

GBAS Testing – Practical Considerations

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1. ABSTRACT

The satellite navigation is part of the ICAO strategy for the future. ICAO and other bodies like RTCA and EUROCAE are already producing the SARP's and other necessary documents for smooth deployment of the satellite equipment into aircraft and on the ground. SBAS (WAAS) and GBAS (LAAS) are two concepts for augmentation of the GPS, GLONASS and GALILEO (when operationally accepted!).

The GBAS stations are installed (or there is intention to install them) in Spain (Malaga), Germany (Bremen and Frankfurt), France (Toulouse) and Switzerland (Zurich), Memphis (USA), Sidney (Australia) and they are already certified or doing some ground testing for certification. **Testing needs time, but certification without ground and flight inspection is not possible!**

Having in mind that the ICAO concept of the testing of NAVAID's equipment is still valid, my intention is to present some consideration about inspection of the satellite based navigation systems connected with new editions of the ICAO Doc 8071, Chapter 4 which is dedicated to the GBAS.

Please, have in mind that ICAO Doc 8071 is produced with common work of the few different entities (regulators, providers, manufacturers, users and flight inspection companies), which, sometimes have quite different understanding of the process, so this document is compromise between quite different considerations!

At the moment there is operational GBAS only in Australia (Sidney), so this is only (very) early considerations of the possible way how to conduct testing of the GBAS in accordance with Doc 8071.

These considerations are only my view, from my experience in Navigation and Flight Calibration. Intention of this paper is to present a proposal and provoke discussion about the future concepts of inspection of the GBAS equipment!

2. SPECIFIC NATURE OF THE GBAS TESTING

The GBAS ground subsystem receives satellite ranging signals and calculates ground-monitored differential corrections and integrity information for each satellite in view. A VHF data broadcast (VDB) transmitter broadcast these and other pertinent data such as approach path information to the air subsystem (FAS). The GBAS air subsystem encompasses the aircraft equipment used to receive and process the satellite ranging signals (GNSS receiver) and VDB receiver, to compute and output a differentially-corrected position solution, deviations relative to a desired reference path, distance information, and appropriate alert annunciations.

There is difference in conducting the testing of the traditional ground-based navigation aids and satellite navigation. Accuracy, availability, integrity and continuity of service in satellite navigation are depending of number of available satellites and DOP.

As it is mentioned in Doc 8071, Chapter 4,

“Unlike ground-based navigation aids, for which system accuracy is measured during flight testing activities, GBAS accuracy assessments must be accomplished on the ground, due to the variation of satellite geometry over time.”

and

“However, GNSS position error distributions change over time due to parameters such as the orbiting of satellites.”

The above-mentioned extracts from DOC 8071 are resulting in very important conclusion: **The testing of GBAS is not possible to be done in a short period of time. The reason is required accuracy has to be maintained in 95% of the time!** It means that the testing of accuracy of

the GBAS is mostly statistical and it is ground testing, because flying with the aircraft for several hours for flight testing of the equipment is not pragmatic solution! Also, it is mentioned in Doc 8071 that:

“The primary purpose of ground testing is to ensure that the GBAS ground subsystem meets the requirements of Annex 10 in terms of system performance and monitor operation.”

and

“Flight tests are used to confirm procedure design, final subsystem alignment, GNSS signal reception, and data link reception within the coverage volume.”

It means that also the philosophy of the testing is different than previous one. Flight testing could provide information about flyability of the procedures, pilot workload and safety. From the GBAS parameters only VDB Coverage (GBAS/H field strength and GBAS/E field strength) and Procedure Validation can be tested only with flight test. The 4 other parameters (Position Domain Accuracy (Functional Test), Broadcast SIS Integrity (GCID indication), Resistance to Interference (Ranging Signal) and Data Content are combination of flight and ground tests. All other parameters (around 21) are subject of ground testing.

So, if we would like to have reliable measurement, our test system shall be consisted from ground and air test equipment or (with other words) there is need to conducting ground and flight testing in the same time! **This is the core of my proposal: Do ground and do flight testing in the same time and compare results (later)!!!**

3. TESTING GBAS

Augmentation delivered by GBAS is included in VDB and this is primary subject of testing. Considering the functioning of the GBAS, there are two possible chances to have errors in overall GBAS system (ground and air subsystem):

- Error in distribution or calculation of the position from the signal gathered from the satellites by the ground subsystem; and
- Error in reception of the VDB transmission from the air subsystem (aircraft).

3.1 Error in distribution or calculation of the position from the signal gathered from the satellites by the ground subsystem

For this error is responsible sitting, problem with GNSS antenna or RSMU.

a) Sitting – Actually, possibility to have wrong WGS 84 coordinates of the receiver sites is not possible, because ICAO Doc 8186 (PANS OPS) foresee checking of the coordinates every 5 years for the navigational sites and every year checking for obstacles in the Designated Operational Coverage (DOC) area. Having in mind that choice of receiver sites is subject of considerable study and testing, there is also very low possibility to have wrong site. So, wrong sitting can not cause problems! But, the constellation of the satellites seen from the particular site is very important for the proper functioning of the system and this has impact on the location of the ground testing.

b) GNSS antenna – Antenna is receiving not only GNSS signal, but also the other signals. So, possible problems can be caused by interference. The Doc 8071 says:

“Typically, ground multipath effects and the ground receiver thermal noise drive the pseudorange correction errors.”

If there is problem in receiving satellite signals, there will be also problem in calculation.

c) RSMU (Remote Satellite Measurement Unit) – If something is wrong with calculation in the RSMU, monitors will detect the problem and they will react. Of course, this considers good adjustment of the monitors. RSMU does not contribute very much in the error budget!

Having in mind above-mentioned, the test system must be installed near the GBAS receivers on the site. Knowing that ground subsystem is containing 2 to 4 GNSS receivers the practical suggestion is: put the test system on the same site as one of them. The place of the test antenna must be determined to have minimum influence between antennae. And, the most important thing shall be the fact that this test system must stay on the site (and conduct measurements) particular period of time. This is due to fact that there are constant changes in the satellite constellation and the testing must satisfy requirement of 95% of the time for GNSS

parameters. Duration of this testing is most important question.

The Doc 8071 does not suggest how much time the measurement will last and this was matter of my investigation. The best practice is to have ground subsystem installed all the time on the GBAS site and conducted the measurement during the testing of the traditional navigational aids. It can be used for the comparison of the results gathered also from air subsystem. Maybe someone can find this not practical. Consulting the literature and Internet, I found the GNSS simulation which lasts 24 hours and was made by AERODATA (Braunschweig) during investigations of the new Position Reference System based on GPS in 1998-1999. The simulations were made using the SatNav Toolbox for Matlab software from GPSoft, Ohio. I recommend this time as minimum!

3.2 Error in receiving of the VDB transmission from the air subsystem (aircraft)

Responsibility for this error is VDB transmitter or reception of the broadcasted signal-in-space (SIS) in the aircraft. SIS error can be caused by interference, multi path, reflection, weak signal, etc.

a) VDB transmitter – Possibility to have problems in transmitter is very low, because the monitors will react immediately. It means that wrong distribution of the data is not caused by transmitter (usually!).

b) SIS – The possibility to have polluted SIS is very big and it comes from the interference from adjacent channels or other transmitters (FM broadcasting, for example) or from reflected signals from ground (snow on the mountains or metal objects near the VDB transmitters, for example). Transmitted VDB signals could be very weak (especially on the distances on the boundary of TMA), so, possibility to have interference is very common. They will affect SNR and it will be part of the error budget. Testing of the SIS quality and availability will provide information for position accuracy and the integrity of the GBAS service. This shall be done by flight testing. But, during the flight testing (as it is mentioned in Doc 8071), the accuracy is not measured! Only FAS data are checked! The flight testing must be done for coverage, procedures (RNAV and approach) and landing. During all these phases of flights the SIS must be clear to have possibility to satisfy ICAO SARP's.

Please, be careful: speaking about checking of flyability of procedures means that only availability of the proper SIS is checked along the flight pat of the procedure! It does not mean that procedure flown by Beechcraft Kingair can be flown also with Boeing 737 (due to different maneuverability of the aircrafts!)! So, checking the flyability of the procedure means checking of the accuracy of the procedure!

Also, satisfactory SNR must be achieved on the input of the aircraft VDB receiver. If there are problems in some areas (interference or low SNR), the reasons for such a signals need to be investigated! **Having the good SIS on the input of the receiver and having no decoding of the data, means that there is interference on the receiving antennae. But, only if the ground testing results are OK!**

There is considerable difference between the flight testing procedures of the traditional navigational aids and GBAS. For the first, coverage is normally a problem at a long distances and low altitudes relative to the site. For GBAS approaches, the problem is more likely to occur at the most critical stage of the procedure, namely at low altitude during the FAS. At low altitudes, the chance of masking of the VDB signal from the site and GNSS signals from the satellites is also very big.

The flight test can start before the test aircraft is airborne. In Doc 8071, Chapter 4, para 4.2.6 (Position Domain Accuracy Functional Test) is mentioned:

“To make the position measurement, place a GBAS receiver at a precisely-surveyed position free of significant multipath, and collect at least three independent samples at intervals of at least 200 seconds.”

Parking of the flight testing aircraft on the Threshold of the runway should be used as reference standard for the future measurement. The date gathered from this point can be very useful and they are actually first test of GBAS. At the same time the measurement of the minimum field strength should be done. This test can be done also with portable GBAS test receiver, but accuracy of the measurement could be affected. **Please, keep in mind that on during this measurement, the aircraft is not standing on the same position as true position of the Threshold! So, proper corrections are necessary!**

During the flight testing of the other ground based navigational aids, the flight testing of accuracy of the GBAS shall be conducted. The results of the GBAS flight testing shall be compared with the results from the ground GBAS testing for the corresponding time of flight testing. The possible non-compliance should be considered. Keep in mind that more satellites are available to the air subsystem than to the ground subsystem due to his height, the expectation to have better results in flight testing than in ground testing is normal.

3. CONCLUSION

The following conclusions may characterize my proposal for the GBAS inspection:

1. The philosophy of GBASinspection is quite different than philosophy of traditional NAVAIDS inspection!
2. The GBAS inspection is mostly ground testing! The ground test equipment shall be installed on the RSMU site at least 24 hours! **RECOMMENDATION: Leave the ground test equipment all the time during testing of other NAVAIDs and GBAS procedures!**
3. **Gather GBAS accuracy data during the flight testing dedicated to traditional NAVAIDS and GBAS procedures! This is mentioned in Doc 8071 only as option, but accuracy is most important thing for the safety. Integrity and CoS are connected with accuracy. If there is no accuracy – there is no safety! So, checking accuracy only on ground (which must be done due to statistical nature of the error!) and not checking it in the air (where we need it utmost!) is not serious!**
4. During the flight testing, accuracy data gathered from runway(s) Threshold(s) (before the FI aircraft is airborne!) can be used as basic standard for results of the flight testing!
5. **Good correlation between data gathered from ground and flight testing is subject of consideration! This is very important: Situation on the ground (RSMU sites) and on the air is quite different! Aircraft has always better availability of the satellites due to his height during the approach! So, corrections delivered from the VDB are not exactly what we need: they are corrections for the number of satellites available on the RSMU sites! Differences in results are expected, but what are the acceptable limits of these differences???**

LITERATURE:

1. ICAO DOC 8071, Chapter 4, Ground Based Augmentative system (GBAS)
2. ICAO ANNEX 10, Volume 1, Fourth Edition, 1996
3. EUROCAE ED 114, MOPS for Global Navigation Satellite GBAS Ground Equipment to support CAT I Operations, September 2003
4. 11th IFIS, Proceedings, Santiago, Chile, 2000
5. SLS 3000 Brochure, Honeywell, 2004

Abbreviation	Meaning
DOC	Designated Operational Coverage
DOP	Dilution Of Precision
FAS	Final Approach Segment
FM	Frequency Modulation
FI	Flight Inspection
GCID	GBAS Continuity Integrity Designator
GBAS/H	GBAS signal radiated with Horizontal polarization
GBAS/E	GBAS signal radiated with Elliptical polarization
RNAV	Area Navigation
RSMU	Remote Satellite Measurement Unit
SARP	Standard And Recommended Practices
SIS	Signal In Space
SNR	Signal to Noise Ratio
VHF	Very High Frequency
VDB	VHF Data Broadcast
WGS 84	World Geodetic System 84