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COMPARISON OF THE EFFICIENCY OF EGNOS PARAMETERS DETERMINATION ALGORITHMS

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Abstract:
This work contains information on the EGNOS (European Geostationary Navigation Overlay Service), its architecture and functions. In this work, using real data for one year, the EGNOS performance is tested. This data is collected at the EGNOS Monitoring Station placed by Eurocontrol in Technical University of Sofia. The results confirm that the designed new algorithms are very promising and allow availability improvement without breaches of the integrity.

Keywords: *Global Positioning System, European Geostationary Navigation Overlay Service, Satellite Based Augmentation System, Approach Procedure with Vertical Guidance, Horizontal/Vertical Protection Level, Dilution of Precision, Safety Index, Position Error, Misleading Information.*

1. Introduction

The global positioning, or determining the exact location of an object, is a technology for self-positioning of the user receiver using signals from artificial Earth satellites. A Global Positioning System is a satellite navigation system for determining the PVT (position, velocity and time) with accuracy of 1 nanosecond at any point of the Earth and orbit in real time.

At the present time the American GPS (Global Positioning System) and the Russian GLONASS (GLObal NAvigation Satellite System) are fully functional. The main difference between GLONASS and GPS is in the orbital structure and the separation of the signals. [11] [13]

An alternative to GPS and GLONASS is Galileo – a global navigation satellite system projected by the European Union and the European Space Agency. The Indian IRNSS (Indian Regional Navigational Satellite System), the Japanese QZSS (Quasi-Zenith Satellite System) and the Chinese BD (BeiDou Navigation Satellite System) regional satellite navigation systems are in the process of development.

The accuracy and the confidence level of the information obtained from an independent GNSS (Global Navigation Satellite System) do not satisfy the high level of reliability necessary for the calculation 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 3 satellite-based augmentation systems (SBAS) are fully functional: The American WAAS (Wide Area Augmentation System), the European EGNOS (European Geostationary Navigation Overlay Service) and the Japanese MSAS (Multi-functional Satellite Augmentation System).

Wide-area systems such as the Indian GAGAN (GPS Aided Geo Augmented Navigation), the Chinese SNAS (Satellite Navigation Augmentation System), the Russian SDCM (System for Differential Correction and Monitoring) and the Canadian CWAAS (Canadian Wide Area Augmentation System) are in the process of development. [7] [8]

2. Composition and functioning of EGNOS

The EGNOS system includes 3 major segments: space, ground and user. The space segment consists of geostationary satellites and its main function is the propagation of the EGNOS signal. The ground segment is a network of ground stations, with the aid of which the production of the EGNOS signal and the management of the whole system are observed. The user segment represents receivers located on objects that use the services of EGNOS.

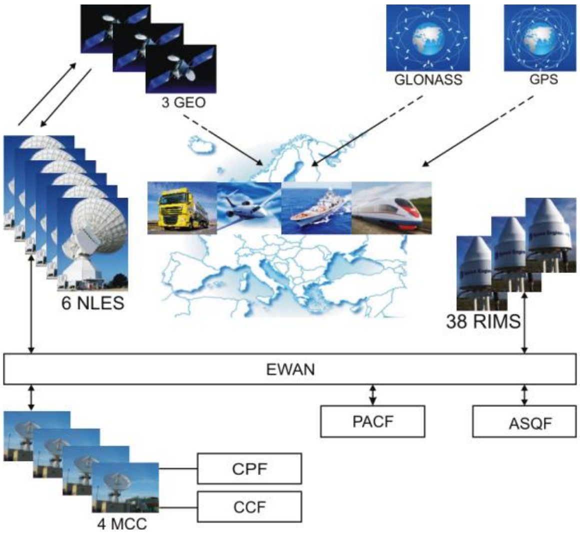

Fig. 1
Architecture of the European Geostationary Navigation Overlay Service

The EGNOS system consists of:

– 3 satellites in geostationary orbit;

– 39 ground stations RIMS (Ranging and Integrity Monitoring Stations) that receive the GPS signal and make comprehensive monitoring and measurement of distances;

– 4 MCC (Master Control Centers) which process data from the ground stations and include CCF (Central Control Facility) and CPF (Central Processing Facility);

– 6 ground stations for navigation messages NLES (Navigation Land Earth Stations) which transmit the signal to GEO satellites after it has been generated;

– 2 auxiliary installations PACF (Performance Assessment and Check-out Facility) and ASQF (Application Specific Qualification Facility) which constitute the ground segment of the system.

The territory of Bulgaria is fully covered by EGNOS. By using EGNOS, the positioning accuracy is improved to a few meters, and notification of impaired integrity reaches users in 6 seconds. [1]

3. Performance indicators of EGNOS

The main parameters of the EGNOS system are accuracy, integrity, availability and continuity.

Accuracy. The requirement for 95% accuracy is accepted as a criterion for the normal operation of the system. The situation is anomalous if the 24 hour 95% horizontal error exceeds 16 meters and the vertical error exceeds 20 meters. GLONASS and GPS have practically the same accuracy.

Availability. It is required no less than 99% system availability. In this case the number of visible satellites can be reduced due to incomplete configuration of the space segment and defects when passing through rough terrain, because of high trees, buildings and engineering constructions.

Integrity. The potential possibility for interruption of the EGNOS integrity is called Safety Index – the ratio between the true Positioning Error and the corresponding Protection Level: SI = PE / PL. When SI > 0.75 the case is treated as a potential possibility for Misleading Information, and when SI > 1.00 the situation is anomalous.

Continuity. Currently the probability of interruption of EGNOS system in the central Europe is satisfactory and represents about 10^{-4}. [4] [15] [6]

4. Error Extraction Algorithm

This paper presents an original method for improving the performance of EGNOS called Error Extraction (EE). Its primary purpose is to achieve improving of the accuracy and availability of the system without loss of integrity. In this work the parameters of the EGNOS system (accuracy, integrity, availability and continuity) before and after the application of the Error Extraction algorithm are experimentally evaluated using real data from EGNOS collected by EGNOS Monitoring Station.

In Bulgaria there are two Monitoring Stations that compile and analyze data system for the needs of EDCN (Eurocontrol EGNOS Data Collection Network). One of them is placed in the Air Traffic Services Authority of Burgas, the other is placed at the Technical University of Sofia. In Sofia it operates with the Pegasus software version 4.6.0 and a Septentrio PolaRx2 reciever. [9]

PEGASUS (Prototype EGNOS Analysis System Using SAPPHIRE) is a software package, which is an important means to control the characteristics of EGNOS. It includes the algorithms for analysis of the positioning characteristics, autonomous control of the integrity and availability of the GNSS signals. It evaluates HPL (Horizontal Protection Level) and VPL (Vertical Protection Level). HPL and VPL are calculated to protect users from potential deterioration of the system, which may result in HPE (Horizontal Position Error) and VPE (Vertical Position Error) exceeding certain levels called HAL (Horizontal Alert Limit) and VAL (Vertical Alert Limit) determined by ICAO, respectively. [5]

The calculation of xPL with the Error Extraction Algorithm is a combined approach that includes zero noise and systematic error and is very promising. In this approach the boundaries of the two errors are combined to give the composite xPL (1): [2]

$$xPL = xPL_{noise} + xPL_{bias} \quad (1)$$

With the Error Extraction Algorithm we achieve the primary purpose: reducing of the conservatism of the xPL levels without sacrificing integrity. [3] [10]

5. Results

The main task is to determine the xPL (Horizontal and Vertical Positional Levels) so that the error can exceed these levels with probability of less than 10^{-7} vertically and 10^{-9} horizontally.

The availability of the system for APV-I (Approach Procedure with Vertical Guidance) for January 2012, July 2013 and May 2014 given by the ESSP (European Satellite Services Provider), is presented in Fig. 2, Fig. 3 and Fig. 4. [12]

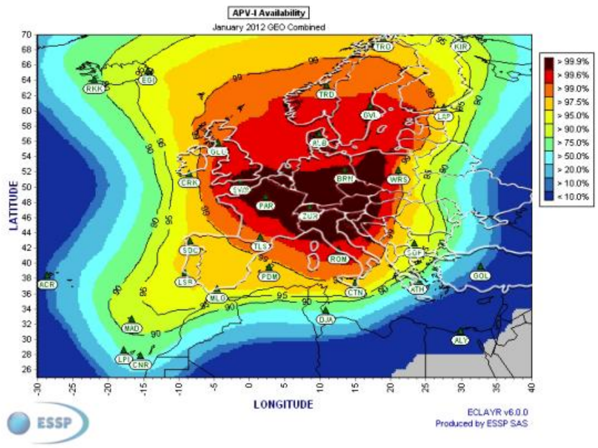

Fig. 2
Sofia, January 2012, 95%

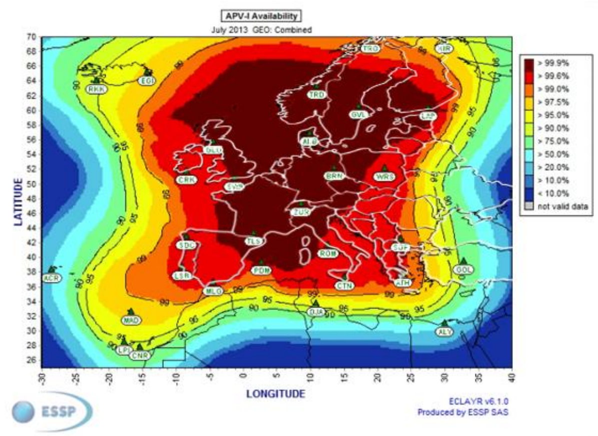

Fig. 3
Sofia, July 2013, 99.6%

The availability of the system for APV-I for Sofia during the discussed period is characterized by high stability. From February 2012 onwards the availability of the system does not fall below 99% and in most months it reaches 99.6% which indicates preserved integrity of the system. On May 2014 it reaches almost 100% (99.9% exactly).

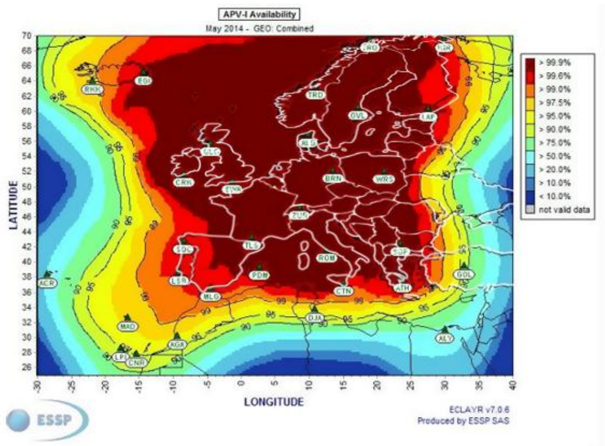

Fig. 4
Sofia, May 2014, 99.9%

Date	Availability of the EGNOS, %
January 2012	95%
Fabruary 2012	99%
March 2012	99.6%
April 2012	99%
May 2012	99.6%
June 2012	99.6%
July 2012	99.6%
August 2012	99.6%
September 2012	99.6%
October 2012	99.6%
November 2012	99.6%
December 2012	99%
July 2013	99.6%
May 2014	99.9%

Table 1
Availability of the system for APV-I (Approach Procedure with Vertical Guidance) for Sofia, given by the ESSP (European Satellite Services Provider)

Comparative diagrams of the availability of the EGNOS system for APV-I (Approach Procedure with Vertical Guidance), APV-II and CAT-I (Precision Approach Flight Phase Category I) for the period of one year are presented on figures 5-7. The data is taken from the daily reports of Delft University of Technology (DELFT – The Netherlands), Eurocontrol Experimental Centre (Bretigny – France), Pansa Warsaw (Warszawa – Poland) and Technical University of Sofia (SOF2 – Bulgaria), in rates. [14]

	APV-I	APV-II	CAT-I
Delft University of Technology	99.261%	98.202	46.848
Eurocontrol Experimental Centre	99.702	98.589	27.566
Pansa Warsaw	98.897	95.889	25.718
Technical University of Sofia	98.816	85.026	5.610

Table 2
Comparison of the system availability at Delft University of Technology, Eurocontrol Experimental Centre, Pansa Warsaw and Technical University of Sofia for APV-I, APV-II and CAT-I for the period of one year

The values of the availability for APV-I, APV-II and CAT-I for the Technical University of Sofia, calculated according to the old algorithm, are remarkably lower than those for the Delft University of Technology, Eurocontrol Experimental Centre and Pansa Warsaw. That demonstrates the need for a significant improvement of the availability of the system.

Table 3 presents a comparison of the values calculated by the old and the new algorithms for the TU-Sofia for the period of one year.

	OLD	NEW
Max SI (hor) Maximum Horizontal Safety Index	0.165	0.303
Max SI (ver) Maximum Vertical Safety Index	0.175	0.391
APV-I Approach Procedure with Vertical Guidance I	98.816	99.809
APV-II Approach Procedure with Vertical Guidance II	85.026	99.018
CAT-I Precision Approach Flight Phase Category I	5.610	88.431
P (disc.) Probabilities of discontinuity	0.129	0.148

Table 3
Comparison of old and new values for Max SI (hor), Max SI (ver), APV-I, APV-II, CAT-I and P (disc.), calculated by old and new algorithms for the Technical University of Sofia

The values of the availability for APV-I, APV-II and CAT-I, calculated according to the old algorithm, are 98.816%, 85.026% and 5.61%, respectively. The same values of the availability for APV-I, APV-II and CAT-I, calculated according to the new algorithm are, as follows: 99.809%, 99.018% and 88.431%. These values testify to a significant improvement of the availability of the system.

It should be noted that the availability of the APV-I, calculated according to the new algorithm, is more than the required 99% and approximates to 100% accuracy of the system.

Conclusion

The existing global satellite positioning systems do not provide the required accuracy, availability, integrity and continuity. With the launch of the European wide-area differential correction system EGNOS, conditions for the implementation of the GPS technologies has improved significantly.

The conducted experiments confirm that the designed new algorithms based on the Error Extraction methodology are very promising. They allow reduction of the standard deviation of the error and significantly improve the availability of the European Geostationary Navigation Overlay Service for Bulgaria.

Acnowledgement

The author would like to express her gratitude for the software package PEGASUS (Prototype EGNOS Analysis System Using SAPPHIRE) created by the European Organization for the Safety of Air Navigation. The EGNOS Monitoring Station is placed by Eurocontrol at the Technical University of Sofia and is an important means to control the characteristics of EGNOS.

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СРАВНЕНИЕ НА ЕФЕКТИВНОСТТА НА АЛГОРИТМИ ЗА ОПРЕДЕЛЯНЕ НА ПАРАМЕТРИ НА ЕГНОС

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Резюме:

В настоящата публикация е представена информация за EGNOS (Европейската геостационарна служба за навигационно покритие), нейната архитектура и основните функции. В тази работа е представен анализ на реалните данни на системата EGNOS, събрани за периода от една година. Тези данни се събират от EGNOS мониторна станция, която е разположена от Евроконтрол в Технически университет – София. Извършените експерименти потвърждават, че проектираните нови алгоритми са многообещаващи и позволяват значително подобряване на достъпността на системата EGNOS без нарушаване на нейният интегритет.

Ключови думи: *Глобална система за позициониране, Европейската геостационарна служба за навигационно покритие, спътникова система за повишаване на прецизността, подход за кацане с управление по вертикала, хоризонтално/вертикално ниво на защита, влошаване на точността, индекса на защита, позиционна грешка, подвеждаща информация.*

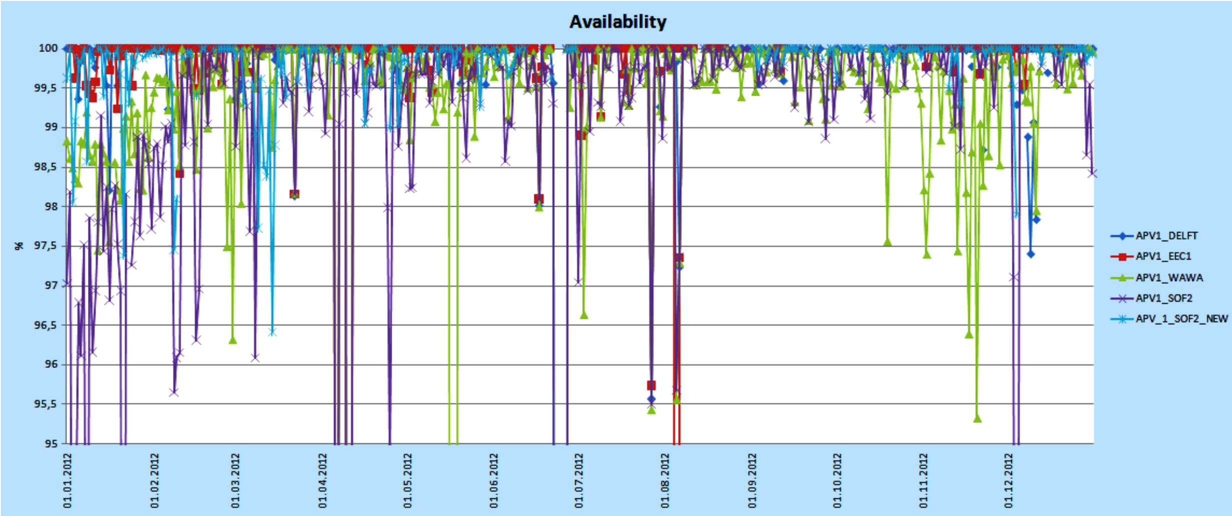

Fig. 5
Comparative diagrams of availabilities for APV-I
(Approach Procedure with Vertical Guidance I)

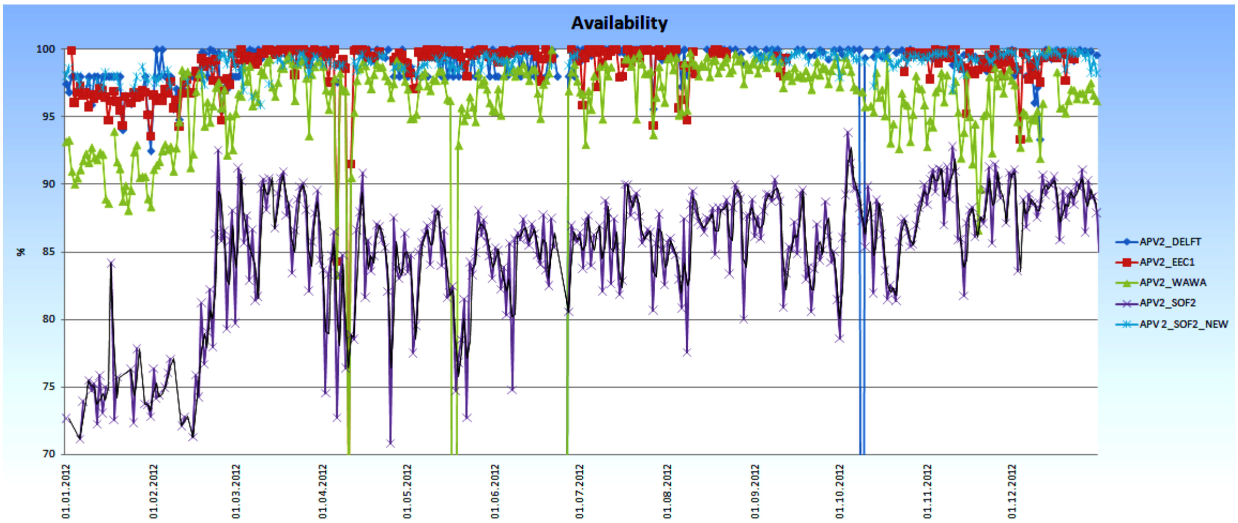

Fig. 6
Comparative diagrams of availabilities for APV-II
(Approach Procedure with Vertical Guidance II)

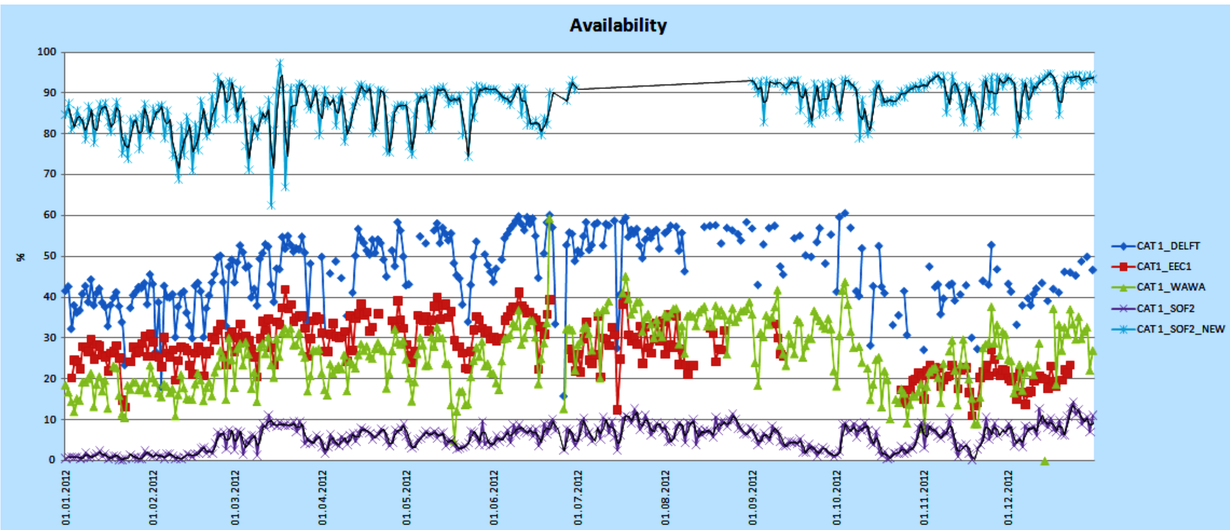

Fig. 7
Comparative diagrams of availabilities for CAT-I
(Precision Approach Flight Phase Category I)