INTERNATIONAL CIVIL AVIATION ORGANIZATION

AFI PLANNING AND IMPLEMENTATION REGIONAL GROUP
EIGHTEENTH MEETING (APIRG/18)
Kampala, Uganda (27 – 30 March 2012)

Agenda Item 3: Performance Framework for Regional Air Navigation Planning and Implementation

3.4 Communications, Navigation and Surveillance (CNS)

DEVELOPMENT OF A GNSS SATELLITE BASED AUGMENTATION SYSTEM FOR THE CAR/SAM REGIONS

(Presented by the Secretariat)

SUMMARY
The SACCSA Project (RLA/03/902) – is studying an SBAS system suitable to the CAR / SAM Regions situated in equatorial regions. This system is planned to be equivalent to WAAS and EGNOS systems. Action by the meeting is at paragraph 3.
REFRENCE(S): • 11th Air Navigation Conference (2003), Report • APIRG Meetings Reports (2003, 2005, 2007, 2010) • ICAO RLA/03/902 Project Document
Related ICAO Strategic Objective(s): C

1. INTRODUCTION

1.1 In 2003, in order to analyze the implementation of an SBAS system in the CAR/SAM Regions, an ICAO technical cooperation project (RLA/03/902) was initiated to study and define the SBAS taking into consideration the ionospheric effects in the equatorial regions. This paper summarizes the Project scope, its objectives and the results obtained up to now.

2. DISCUSSION

Background

2.1 One of the major challenges of the aviation community in CAR/SAM regions is the implementation of the Performance Based Navigation (PBN) concept. GNSS technologies play an important role to achieve this objective. The particularities of the CAR/SAM regions, as for example the behavior of the ionosphere, impose limitations on the performances of these types of technologies in comparison with other regions of the world. SACCSA project objective is to study the improvement of the air navigation environment in the Caribbean and South America (CAR/SAM) Regions with an SBAS solution.

2.2 The use of GNSS for safety critical applications requires augmentation systems to complement core GNSS signals in terms of availability, integrity, accuracy and continuity, mainly in non-medium-latitude regions or equatorial regions such as AFI, ASIA/PAC, CAR/SAM and MID regions.

2.3 ICAO has standardized three augmentation systems: ABAS, GBAS and SBAS. Currently, SBAS systems such as WAAS, EGNOS and MSAS are operational; while other SBAS systems are currently under development (such as SDCM in Russia and GAGAN in India) or under study such as SACCSA project in Latin-America.

2.4 During its review of GNSS vulnerabilities, the 11th Air Navigation Conference (AN-Conf/11) had noted a number of concerns raised in regard to the ionospheric effects in equatorial regions, and several States reported that they had established data collection programmes. AN-Conf/11 therefore recommended that ICAO assess the results of such studies and provide appropriated guidance to States (Recommendation 6/3 refers).

SACCSA Project

2.5 The project is an ICAO technical assistance project (RLA/03/902) whose main objective is to conduct technical feasibility studies aimed at improving air navigation operations in CAR/SAM regions through the implementation of an SBAS solution, taking due account of system performance criteria and safety considerations.

SACCSA Phase I

2.6 Initially called EDISA (EGNOS Demonstrations In South America), the project began in 2003 with a series of tests and demonstrations based on the extension of the European system to the CAR/SAM region. Further studies based on the extension of the WAAS to South America (RLA/00/009 project) concluded that the extension of EGNOS and WAAS to CAR/SAM was not feasible (GREPECAS conclusion 13/84), mainly due to the particular characteristics of CAR/SAM regions.

SACCSA Phase II

2.7 This lead to a new approach under Phase II of the Project RLA/03/902 (SACCSAII), whereby SACCSA was defined as stand-alone system interoperable with other SBAS systems. The objective of SACCSAII was to: "develop and plan the technical, financial, operational and institutional aspects of an SBAS system for the CAR/SAM regions" as identified in the ATM/CNS Sub-Group meeting, held in Rio de Janeiro, Brazil, March 2004.

2.8 The outcome of the project appeared to be quite positive and promising, and provided the basis for the resolution of some problems inherent to the system´s definition, such as the ionosphere's behavior in equatorial regions.

SACCSA Phase III

2.9 Due to the special conditions in the CAR/SAM regions, the high cost of SBAS system and the difficulties linked to the system´s development, it was decided to launch a third phase of the project to complete the previous studies. SACCSA third phase is currently running and it is expected to finish during 2012.

2.10 Phase III of RLA/03/902 – SACCSA Project will conclude the studies started in Phase II and determine the technical and financial feasibility of a stand-alone SBAS in CAR/SAM regions, including a central processing facility prototype and system validation and certification processes. This will enable GREPECAS and CAR/SAM States and International Organizations to make an informed decision with respect to SBAS development and implementation.

2.11 The SACCSAIII activities started in February 2010 and the duration of the project is 24 months. The SBAS signal in test mode was broadcast from 14 to 15 October 2010 for the first time over the CAR/SAM region during the Seventh Meeting of the Project Coordination Committee (RCC/7). Appendix to this paper provides detailed information on SACCSA trials.

3. ACTION BY THE MEETING

3.1 The meeting is invited to:

a) Note the information provided in this paper on CAR/SAM experience; and

b) Request APIRG, through its relevant auxiliary bodies and the SAT Informal Group, to monitor SBAS developments in other ICAO regions in the equatorial band exposed to GNSS vulnerabilities such as CAR/SAM regions, for consideration as appropriate when developing/updating its strategy for a cost-effective implementation of GNSS in the AFI Region.

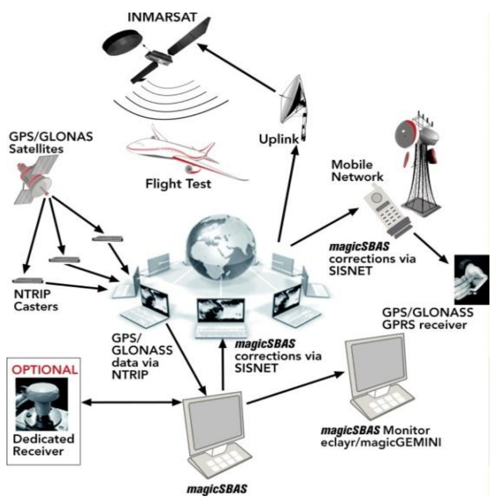
Appendix

SBAS DEMONSTRATION:

FIRST SACCSA TEST SIGNAL BROADCAST IN CAR/SAM

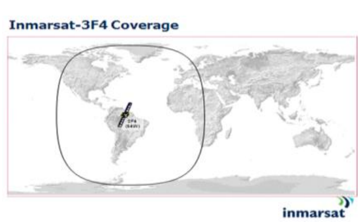
The demonstration of an SBAS test signal was presented to participants at the RCC/7 Meeting of the following States and International Organization: Argentina, Bolivia, Brazil, Colombia, Costa Rica, Guatemala, Panama, Spain, Venezuela, COCESNA, IFALPA and ICAO. The success of the demonstration was possible thanks to the collaboration between GMV and Inmarsat, which involved integrating their different technologies. GMV provided its new SBAS processing center, *magicSBAS* which accepts real-time data from any place in the world; while Inmarsat provided the Ground Uplink Station located in Fucino (Italy) and the space capacity – the navigation transponder on the Inmarsat-3F4 positioned over the Americas continent.

The purpose of the transmission was to complete the integration of *magicSBAS* with Inmarsat GEO payloads and to show that the performance of SBAS-SACCSA test signals is affordable with minimum infrastructure investments. The presented technology represents a fundamental asset for those entities considering the deployment of a SBAS in any region.



magicSBAS web page: http://www.gmv.com/en/space/magicSBAS/index.html

Inmarsat provided the space capacity for the demonstration. The navigation transponder on the Inmarsat-3F4 positioned over the Americas continent was used allowing broadcasting the SBAS messages (SARPS compliant) over the Latin-American region. Next figure shows the location of 3F4 Inmarsat GEO satellite used for the demonstration (Longitude 54ºW) and the Inmarsat communication station located in Fucino (Italy) and used for the uplink of the SBAS signal for the demonstration.



Obtained Performances

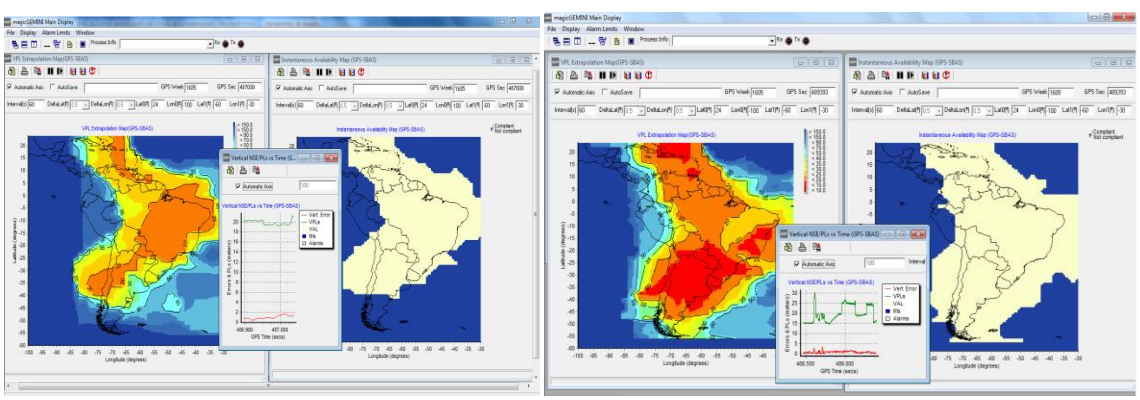
For the demonstration, a user receiver (GPS map 276C Garmin) was used to show in-situ the reception of the SBAS GEO test signal broadcast by the Inmarsat 3F4 satellite PRN 122. As commented previously, magicSBAS was used as the SBAS processing facility for the demonstration.

The GPS receiver was configured to process test SBAS signal (enabling Message type 0 receptions) and PRN 122 (Inmarsat GEO satellite, index 35 in Garmin receivers) was selected.

The GEO test signal was properly received in-situ by the Garmin receiver. For doing this, the participants in the meeting went up to the terrace roof of the building to check in-situ the signal reception. It could be seen that all the GPS satellites in view were monitored by the SBAS test signal broadcast by PRN 122 GEO satellite.

Note: PRN 122 corresponds to Satellite Garmin internal index 35, as it can be seen in the previous figure.

Detailed performances were analysed by using *magicGEMINI* tool connected through the Internet in real time to a NTRIP station and processing GPS data and SBAS messages provided by *magicSBAS*. The following figures present the worst and the best case real-time obtained performances during the demonstration in terms of APV-I availability (VAL=50m).

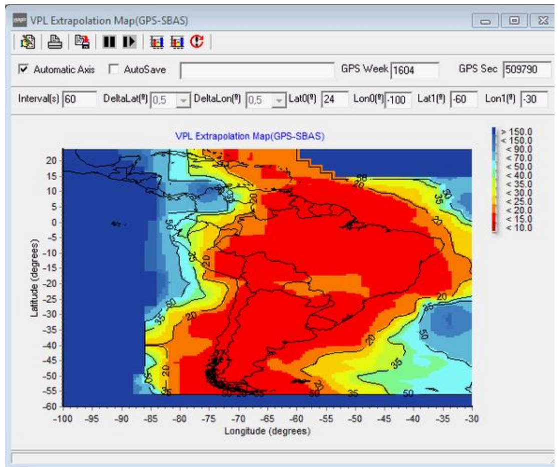


In both cases the test signal navigation performances are provided as measured from a receiver in Brazil:

- on the left, the APV-I availability measured as the probability of having a vertical and horizontal protection level greater than the vertical and horizontal alarm limit respectively (VAL=40m and HAL=50m)
- on the right hand of the figure the region where APV-I requirements are met is shown (in terms of availability), and

- in the middle the vertical protection level is compared with the vertical error to analyze the integrity.

Next figure shows the vertical protection level obtained with *magicGEMINI* tool, in the region in this case at 18:40 LT (Local Time)



SACCSA PRESENT AND FUTURE

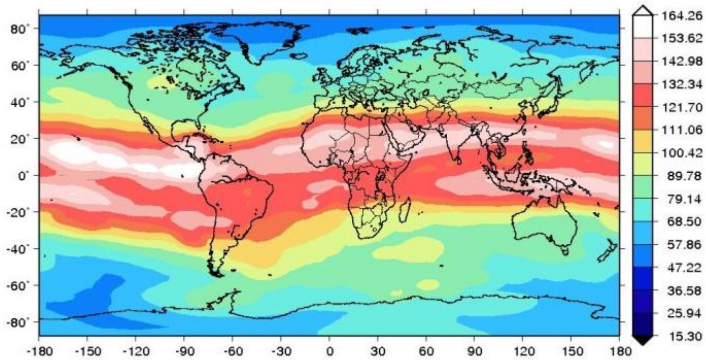
With respect to SACCSA project, the technical studies in SACCSAIII are now being finalized with very promising results. The project outcomes will be presented in the next Coordination Meeting (RCC 08), to be organized in the coming months.

From the technical analysis performed so far it is clear that the main critical problem for the SBAS feasibility is the behavior of the ionosphere in equatorial regions. The ionosphere imposes important limitations to GNSS. A great effort has been devoted to deeply study the problematic of GNSS on the equatorial region and to particularize the results to SBAS systems. From a general point of view, the main strategy was first to analyze the problematic, understand the current situation of the CAR/SAM regions, their needs, the environment (not only from a technical point of view), and then to identify potential solutions that could provide valuable benefits. The solutions were proposed with an innovative and open-minded vision and seeing the problem from a different perspective that the one applied in other SBAS systems in the world, in other words from a user-oriented perspective

Next figure, obtained in SACCSA project, represents the worldwide maximum ionosphere values (in TECUs) for the previous solar cycle (3 days per month during 12 years). It is a good figure to understand easily the problematic and to map it to a specific region. As a general conclusion and from a qualitative point of view:

- Regions marked in white and red are clear equatorial ionospheric regions. GNSS systems (SBAS and GBAS) designed for medium latitudes will have important limitations. Adaptation to the ionosphere in equatorial regions is mandatory and technical feasibility will depend on that adaptation.
- Regions labeled in orange and yellow could have problems in high solar activity periods for GNSS systems (SBAS and GBAS)
- Regions marked in green and blue are considered medium latitudes regions and it is not expected to have limitations in GNSS systems (SBAS and GBAS) related to the ionosphere (except for iono *storms).*

Note: Additionally, polar regions would be affected by scintillations and other local ionospheric effects.



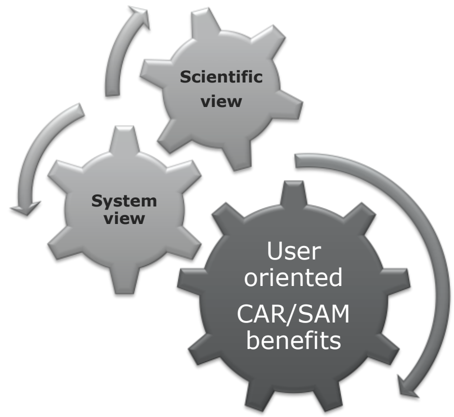
As it can be seen CAR/SAM regions are almost completely included in the iono equatorial region. The same occurs in India GAGAN SBAS program.

The strategy followed in the analysis is the following:

- First to study the ionosphere behavior of the main effects that affect GNSS (and in particular SBAS systems) from a scientific point of view. For doing this, regional real data were analyzed during an entire solar cycle (more than 10 years of data) and statistics were computed mainly to characterize the equatorial anomaly (temporal and spatial), depletions and scintillations, as well as the mapping to MOPS standards.
- Once the iono was statistically characterized we analyzed the impact on SBAS systems. For doing this we used a simulation platform fed with ionospheric scenarios based on real ionospheric data characterized according to nominal ionospheric case and a worst-case ionospheric case (based on the previous iono solar cycle). With these data the *magicSBAS* was run for both scenarios and the performances obtained were analyzed. It is important to clarify that it was necessary to adapt the ionospheric algorithms to the region because with medium latitude SBAS iono algorithms the technical requirements (objective APV-I) were not met.
- Additionally, an extrapolation of the results at system and user level was performed in order to analyze the technical feasibility of a SBAS solution, taking into account all the analyses performed.

Once the technical limitations were analyzed a great effort was devoted to understand the situation on CAR/SAM regions and their needs. Different solutions, from a user oriented perspective, are proposed to improve the air navigation and obtain the major benefits in the CAR/SAM Regions. These proposed solutions are identified for the areas with limited performances as a contingency element for high solar activity periods.

More information will be available after RCC SACCSA meeting where all the project results will be presented to the SACCSA member states.



One of the critical aspects in relation with the technical feasibility is the effect of ionospheric depletions and the capacity of the system to observe and detect them. The analyses performed in SACCSA indicate that the use of an additional constellation (for example GLONASS) can largely improve the ionospheric observability/detection capability. Additionally, it was found that the equatorial anomaly itself imposes severe limitations (APV-I requirements were not met) in high solar activity scenarios to current SBAS systems that were designed for medium latitudes (as it is the case of EGNOS). This limitation mainly disappears after the re-engineering performed in the iono algorithms prototyped in *magicSBAS* for SACCSA. As a general conclusion, SBAS feasibility highly depends on the algorithms adaptation and also in considering multi-constellation at system level (for iono algorithms only).

During the project it has been also found that a dual-frequency SBAS solution could improve the situation with respect to the previous mentioned effects. Hence, the study will recommend that SACCSA is defined with a view to be easily upgradable to dual-frequency solution. Dual-frequency full capability (satellite, avionics, user level) is expected around 2025-2030.

Ionospheric scintillations also impose limitations both for a single-frequency and a dual-frequency solution, and the critical point is the one related to the GEO satellite. The studies recommend having a redundant GEO constellations designed to minimize the effect of the scintillations.

A preliminary roadmap for SACCSA has been also defined. From a short-medium term perspective the study recommends to have a single-frequency SBAS solution to start obtaining benefits. From a long term perspective, a dual-frequency SBAS solution is recommended with single-frequency as backup.

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