SBAS APPROACH AND ITS COMPARISON WITH OTHER TYPES OF APPROACH

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Summary: This paper discusses SBAS approach based on GNSS with aim to compare it with other systems. The first part addresses the basics of SBAS and approaches conducted using SBAS. The second part offers basic comparison of SBAS approach to APV Baro, ILS and GBAS.

Key words: SBAS, GBAS, ILS, approach, GNSS.

INTRODUCTION

One of the most significant aeronautical disciplines is undoubtedly navigation, which purpose is to determine the aircraft's position and guide it along its trajectory. Because of the fast expansion of air transport, conventional navigational means are becoming obsolete, unacceptable and it is necessary to replace them with new means. Development of these new means is lately focusing on the Global Navigation Satellite System (GNSS) with an effort to meet requirements of flight procedures. Because basic GNSS systems such as GPS are not satisfactorily accurate for the needs of navigation in critical phases of flight, they are augmented to reach required accuracy. Satellite based augmentation system (SBAS) is one of these augmentations.

Basic principle of Satellite navigation systems lies in receiving navigational messages from at least 4 visible satellites and on-board computing of so called pseudorange based on the measured time between when the message is sent and received. It is pseudo, because there are accuracy errors in the time measurement. These errors rule out the use of GPS (or GLONASS) without augmentation in critical phases of flight.

1. SBAS

SBAS is a system that contributes to improvement of the performance of GNSS systems. This performance is assessed according to four criteria: Accuracy, Integrity, Continuity and Availability (1), (2). SBAS provides real-time corrections for ephemeris, time and ionosphere errors. There are two major SBAS systems currently operational: Wide Area Augmentation System (WAAS) and European Geostationary Navigation Overlay Service (EGNOS). WAAS is a system developed by Federal Aviation Administration (FAA) in the

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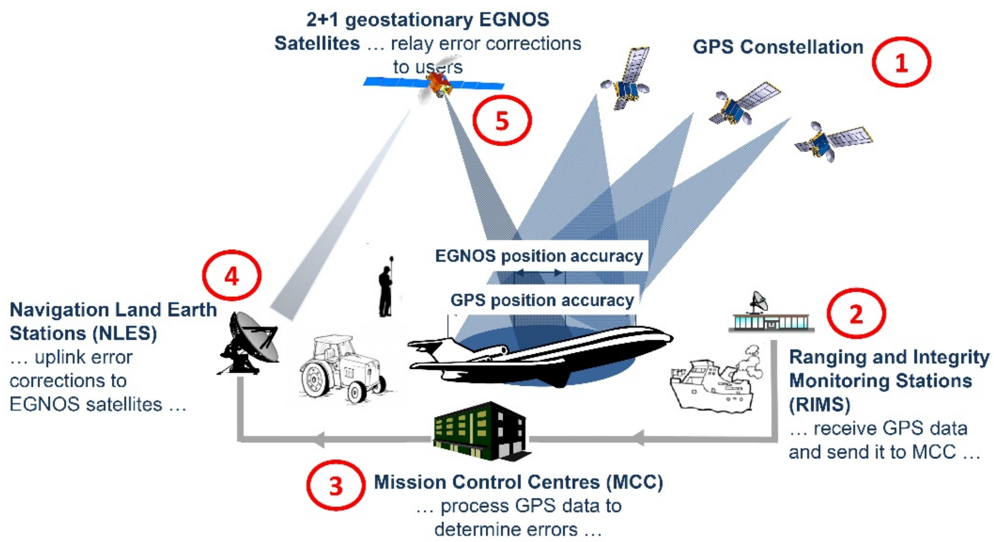
USA and put into service in 2003. It covers North America and is being expanded to cover Central and South America. EGNOS, as the name states, is European system developed by European Space Agency (ESA) and EUROCONTROL (3). It covers Europe and part of Northern Africa.

The SBAS infrastructure consists of wide area network of ground stations, geostationary satellites and a GNSS system (GPS). To provide more detailed description it is necessary to choose one particular system, in this case it will be EGNOS. Figure 1 shows the specifics of EGNOS infrastructure. The ground stations can be separated into 3 groups:

- Ranging Integrity Monitoring Stations (RIMS) – fixed ground stations with precisely known position which receive GPS data and send it further.
- Mission Control Centres (MCC) – these stations receive the data from RIMS and process it to determine errors.
- Navigation Land Earth Stations (NLES) – these stations send error corrections to EGNOS geostationary satellites.

There are 3 geostationary satellites, but only one is needed for proper functionality. However, two are always running. These satellites send the error corrections to users. Besides that, they also serve as GNSS satellites, because they sent their own navigational messages which can be read by the navigational units on board[5].



Source: https://www.thalesgroup.com/sites/default/files/asset/document/day_1_-_10.10_gsa_-_what_is_sbas_v0_7.pdf

Fig. 1 – EGNOS infrastructure

1.1 SBAS Avionics

There are several ways of integrating equipment that will support, receive and evaluate SBAS signal, into an aircraft. These can be:

[5] Although the article talks about EGNOS satellites, they are not made solely for that purpose. They are actually normal commercial satellites carrying a few instruments for EGNOS purposes as part of their load.

- Chipset – one or two parts installed on a board of existing GNSS receiver
- Auxiliary card (piggyback) or OEM (Original Equipment Manufacturer) – a separate board, that consists of all the necessary components. It has to be connected to the avionics motherboard.
- Stand-alone – a complete portable or fixed receiver. Commonly used in general aviation aircraft. (5)

Certification requirements for SBAS avionics are in RTCA (Radio Technical Commission for Aeronautics) DO 229D and in ICAO Annex 10 (L-10 in the Czech Republic). SBAS standards were created in a way, so that they would meet the performance requirements of civil aviation for approach a landing phases. Besides horizontal navigation, emphasis is also given to vertical guidance and information integrity. Receivers are divided by the RTCA DO 229D into 4 classes according to the phase of flight and a type of approach they are intended for (4). This is shown in Table 1.

Tab. 1 – Performance classes of SBAS avionics

Class	Phase of flight
I	en-route + approach + LNAV approach
II	class I + LNAV/VNAV approach
III	class II + LPV approach
IV	final approach only

Source: RTCA DO-229D

The standards also provide 3 levels of performance for approach: LPV, LNAV/VNAV and LNAV. The LPV approach can be conducted only by using receivers of class III and IV (7), (6). Table 2 shows the levels of SBAS approach performance.

Tab. 2 – Levels of SBAS approach performance

Labels of OCA/OCH minima	Description
LNAV	Non-precision approach
LNAV/VNAV	Approach with vertical guidance APV Baro
LPV	Approach with vertical guidance APV SBAS

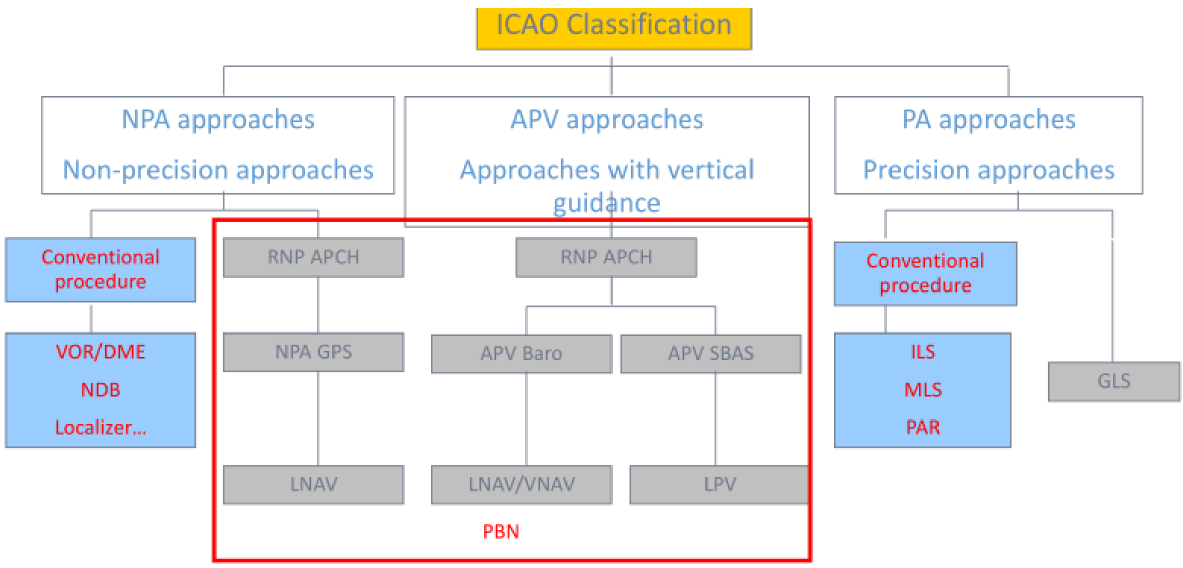
Source: ANS CR

Each of these approaches has defined a necessary level of integrity by horizontal and vertical alert limit (HAL and VAL) (8). These limits (or boarders) create an area of maximal error, that cannot be exceeded in order to comply with integrity requirements for given approach. The avionics is constantly predicting horizontal and vertical protection limits (HPL and VPL) and compares them with HAL and VAL in order to ensure integrity requirements are met. In case one of the protection limits exceeds its alert limit, a pilot is warned and instructed to discontinue current activities, that is to discontinue the current approach (9), (10).

There is an effort made by ICAO to ensure functionality of SBAS avionics in areas covered by any SBAS (WAAS, EGNOS…) and to provide continuous worldwide coverage.

2. COMPARISON OF SBAS APPROACH WITH OTHER TYPES OF APPROACHES

SBAS approach is part of the Performance Based Navigation (PBN), which, as the name suggests, is a navigation based on performance of the system (not on the specification of a sensor) and is defined by accuracy, integrity, availability a continuity (11). The following figure shows the ICAO classification of approaches with basic division into 3 groups: Non-precision approach (NPA), Approach procedures with vertical guidance (APV) and Precision Approach (PA).



Source: http://www2010.icao.int/WACAF/Documents/Meetings/2014/OPS-Approval/15%20October%202014/08%20-%20RNP%20APCH.pdf

Fig. 2 – ICAO classification of approaches

SBAS is used to conduct a LPV approach (Localizer performance with vertical guidance), which is fairly comparable to ILS (Instrument Landing System) CAT I approach in the means of accuracy (12), (26). Although the LPV approach has similar performance characteristics as ILS CAT I, it does not meet (with exception of LPV200) specific requirements for precision approaches and therefore cannot be put in that category. The LPV approach will be compared to APV BARO, ILS and GBAS approaches (13).

2.1 APV Baro vs. APV SBAS

APV approach in general is characterized by horizontal and vertical guidance and is defined in ICAO doc. 8168 as: “An instrument approach procedure which utilizes lateral and vertical guidance but does not meet the requirements established for precision approach and landing operations.” (10)

At the APV Baro approach, the glide path of barometric vertical navigation is generated by an on board computer based on information from barometric altimeter. Lateral guidance is based on GNSS or multisensory system (for example RNAV INS/GNSS) (14), (15). This type of vertical navigation has temperature limitations, which can be compensated for manually by crew or automatically (16). In general, with lower temperatures, the indicated height is higher than the real height; therefore there is a risk of collision with obstacle. Every airport has to publish a minimal temperature under which it is not allowed to use barometric vertical navigation without compensations.

The APV SBAS is an approach with geometric vertical guidance flown to the LPV Decision Altitude/Height (DA/H). The performance of lateral guidance is equivalent to ILS localizer. The whole procedure is stored in an aircraft’s avionics database. There is no need for temperature compensation. The consequence of these facts is reduction of obstacle clearance height/altitude and also reduction of DA/H compared to APV Baro. The GNSS SBAS avionics allows for various descent angles based on the approach procedure, provides timely alert of vertical performance and ensures navigation throughout the whole flight as primary navigational system. Undisputable advantage of SBAS is increased availability of regional airports for general aviation and most importantly increased safety for both airplanes and helicopters (14), (16).

2.2 ILS vs. APV SBAS

ILS is a ground system for precision approach. It provides precision lateral and vertical guidance to an aircraft using a combination of radio signals. It consists of two sets of antennas; one is called Localizer (LLZ) and is located at approximately 300 to 400 meters behind the runway end. The other one is a glide slope station which “creates” a glide path and is located about 300 meters behind the approach end of a runway and 120 meters to the side of centerline (24), (25). Other parts are markers to advice pilots on the distance from runway, which are being replaced by DME. There is also a monitoring system of the ground segment.

ILS approach is classified as precision approach. Both vertical and lateral guidance is provided from ground equipment installed at the airport. Pilots select given frequency of LLZ for a specific runway and the remaining frequencies are automatically picked up, if they are installed. This frequency pairing is an ICAO standard (18).

For the APV SBAS approach, the lateral and vertical positions are computed by on board equipment (GNSS sensors) from information not coming from the airport. Any of these sensors is a source of further errors (19). Despite that, an LPV 200 (200 feet decision height (DH)) approach reaches the same performance qualities as ILS CAT I approach, therefore meeting the requirements for ICAO Annex 10 for CAT I approach, but is not considered a precision approach. It can provide the same level of accuracy without the need to install expensive ground equipment. Furthermore, the LPV approach is designed as ILS look-like approach, which makes the visual projection on the cockpit instruments similar to the ones for ILS. Pilots can only tell the difference by seeing what kind of approach is selected on their Primary Flight Display (PFD).

The claims of similar performance of SBAS (using EGNOS) and ILS approach are based on a test conducted by Defence Evaluation and Research Agency (DERA). Measurements were conducted during several approaches using two geodetic stations (one on board of an aircraft, the other one at the airport) and the results compared to ILS. The data evaluation discovered that the position accuracy is less than +/- 1 meter and that it is comparable to the accuracy of ILS (18), (20).

2.3 Ground based augmentation system (GBAS) as an ILS successor vs. APV SBAS

GBAS is a GNSS approach system with the augmentation equipment located at the airport, therefore providing very accurate and precise correction and integrity data to the on board avionics. This fact allowed the GBAS approach to be classified as a precision approach CAT I. In future it is expected to be available from CAT II and III as well. This makes it the system of the future and should slowly start replacing ILS.

ILS has limitations that are becoming unacceptable for the growing aviation industry. One of them is the need to design ILS Sensitive and Critical Areas. These areas are to protect the approaching aircraft from ILS signal corruption caused by other objects or aircraft on taxiway close to runway. Other limitation is the need to install expensive equipment for every runway direction intended to be used for precision approach. GBAS, on the other hand, only requires installation of a few small antennas (receiving and distributing signal) and a ground station at the airport. The approaches are then programmed into aircrafts avionics database.

One can imagine GBAS as an SBAS, but with the correction data coming from ground segment instead of space segment (22). It receives navigation messages from GNSS satellites, calculates correction data for each satellite and then broadcasts this data to up to 20 nautical miles from the airport. GBAS and SBAS share disadvantages, too: required signal availability, sufficient monitoring, sufficient integrity and timely alerting to pilots (21), (23).

CONCLUSION

GNSS based approaches are slowly but surely getting more attention. SBAS approach already offers performance at the level of CAT I approach and might go even further. Its main advantage is no need for expensive equipment at every airport, therefore it is a very good alternative for smaller airports that cannot afford ILS, but would like to attract more customers. GBAS is now used as a CAT I precision approach with possibility to becoming certified for CAT II and III approaches. It might replace ILS as a main instrument for precision approaches.

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