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FUTURE EGNOS APV PROCEDURES IMPLEMENTATION IN POLAND AS A CHANCE FOR SMALL AND MEDIUM AIRPORTS DEVELOPMENT

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Abstract

This paper presents original researches and analysis of EGNOS (European Geostationary Navigation Overlay Service) due to readiness for Approach Procedures with Vertical Guidance (APV) implementation and development for small and medium airports on Polish territory according to present situation in the western part of Europe. Improving safety, availability, usefulness and cost-effectiveness for aviation transport sector.

This work carries out a detailed analysis of the parameters describing and characterizing each augmentation navigational satellites system: accuracy, integrity, continuity and availability. Faults has been pointed out and shortcomings of EGNOS factors according to improvement air transport safety in the most sensitive landing phases.

The validated Approach Procedures with Vertical Guidance, using Satellite-Based Augmentations System is paving the way for flying Instrument Landing System type approaches to small and medium airports in the western part of Europe independently of ground-based infrastructure.

The instrument APV procedures consists of four phases of flight: Initial Approach, Intermediate Approach, Final Approach and Missed Approach – parts of approach segments. SBAS (Satellite Based Augmentation System) seems to be the first satellite based system that can support FAS (Final Approach Segment) which is the most "sensitive", important and dangerous part of the instrumental approach procedures based on aircraft's avionics equipment most time without vertical and horizontal visibility. EGNOS augments the GPS system in order to meet the necessary: accuracy, integrity, availability, continuity envisaged for APV procedures [9]. APV procedure based on EGNOS system is recently the only low-cost chance for small and medium Polish airports development in the aviation transport sector, according to extension and improving augmentation system factors mentioned above.

Keywords: EGNOS, Satellite Based Augmentation System, Approach with Vertical Guidance, Signal in Space.

1. INTRODUCTION

With reference to an agreement between PANSA (Polish Air Navigation Services Agency) and ESSP (European Satellite Service Provider) called "EGNOS Working Agreement", about implementation in Polish airports approach procedures based on satellites navigation. Country face new technologies in accordance with European strategies and future plans for GNSS approach procedures. Priority measure for information about aircraft's three-dimensional position in the most important phase of flight – landing. This agreement became possible because a lot of work has been done in accordance with EGNOS APV procedures and the first experimental approach and landing using APV I procedure. This was a part of HEDGE and EGNOS APV program. Piper PA-34 Seneca II Royal-Star aircraft with certified Garmin GNS430W receiver on 14th and 15th March 2011 in the International Airport Katowice in Pyrzowice was used.

EGNOS as a joint project of the European Space Agency, European Commission and Eurocontrol (European Organization for the Safety of Air Navigation), the first step to GNSS and precursor to Galileo (full globe satellite navigation system) is European wide area SBAS system. Main task is to evaluate and broadcast correct GPS (Global Positioning System) data over the whole continent by improving integrity via real-time monitoring, accuracy via differential corrections, availability and continuity [10].

System uses a combination of geostationary satellites and ground-based stations. It receives, evaluates, corrects and sends back data to GPS receivers. RIMS (Remote Integrity and Monitoring Stations) collect data from the GPS satellites and transmit it towards a processing facility. MCC (Master Control Centers) process, elaborate to be diffused and format of the EGNOS signal. NLES (Navigation Land Earth Stations) transmit data towards geostationary satellites [8].

Three types of positioning services are provided: Open Service (OS) available since 1st October 2009 mainly support mass market, Commercial Data Distribution Service (CDDS) using Internet to broadcast data for commercial and professional users requiring enhanced performance, Safety of Life Service (SoL) providing the most stringent level of signal-in-space performance to all Safety of Life users in particular aviation via Geostationary satellites available since March 2, 2011 [1].

In order to take benefit from SBAS performance in Europe in 2002 a new classification of the instrumental approach procedures was established. Two levels were defined: APV I and APV II. Later LPV was introduced, means Localizer Performance with Vertical guidance and referring to APV I, II. The ICAO OCP (Obstacle Clearance Panel) prepared materials for LPV procedures design, from now on titled "RNAV(GNSS)", with addition of minima box line, LPV in it [6]. It should be mentioned that LPV procedure is based on the RNAV concept [11]. It permits aircraft operation on any desired flight path within the coverage of ground or space based navigation aids or within the limits of the self-contained aids also combination of these [5]. Because of high safety parameters and low costs there is no need for installing additional airport infrastructure equipment. It is a chance for small and medium Polish airports to develop in the aviation transport sector.

2. EGNOS APV APPROACH PROCEDURES CONCEPT

EGNOS APV procedures consist of four phases of flight: Initial approach, Intermediate approach, Final approach and Missed Approach. One that can support FAS (Final Approach Segment). The most "sensitive" part of the instrumental approach procedures is based on aircraft's avionics equipment for most of the time without vertical and horizontal visibility. SBAS augments the GPS system in order to meet the necessary accuracy, integrity, availability, continuity envisaged for EGNOS APV procedures. These approaches are similar and equivalent to the legacy of ILS (Instrument Landing System). Radio beam transmitter that provides a direction for approaching aircraft (which tuned their receiver to the system frequency) providing precision lateral and vertical guidance. But it is more economical because no navigation infrastructure needs to be installed on the airfield with minimal equipment installed in the aircraft [4].

There have been 150 airports with LPV approaches in use till 2015 in EUROPE and six kinds of benefits improvements of the instrumental approach are related to APV [7]:

- approach procedures are safer than conventional NPA (Non Precision Approach), because of geometric vertical guidance provision,
- reduced the CFIT (Controlled Flight Into Terrain) not allowed to perform "dive and drive" navigation which occurs without vertical guidance information,
- improve capacity and regularity at airports without ILS or out of service provides a procedure having lower operational minima than in a NPA,
- reduced noise because of a constant descent angle through FAS,
- due to RNAV/Baro-VNAV (Barometric Vertical Navigation) procedures, EGNOS APV temperature restriction does not exist,
- decommissioning ground-based navigation aids decrease costs (but back-up system is needed in case of SIS unavailability) [2].

3. ICAO REQUIREMENTS FOR EGNOS APV PROCEDURES

There are four main important factors which characterize each SBAS system and stringent for precision landing instrumental approaches: accuracy, integrity, continuity and availability.

Accuracy:

Difference between the estimated position and the actual position. For a large set of independent samples, at least 95% should fulfill accuracy requirements. It is defined to ensure pilot's acceptance, since it represents the errors which will be experienced. The requirement is for worst-case geometry under which is the declaration of the system availability. Accuracy of the position domain has to be less than 16 m in the horizontal and 20 m in the vertical space with 95% confidence level.

Integrity:

Measure of the trust which can be placed in the correctness of the information supplied by the total system. Integrity includes the ability of the system to alert the user when the system should not be used for the intended instrumental approach phase. The necessary level of integrity for each operation is established with respect to specific alert limits. When the integrity estimates exceed these limits, the pilot is to be alerted within the prescribed time period. Allowable probabilities of non-integrity event (probabilities of Hazardous Misleading Information) per landing approach, are $1-2\times10^{-7}$ for the horizontal and vertical components each. Misleading Information situation occurs where there was an HPE/HPL and VPE/VPL ratio of more than 1-real MI (Misleading Information) or more than 0.75-near MI.

Availability:

The ability of the SBAS to provide function required and performance at the initiation of the intended operation. It occurs as an indication to provide usable service within the specified coverage area of the system. Availability of SIS is the percentage of time that navigational signals transmitted from external sources are available for use. The availability is a function of both the physical characteristics of the environment and the technical capabilities of the transmitter facilities. The local availability of EGNOS SBAS for APV shall be better than 99% over the nominal operational lifetime of the service.

Continuity:

SBAS system ability (comprising all elements necessary to maintain aircraft geographical position within the defined airspace) to perform its function without interruption during the intended operation. To specify it, continuity is the probability that the specified system performance will be maintained for the duration of a phase of operation, presuming that the system was available at the beginning of that phase of operation, and predicted to exist throughout the operation. Due to ICAO Annex 10 requirements each SBAS SIS has to meet standards showed in Table 1 [3].

Table 1. ICAO SiS requirements for EGNOS APV

	Accuracy 95%		**Integrity**				**Continuity**	**Availability**
	Lateral	***Vertical***	***Integrity Risk***	***Time to Alert***	***Horizontal Alert Limit***	***Vertical Alert Limit***		
APV I	16m	20m	$1-2\times10^{-7}$	10s	40m	50m	$1-8\times10^{-6}$	0.99 to 0.99999
APV II	16m	8m	$1-2\times10^{-7}$	6s	40m	20m	$1-8\times10^{-6}$	0.99 to 0.99999
CAT I	16m	6-4m	$1-2\times10^{-7}$	6s	40m	15-10m	$1-8\times10^{-6}$	0.99 to 0.99999

4. EGNOS APV IMPLEMENTATION EXPERIMAL PHASE IN POLAND

The experiment was conducted in three Polish airports: Warszawa “Okecie”, Krakow “Balice” and Rzeszow “Jasionka” thanks to the courtesy of PANSA (Polish Air Navigation Services Agency). Septentrio PolaRx 2/3 receiver was used during the experiment in all three airports, which is a high-end dual frequency GNSS receiver, provides:

- dual frequency high sensitivity tracking of GPS signals (code tracking maintained down to 19dB-Hz),
- tracking of the L2C signal,
- simultaneous tracking on up to three antennas for attitude determination,
- simultaneous tracking of up to six SBAS,
- high accuracy code, carrier, and Doppler measurements at sampling rates up to 10Hz,
- decoded and/or raw navigation messages for both GPS and SBAS satellites,
- receiver Autonomous Integrity Monitoring.

Analyses of the experiment results was carried out on recorded data from the period of time between 1st of January 2014 and 30th of June 2014 in the airports mentioned before. Samples were recorded at every second for twenty four hours per day, for samples evaluation Pegasus 4.7.5 was used thanks to the courtesy of Eurocontrol [9] [own study]. Experiment results are shown in Tables 2-4.

Table 2. Experiment results for Warszawa "Okecie" [own study]

	APV – I					HPL	VPL	DE
	HNSE[1]	***VNSE***[2]	***AV***[3]	***HPE***[4]	***VPE***[5]	***99%***	***99%***	***APV***
JANUARY	1.23	1.50	99.56	1.04	0.62	14.86	22.28	4.07
FEBRUARY	1.42	1.61	99.05	1.03	0.71	16.27	24.15	7.33
MARCH	1.3	1.71	99.87	1.14	3.16	18.53	25.90	3
APRIL	1.2	1.65	99.48	1.08	0.68	18.24	25.23	5.92
MAY	1.1	1.52	99.35	0.99	0.63	18.02	25.95	14.70
JUNE	1.2	1.35	99.46	0.99	0.54	18.01	25.73	6.62
ARITHMETIC MEAN	1.24	1.56	99.46	1.04	1.05	17.32	24.87	6.94

[1] Horizontal Navigation System Error [m]
[2] Vertical Navigation System Error [m]
[3] Availability [%]
[4] Horizontal Position Error [m]
[5] Vertical Position Error [m]

Table 3. Experiment results for Krakow "Balice" [own study]

	APV – I					HPL[6]	VPL[7]	DE[8]
	HNSE	***VNSE***	***AV***	***HPE***	***VPE***	***99%***	***99%***	***APV***
JANUARY	0.68	1.16	99.54	0.34	0.49	20.93	27.09	2
FEBRUARY	0.79	1.27	99.90	0.39	0.52	21.48	29.12	23.85
MARCH	0.87	1.30	99.94	0.43	0.53	21.66	28.45	2.4
APRIL	0.79	1.40	99.87	0.39	0.59	19.84	26.13	3.91
MAY	0.71	1.34	99.56	0.37	0.58	17.88	24.94	1.76
JUNE	0.74	1.34	99.93	0.40	0.64	17.46	24.61	1.33
ARITHMETIC MEAN	0.76	1.3	99.79	0.39	0.56	19.87	26.72	5.87

[6]Horizontal Protection Limit [m]
[7]Vertical Protection Limit [m]
[8]Discontinuity Events

Table 4. Experiment results for Rzeszow "Jasionka" [own study]

	APV – I					HPL	VPL	DE
	HNSE	*VNSE*	*AV*	*HPE*	*VPE*	*99%*	*99%*	*APV*
JANUARY	0.7	7.48	99.79	0.37	0.63	23.82	30.49	3.83
FEBRUARY	0.91	1.62	99.91	0.44	0.72	22.41	30.57	2.09
MARCH	0.9	1.64	99.97	0.42	0.73	23.19	31.83	1.66
APRIL	0.84	1.61	99.78	0.41	0.66	22.39	29.04	2.8
MAY	0.83	1.45	99.58	0.43	0.59	20.93	27.95	2.33
JUNE	0.84	1.27	99.94	0.42	0.5	20.31	28.5	2.11
ARITHMETIC MEAN	0.85	2.51	99.83	0.42	0.64	22.17	29.73	2.47

5. CONCLUSIONS

After detailed analysis of system factors with main meaning for flight safety when satellites navigation system is used: accuracy, integrity, continuity and availability were taken into consideration. According to EGNOS APV procedures requirements for SBAS the following conclusions were made:

Accuracy, in every airport both horizontal and vertical meets ICAO annex 10 requirements for EGNOS APV implementation.

Secondly, there were no integrity events during experiment period, as “a measure of trust” EGNOS is real trustworthy as a tool for safe approach and landing.

Third factor – continuity – was taken into consideration, some of discontinuity events appeared, that is why in this case the system needs “attention” and appropriate actions.

The last but not least is availability which is strictly related to continuity, showed during detailed analysis of SIS, days without required percentage precision, although average of each month is more than 99%.

To sum up the foregoing conclusions, in spite of days with continuity and availability inefficiency, EGNOS APV procedures are ready for development and implementation in Poland. Based on researches evaluation in the airports situated in the north, south and east on Polish territory, it proves EGNOS system readiness for EGNOS APV procedures implementation at small and medium airports in Poland.

These procedures are the greatest chance for Polish aviation transport sector, for both small and medium airports development without high cost aerodrome equipment, which in most cases requires higher grade infrastructure.

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IMPLEMENTACJA PROCEDUR EGNOS APV W POLSCE SZANSĄ ROZWOJU MAŁYCH I ŚREDNICH PORTÓW LOTNICZYCH

Streszczenie

W artykule przedstawione zostały oryginalne badania i analiza system EGNOS (European Geostationary Navigation Overlay Service) w odniesienu do implementacji i rozwoju Procedur Podejścia do Lądowania z Prowadzeniem Pionowym w małych i średnich portach lotniczych na *terenie Polski, biorąc pod uwagę stan w Europie Zachodniej. Poprawiając tym samym bezpieczeństwo, dostępność, użytkowość i koszty eksploatacji w sektorze transport powietrznego.*

Praca ta przedstawia dokładną analizę czynników opisujących każdy system wspomagania satelitarnego: dokładność, wiarygodność, ciągłość I dostępność. Niedoskonałości systemu zostały przedstawione w odniesieniu do poprawy bezpieczeństwa transport powietrznego w najdelikatniejszej fazie lotu − podejścia do lądowania.

Powyższa procedura z wykorzystaniem system wspomagającego otwiera szansę rozwoju małym i średnim portom lotniczym w Europie Zachodniej uniezależniając podejście do lądowania od infrastruktury lotniskowej.

Podejście instrumentalne APV składa się z czterech faz lotu: Podejście Początkowe, Podejścia Pośredniego, Podejścia Końcowego, Odlotu po Nieudanym Podejściu. System wspomagania satelitarnego, jako pierwszy wspomóc może także fazę Podejścia Końcowego, która jest najniebezpieczniejszą, najważniejszą fazą opartą na urządzeniach pokładowych w większości bez widoczności terenu. EGNOS wspomaga działanie GPS poprawiając niezbędne czynniki: dokładność, wiarygodności, dostępności, ciągłości przewidzianych w procedurach APV. Podejście oparte o EGNOS jest jedyną, niedrogą szansą dla małych i średnich polskich portów lotniczych, na rozwój w sektorze transportu powietrznego w nawiązaniu do rozszerzenia i poprawy czynników wyżej wymienionych.

Słowa kluczowe: EGNOS, Satelitarne Systemy Wspomagające, Podejście z Prowadzeniem Pionowym, SiS.