary installations PACF (Performance Assessment and Check-out Facility) and ASQF (Application Specific Qualification Facility).

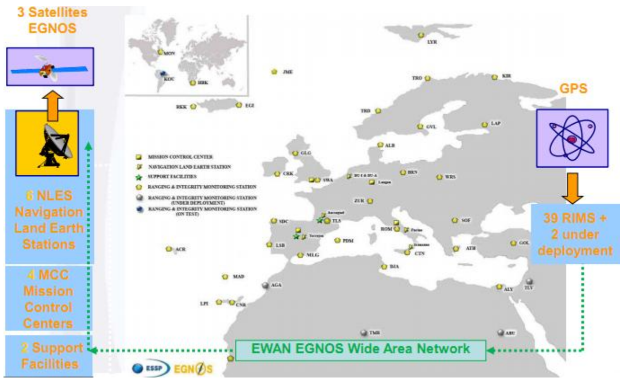

Fig. 2
The network deployment of EGNOS

EGNOS support segment. In addition to the previously mentioned stations/centers, the system has other ground support installations that perform the activities of system operation planning and performance assessment.

Space segment. It is composed of three geostationary satellites: two Inmarsat III satellites and one Artemis satellite from the European Space Agency.

User segment. It is a set of EGNOS receivers developed for various types of users. [11] [12]

Currently EGNOS offers full coverage (APV-1 99%) over Austria, Belgium, Denmark, France, Germany, Luxemburg, Netherlands, Slovenia, Switzerland, Croatia, Bosnia and partial coverage over Czech Republic, Finland, Hungary, Ireland, Italy, Poland, Portugal, Slovakia, Spain, Sweden, United Kingdom, Norway, Montenegro and Serbia. [13]

Fig. 3
EGNOS implementation status in European Airports

Country	Airports	LPV Procedures	APV Baro Procs
France	50 (3 new)	65 (4 new)	1
Spain	1	2	0
Switzerland	5 (1 new)	5 (1 new)	0
Guernsey	1	2	0
Germany	40 (9 with LPV)	15	71
Italy	4	7	0
Finland	1	2	0
Austria	2	2	0
Czech Republic	3 (1 new)	4	4
Norway	1 (1 new)	2 (2 new)	0
Poland	1 (1 new)	2 (2 new)	0
Total	108 (77 with LPV)	108	76

Table 1
List of Airports with EGNOS-based procedures (operational airports till May 1, 2014)

The EGNOS coverage area is Western Europe, but could be readily extended to include other regions within the broadcast area of the geostationary satellites such as Africa, Eastern European countries and Russia. EGNOS is the first element of the European satellite-navigation strategy and a major stepping-stone towards Galileo, Europe's own future global satellite navigation system.

Fig. 4
Plans by 2018 (>440 LPV planned by 2018)

EGNOS performance parameters are usually described in terms of accuracy, integrity, availability and continuity. Although the concept of position accuracy is easy to understand, the other three notions are frequently misunderstood. The definitions of these terms are:

Accuracy. The 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 percent the position error is within the accuracy requirement.

Integrity. It is a measure of the trust which can be placed in the correctness of the information supplied by the whole 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. It 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. It is characterized 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. [14]

4. Benefits of EGNOS LPV for the current navigation aids

LPV stands for Localizer Performance with Vertical guidance. It is an Instrument Approach Procedure that provides lateral and vertical guidance based on GPS augmented by EGNOS (SBAS). The main advantage of this kind of procedures is to enable ILS like approaches (down to 250 ft minima) with a limited ground infrastructure (runway lighting). Therefore, EGNOS provides the benefit to extend the ability to perform instrumental approaches of almost ILS Cat I minima to runways where the installation of an ILS is not cost effective or technically feasible, as well as to provide an inexpensive backup to runway ends already equipped with an ILS. The benefits of this kind of procedures to the airlines is particularly significant to those operating from/to medium sized or light traffic aerodromes where an ILS is not available or cost effective due to both, the decreased number of flights cancelled or delayed and the commercial opportunities derived of an extended operational availability of the aerodromes.

Using EGNOS for instrument approaches can bring the decision height down to as low as 250 feet (about 75 meters), which is close to ILS Cat I. This means that the pilot can take the aircraft down "blind", without visual contact to the ground, to as low as 250 feet above ground. A future version of EGNOS will allow for 200ft minima which is equivalent to Instrument Landing System Cat I. [15]

5. Investigation of the state of EGNOS Approach with Vertical guidance (APV-I) for the period April 2012 – March 2013 and for May 2014 for Sofia given by ESSP

EGNOS APV-I Availability. It is defined as the percentage of epochs in a month/in the period in which the Protection Level is below Alert Limits for this APV-I service (HPL<40m and VPL<50m) over the total period.

Figure 5 presents the EGNOS APV-I Availability for the period April 2012 – March 2013 for Europe:

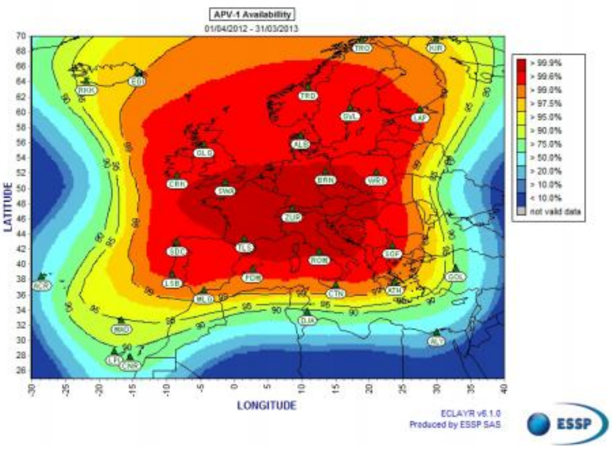

Fig. 5
EGNOS APV-I Availability, April 2012 – March 2013

Figure 6 presents the EGNOS APV-I Availability for May 2014 for Europe:

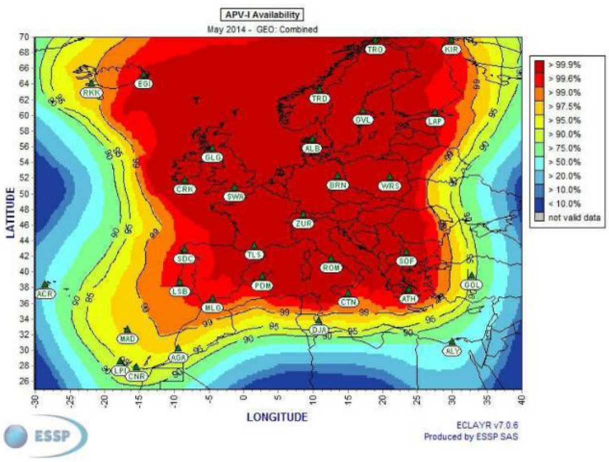

Fig. 6
EGNOS APV-I Availability, May 2014

The availability of the system for APV-I for Sofia for the period April 2012 – March 2013 reaches 99.6%. The availability of the system for APV-I for Sofia on May 2014 reaches 99.9%.

EGNOS APV-I Continuity Risk. It is defined as the result of dividing the total number of single continuity events using a time-sliding window of 15 seconds by the number of samples with valid and available APV-I navigation solution. A single continuity event occurs if the system is available at the start of the operation and in at least one of the following 15 seconds the system becomes not available.

Figure 7 presents the EGNOS APV-I Continuity for the period April 2012 – March 2013 for Europe:

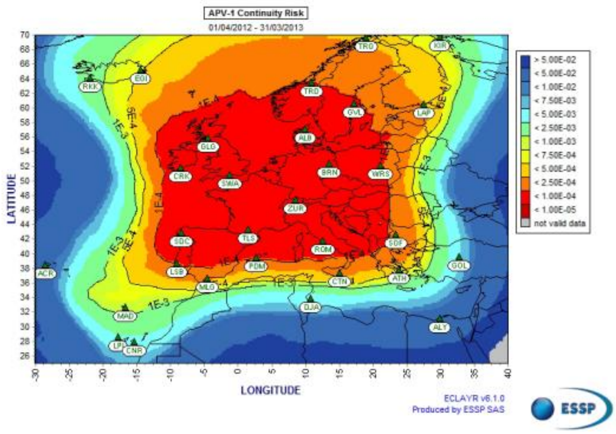

Fig. 7
EGNOS APV-I Continuity Risk,
April 2012 – March 2013

Figure 8 presents the EGNOS APV-I Continuity for May 2014 for Europe:

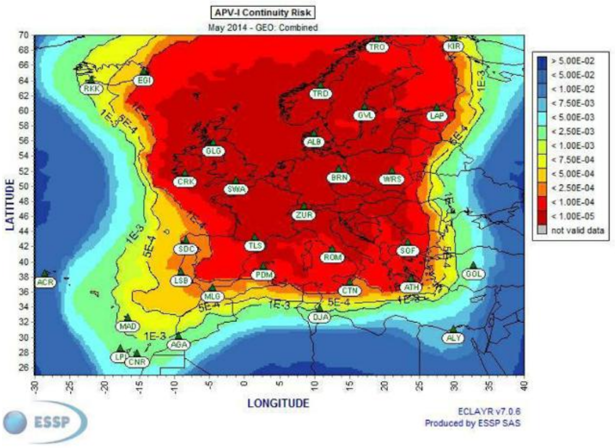

Fig. 8
EGNOS APV-I Continuity Risk, May 2014

APV-I continuity between April 1st 2012 and March 31st 2013 is reported as the number of single continuity events in a time-sliding window of 15 seconds over the total number of available samples in the period. The result is presented as the probability per 15 seconds of occurrence of one discontinuity event.

The continuity of the system for APV-I for Sofia for the period April 2012 – March 2013 is about $2.5x10^{-4}$. The continuity of the system for APV-I for Sofia on May 2014 is about 10^{-4}.

EGNOS APV-I Integrity Event. It is defined as an event when the Navigation SE (System Error) is greater or equal to the corresponding PL (Protection Level) for APV-I.

No integrity event has been identified for any receiver of the monitoring network for the period April 2012 – March 2013 and for May 2014.

Safety Index is defined as the relation between Navigation System Error versus Protection Level (assuming PA algorithms to compute xNSE and xPL) for each second. In case of ratio xPE/xPL is over 1; it indicates that a Misleading Information situation has occurred.

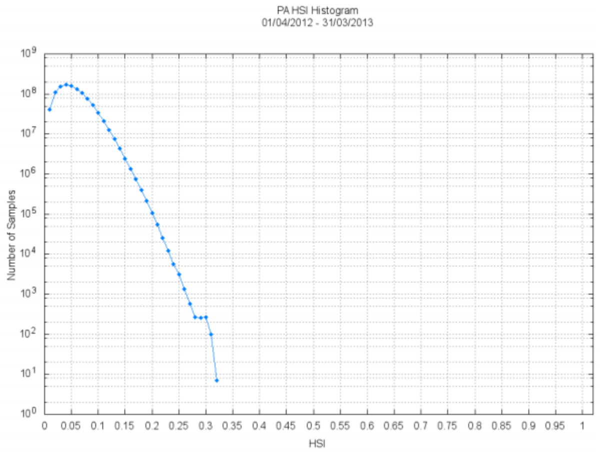

Fig. 9
EGNOS APV-I Horizontal Safety Index, April 2012 – March 2013

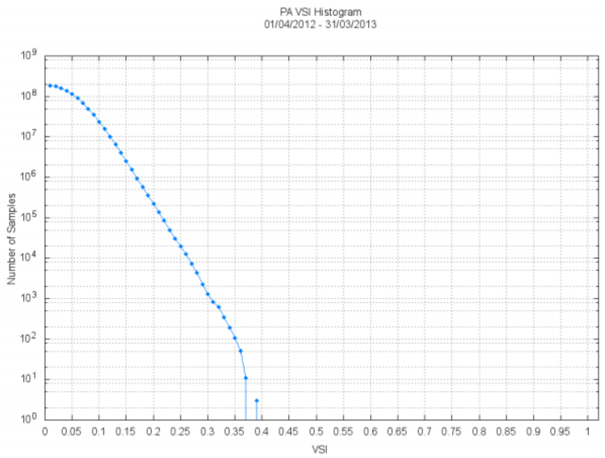

Fig. 10
EGNOS APV-I Vertical Safety Index, April 2012 – March 2013

Figures 9 and 10 provide the histogram for HSI (Horizontal Safety Index) and VSI (Vertical Safety Index) corresponding to the RIMS sites located inside the APV-I for the period April 2012 – March 2013 for Europe.

The Horizontal and Vertical Safety Indexes remain below 0.4 for all stations throughout the whole period, which represent a very good integrity margin.

Figures 11 and 12 provide the histogram for HSI and VSI for each second when accumulating measurements from the different EGNOS stations of Europe for May 2014:

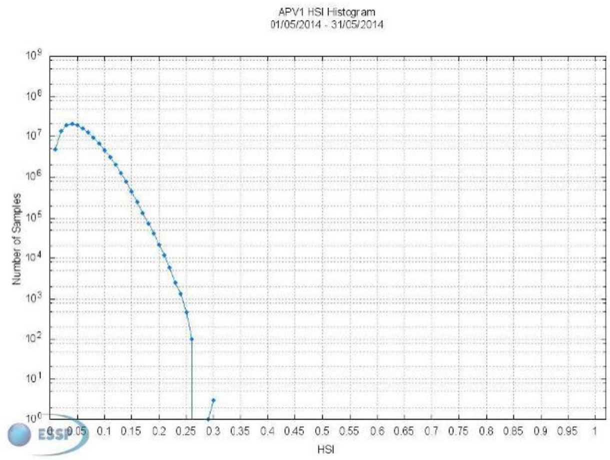

Fig. 11
EGNOS APV-I Horizontal Safety Index, May 2014

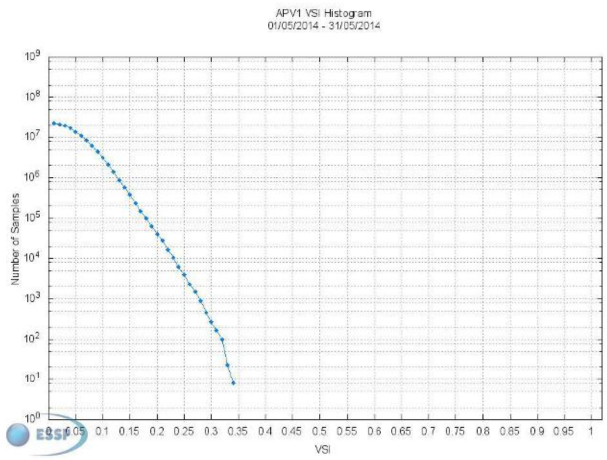

Fig. 12
EGNOS APV-I Vertical Safety Index, May 2014

HSI and VSI are <0.75 so there is no potential possibility for Misleading Information. These histograms have considered that Protection Level is below APV-I Alarm Limit.

EGNOS APV-I Accuracy. It is reported as the 95th percentile of the Horizontal and Vertical Navigation System Error over the month, at the monitored sites when the APV-I service is available (HPL<40m and VPL<50m).

The APV-I accuracy values in meters for all stations in Europe for the period April 2012 – March 2013:

HNSE 95% – 1.3 m, VNSE 95% – 2.3m.

The APV-I accuracy values in meters for Sofia station for May 2014:

HNSE 95% – 1.2 m, VNSE 95% – 2.4m,

99.97% of samples with APV-I service available.

These results represent a very good level of accuracy. [16] [17]

Conclusion

The past years of EGNOS Service Provision have demonstrated ESSP excellent service performance. The continued trend of implementation of EGNOS Approach procedures by Air Navigation Service Providers confirms the need for the EGNOS service and its availability in Europe. Additional Air Navigation Service Providers have signed the EGNOS Working Agreement with ESSP, the first essential step on the way towards implementation of EGNOS Approach procedures. The number of registered users of the EGNOS Data Access Service (EDAS) confirms the eagerness of Europe to develop "added value services", based on EGNOS data.

The availability of EGNOS to aviation means that aircrafts will be able to use satellite technologies to establish their vertical positioning during approaches. The established results support the claim: nowadays EGNOS performance is stable with high quality of the accuracy and integrity.

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ЕВРОПЕЙСКАТА SBAS: АЛТЕРНАТИВАТА НА ИНСТРУМЕНТАЛНА СИСТЕМА ЗА КАЦАНЕ

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Резюме:
В настоящата работа е представена информация за Европейската геостационарна служба за навигационно покритие. В тази публикация е направен обзор на EGNOS, разгледани са основните му функции и предимства, състав и параметрите на системата. Извършено е изследване на състояние на EGNOS при подход за кацане с управление по вертикала.

Ключови думи: *Спътникова система за диференциялна корекция, Европейската геостационарна служба за навигационно покритие, Европейският доставчик на спътникови услуги, подход за кацане с управление по вертикала, интегритет, достъпност, непрекъснатост, точност.*