ORGANIZACIÓN DE AVIACIÓN CIVIL INTERNACIONAL

Proyecto RLA/03/902 –"*Transición al GNSS en las Regiones CAR/SAM – SACCSA*"
Séptima Reunión del Comité de Coordinación (RCC/7)
(San Carlos de Bariloche, Argentina, 11 al 15 de octubre de 2010)

Cuestión 8 del Orden del día: **Posturas del Proyecto sobre reuniones del mecanismo del GREPECAS y Organizaciones Internacionales para el progreso del GNSS**

PRESENTACIÓN DEL PROYECTO SACCSA EN LA CONFERENCIA ION GNSS 2010

(Nota presentada por la Secretaría)

RESUMEN

Esta nota informa sobre la presentación del Proyecto SACCSA que GMV mostrado en la Conferencia ION GNSS 2010.

1. INTRODUCCIÓN

1.1 El Instituto de Navegación (ION – Institute of Navigation) es una sociedad mundial sin fines de lucro dedicada al fomento de las artes y ciencias de posicionamiento, navegación y tiempo. Fundada en 1945, que proporciona servicios a diversas comunidades incluyendo aquellas interesadas en el aire, espacio, marina, navegación terrestre y determinación de la posición. Su membresía es mundial y está afiliada con la Asociación Internacional de Institutos de Navegación.

1.2 Entre otros eventos, ION realiza anualmente una conferencia sobre el GNSS; la Conferencia ION GNSS 2010, se realizó en Portland, Oregón, Estados Unidos, desde el 21 al 24 de septiembre de 2010.

2. PRESENTACIÓN DEL PROYECTO SACCSA EN LA CONFERENCIA ION GNSS 2010

2.1 Basado en la autorización dada por la OACI, GMV presentó una nota sobre el Proyecto RLA/03/902 – SACCSA en la Conferencia ION GNSS 2010. Una copia de la nota referida se presenta en el **Apéndice** de esta nota informativa.

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SACCSA - SBAS in the CAR/SAM Regions: Feasibility Analysis

Authors: A. Cezón, M. Cueto, I. Hidalgo. *GMV, Tres Cantos,* L. Andrada. *AENA, Spain*

BIOGRAPHIES

Ana Cezon has a M.Sc. in Physics. She is working at GMV (Spain) in the GNSS Navigation Area, where she started her career in 1999. She has worked on ESTB, EGNOS and Galileo programs, CELESTE, SACCSA and GNSS evolution programs projects (MRS, GSC, etc). She is currently working as the person responsible for area and project management.

Marta Cueto holds a Ph.D. in Physics at the Universidad Complutense de Madrid (UCM). She joined GMV in 2005, and since then has workeds on ionospheric activities within GMV´s GNSS business unit.

Irene Hidalgo holds a Ph.D. in Physics at the Universidad Autonoma de Madrid (UAM). She works in Orbit Determination & Time Synchronization and ionospheric activities within the GNSS business unit of GMV.

Luis Andrada-Márquez is Aeronautical Technical Expert in NAV-AIDS, and Fly Engineer. Currently he is Head of the GNSS Operations Department within the GNSS Division of AENA.

ABSTRACT

SACCSA project Phase III's (Solución de Aumentación para Caribe, Centro y Sudamérica) objective is to study the improvement of the Air Navigation Environment in the Caribbean and South America (CAR/SAM) Regions with a SBAS solution. The project is managed and internationally coordinated by ICAO (International Civil Aviation Organization) on behalf of the Participants/Member States and International Organizations that are the founders of the SACCSA Project. Phase III of the project has recently started with GMV as Prime Contractor.

The main objective of this phase of the project is to perform a detailed technical feasibility analysis of the SBAS solution. For doing this, two main guidelines will be followed: on one hand a detailed study will be done to cover aspects like performances, ionosphere, communications, network topology, and on the other hand a SBAS prototype will be developed and operated aimed at complementing the analysis.

This paper describes the SACCSA project phase III, and the obtained performance analysis is also shown.

At equatorial latitudes, the ionospheric activity can become a significant problem on GNSS, and a critical and complete analysis will be performed focused on the impact of this atmospheric effect on SBAS systems. GPS real data will be analysed completing the study performed in the previous phase of the project, and the main preliminary results are presented in this paper.

Additionally, SACCSA performances will be analyzed through simulated data tuned with real ionospheric data in the CAR/SAM Regions to obtain the expected performance of the SACCSA system in a controlled, complete and realistic environment. Ionospheric data (simulated data based on real data) will feed the EETES Simulator (End to End Egnos Simulator) to obtain a set of RINEX data for different scenarios that will be the input for SACCSA UCP prototype (Unidad Central de Proceso) that is the computational heart of a SBAS System. SACCSA prototype will be based on magicSBAS, a Flexible GMV proprietary product that includes the algorithmic SBAS and Ionosphere experience of GMV. Main available results will be presented in the paper.

magicSBAS product will also be used as the core product for a SACCSA prototype (with real data) that will be operated in the region over 6 months.

INTRODUCTION

A SBAS (Satellite Based Augmentation System) is in charge of augmenting the navigation information provided by different satellite constellations (such as GPS or GLONASS and in the future Galileo) by providing ranging, integrity and correction information via geo-stationary satellites.

The current map of satellite navigation systems includes global systems without integrity service (GPS and GLONASS), regional systems with integrity service (WAAS, EGNOS, MSAS), and future navigation systems providing integrity with global coverage (Galileo).

Other SBAS systems are currently under development (as for example SDCM in Russia and GAGAN in India) or under study as is the case of SACCSA program in Caribbean, Central America and South-America.

Next figure shows the distribution of SBAS programs in the world:

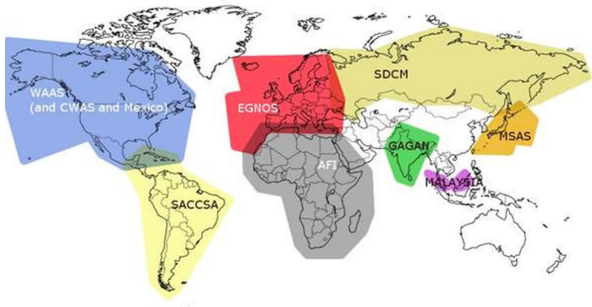

Figure 1 SBAS in the World

The paper describes SACCSA program and shows the preliminary results obtained within the project.

The paper is structured as follows: First, a description of SACCSA program is presented. Second, technical performance analysis will be presented along with the methodology used. Performance analysis is presented both for simulated and real data. Additionally, a high level view of the SACCSA prototype is also presented. Lastly, main conclusions at the light of the presented results will be provided.

SACCSA PROGRAM DESCRIPTION

SACCSA program (Solución de Aumentación para Caribe, Centro y Sudamérica) objective is to study the improvement of the Air Navigation Environment in the Caribbean and South America (CAR/SAM) Regions with a SBAS solution.

The project is an ICAO RLA one (RLA/03/902) founded by the Participants/Member States of the SACCSA Project: Argentina, Bolivia, Colombia, Costa Rica, Guatemala, Panama, Spain, Venezuela and COCESNA (Corporación Centroamerica de Servicios de Navegación Aérea).

In order to understand the current phase of SACCSA program and to have a complete view, it is important to know the previous phases of the SACCSA project and to clearly identify the context of the Project within CAR/SAM regions and within the related activities that are implemented in the region.

ICAO RLA/03/902 (SACCSA) Project emerges from the result of the negotiation process held during the last years, in which the potential alternatives and trials that lead to the implantation of an own SBAS system in the ICAO CAR/SAM Regions were reviewed.

The program began in the year 2003 with some preliminary analysis, studies and trials over the regions of the Caribbean, Central America and South America (CAR/SAM).
In 2005, as part of the RLA/03/902, as by Project RLA/00/009 (SBAS Regional Trials in South America), it was concluded that neither the European system EGNOS nor American WAAS could feasibly be extended towards the regions of the Caribbean, Central and South America (GREPECAS conclusion 13/84), mainly due to the CAR/SAM regions' particular characteristics. This imposes differential elements to be considered in a different way than in other regions.

From this point in the SACCSA program, SACCSA was defined as an own system, independent of other neighbor SBAS systems but interoperable with them.

The objective of the second phase of the Project RLA/03/902 (SACCSAII) was to: "develop and plan the technical, financial, operational and institutional aspects of a SBAS system for the CAR/SAM regions as identified in the ATM/CNS/SG meeting, held in Rio de Janeiro, Brazil, March 2004.

The problem of the region was already analyzed in the second phase of the Project (SACCSA II), identifying several topics that were considered critical to ensure the feasibility of a SBAS solution in the CAR/SAM regions.

Results of the analyses developed during the second phase of the project were quite positive and promising, and make it possible to settle the basis to solve some of the problems inherent to the system´s definition, such as the ionospheric behavior in equatorial regions.

Due to the special conditions in the CAR/SAM regions, the high cost of the 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.

Phase III of RLA/03/902 – SACCSA Project, will conclude the studies started in Phase II and will determine the feasibility of implementation of an own SBAS in CAR/SAM regions, confirming the technical – financial viability of the SACCSA Project. This will make possible a solid base for the analysis by GREPECAS (Grupo Regional de Planificación y Ejecución Caribe y Sudamérica (CAR/SAM)) and a future decision of developing a SBAS solution in CAR/SAM regions for satisfying the needs of the users and the States, Territories and International Organizations.

Due the SACCSA Project – Phase III complexity and the cost of the tasks to contract the ICAO Technical Co-operation Bureau (TCB) in compliance with its procedures, in August 2009 ICAO invited specialized companies to participate in the tender process for the best proposal for the execution of the Phase III tasks.

In this tender process the bid of the Consortium formed by GMV as Prime Contractor and by INDRA, SENASA, Raytheon, GESA-La Plata and CENAT was selected. In order to deal with the RLA/03/902 Project Phase III, a work group has been created under ICAO management and International coordination, with AENA as technical coordinator for the implementation of the technical activities.

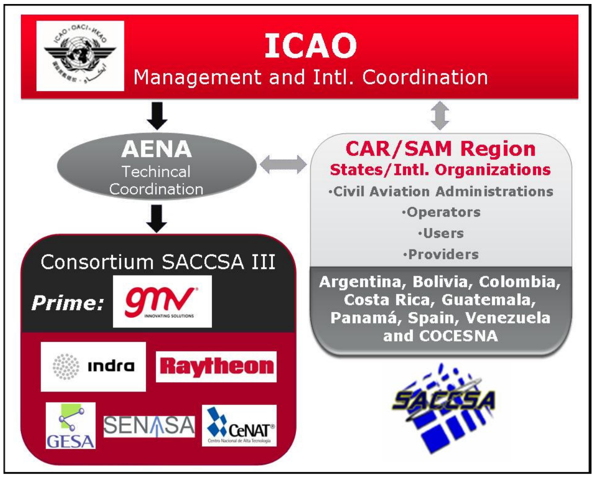

Figure 2 SACCSA Structure

In order to fulfill with SACCSAIII objectives, the strategy proposed allows tacking the problem through 2 main activities plus a set of complementary tasks.

Main activities contribute to have a complete and global vision of the proposed solution in the region. The following main activities will be done:

- ➢ Study analysis completing the results obtained from the previous phase as part of the feasibility technical analysis.
- ➢ Complete the technical feasibility analysis with a UCP SACCSA Prototype (Unit Central Processing). This prototype will be based on GMV magicSBAS demonstrator and adapted to CAR/SAM Regions, taking special care on ionospheric aspects. magicSBAS will be fed by reference stations as part of the monitoring network. magicSBAS has been used with excellent results in different regions in the world and preliminary results in CAR/SAM regions presented in this paper.

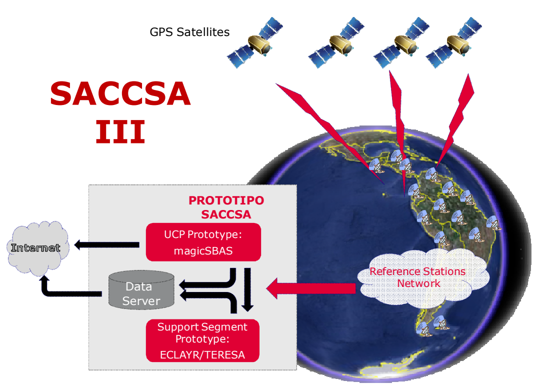

Figure 3 SACCSA prototype

Additionally, different complementary activities will be done to adapt the proposed solution to the region's needs.

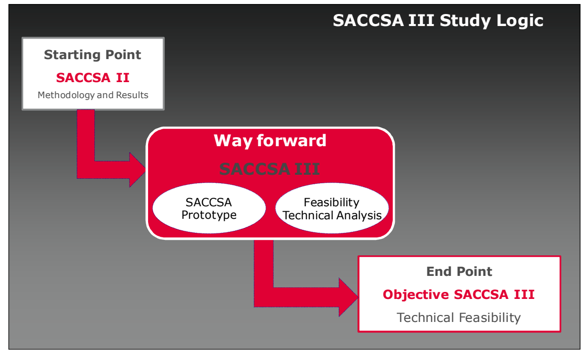

Figure 4 SACCSA Study Logic

As part of the activities to be done in SACCSAIII project the following tasks are highlighted:

- Monitoring Network and its control
- Complete Phase II studies, concluding subjects such as the ionosphere, communications, ground network topology of reference earth stations, complete system definition, performance analysis, requirements verifications
- SACCSA UCP (Central Processing Facility) prototype and its operation
- Definition of supporting activities to system validation/certification process
- Analysis of complementary options in poor or limited performance areas
- SACCSA Web site

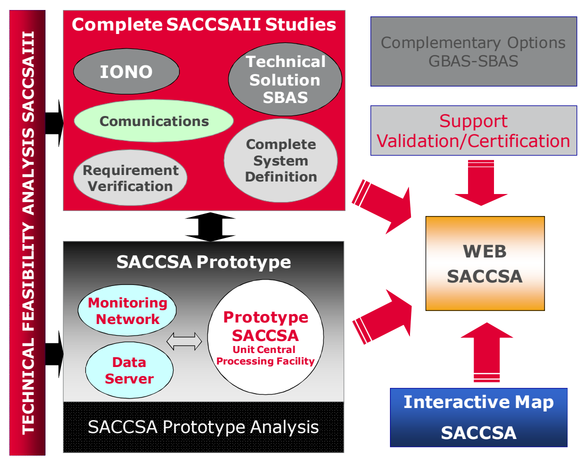

Figure 5 SACCSA III tasks

SACCSAIII activities started in February 2010 and the duration of this phase is 24 months.

The Seventh Coordination Committee Meeting (RCC/7) of the SACCSA Project (first for this phase of the project) will take place in Bariloche, Argentina, 11 – 15 October 2010, which will deal with important issues concerning the status and the preliminary results of the Project.

This paper includes some of the results obtained within SACCSA project, including performance analysis, both with simulated and real data.

SACCSA RESULTS

The development and deployment of a SBAS system in any region of the World is in general a serious challenge from a technological and algorithmic point of view. Moreover, in the CAR/SAM regions there is a set of additional technical aspects or conditions that complicates it even more than in other regions, as for instance the ionospheric conditions and the corresponding standards applicability.

During the previous phase of the project (SACCSAII), a set of technical topics were identified and a set of solutions were proposed. Additionally a preliminary system architecture was proposed. It is important to point out that this architecture can be subject to modifications as part of SACCSAIII results.

Three different segments are identified as part of SACCSA:

- **Space Segment**, composed by SBAS geostationary Satellites;
- **User Segment**, composed by the user´s SBAS receivers, and
- **Ground Segment**, that is split in the following components:
  - *ERS* (Estaciones de Referencia de SACCSA): Reference Stations which receive the data from the navigation satellites.
  - *CPCS* (Centros de Proceso y Control SACCSA): SACCSA Processing and Control Centers that will be in charge of controlling the processes. Based on data collected from ERS, they compute integrity, corrections and ranging data which form SBAS signal-in-space (SIS) according to the specifications.
  - *EAS* (Estaciones de Acceso al Satélite): Satellite Uplink Stations that will be in charge of broadcasting computed information to the final users
  - And finally, the *Support and Analysis Centre*.

Next sections present the results obtained in the previous phase of the project as part of the SACCSA performance evaluation. Please, note that SACCSAIII results are not currently available for publication.

SACCSA PERFORMANCES EVALUATION

Methodology

Before entering in the details of the SACCSA project´s results, it is important to identify the methodology or strategy used in the analysis.

Augmentation system performances are defined with respect to the service level provided. Most of the analyses to characterize system performances are provided at user level, where the main concepts can be measured in a simplified way in the following terms:

1. *Availability*: sufficient information is broadcast by the system to compute a valid navigation solution and the horizontal/vertical protection levels (HPL and VPL, respectively) do not exceed the horizontal and vertical alarm limits (HAL and VAL, respectively) for the corresponding service level.
2. *Accuracy*: difference between estimated and real user position.
3. *Continuity*: service level declared available for the whole operation.
4. *Integrity*: navigation error not exceeding the alarm limits.

It is important to mention that the main performance indicator is the availability map (the larger availability, the better result) provided that the integrity of the system is maintained (accuracy is generally met).

Different analysis has been done in the project depending on the source of data available. In particular, three different types of approximations have been selected:

a) On one hand, Service Volume simulations (***polaris*** GMV´s tool [10]) are done to estimate from a high-level point of view the expected performances of SACCSA system. In particular SACCSA network topology (reference stations) were initially selected from these analysis.

b) On the other hand, End-to-End simulations are used to evaluate the expected performances in different representative scenarios and with realistic measurement models (dynamics, clocks, ionosphere). In this case GMV´s EETES simulator is used and adapted to the SACCSA system.

c) Additionally, analyses with real data using SACCSA prototype are foreseen as part of SACCSAIII.

In order to define the representative scenarios and also to complete the SACCSA analysis, a specific analysis of the ionospheric behaviour in the region focusing on the impact of the ionosphere on SBAS equatorial systems is also performed, as the ionosphere is considered one of the key-points for the feasibility of a SBAS in equatorial regions. Preliminary results of ionospheric analysis in CAR/SAM were presented in ION 2007 meeting (see [2] for reference).

Next sections present the preliminary results obtained within the project with respect to Simulated and Real data (cases b and c respectively).

SACCSA performance analysis with simulated data

The strategy followed for the performance´s evaluation can be summarized as follows:

1. Define two representative scenarios for SACCSA: nominal and degraded cases;

2. Configure the EETES Simulation tool according to the previous scenario's definition and run a simulation;
3. EETES´s outputs are preprocessed and used as input of the UCP specially configured for the CAR/SAM regions, and;
4. UCP outputs are compared with real outputs (in our case EETES Simulator´s outputs).

Following the aforementioned process, the navigation´s performances are obtained using a tool developed by GMV to analyze the performances both at user and pseudorange levels. This tool is named ECLAYR [9].

The nominal and degraded scenario's definition is based on the ionospheric study done in SACCSA. This study is based on an analysis of more than 6 years of real data (corresponding to the region of interest) covering the last solar maximum. As part of this analysis a degraded scenario was defined.
The next plots show an example of the global ionospheric vTEC values from the IONEX files, both for the nominal and degraded conditions.

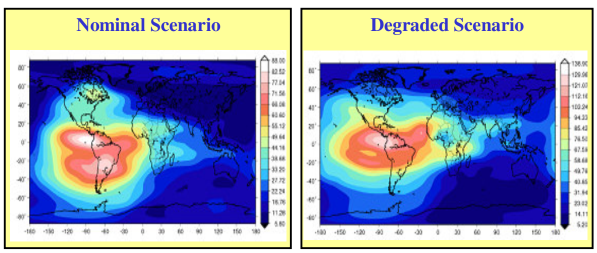

Figure 6 Input IONEX files for the EETES Simulator.

As part of the SACCSAIII activities that are currently under development, a set of ionospheric reference scenarios are being generated by La Plata University in Argentina (GESA Laboratory). Each of these scenarios will be used as input of the EETES´s simulator instead of the IONEX files previously used, to obtain a more realistic scenario of the CAR/SAM regions' conditions.

Performances for Nominal Scenario

The horizontal and vertical protection levels (HPL and VPL, respectively), as well as the horizontal and vertical position´s errors (HPE and VPE, respectively) at user´s level have been analyzed by means of GMV´s ECLAYR tool in the SACCSA Service Area.

The accuracy in the position is the difference between the real and the estimated user´s position, which corresponds in this case to the vertical position errors, i.e. VPE.

Next plots show the 95% percentiles of the vertical position´s errors, for the whole service area. These plots have been generated by ECLAYR tool.

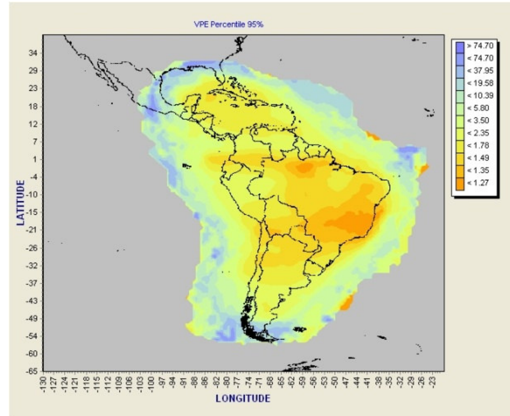

Figure 7 ECLAYR. User´s level accuracy: VPE 95% percentile.

Next plots show the horizontal 95% protection levels for the CAR/SAM regions.

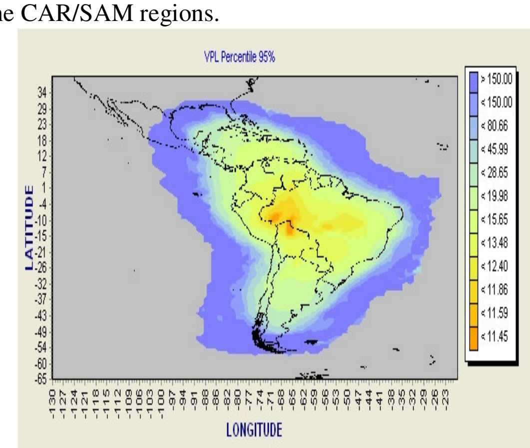

Figure 8 ECLAYR: VPL at 95%.

The availability level is measured as the temporal percentage of the analyzed period for which the horizontal and vertical position errors (HPE and VPE) are below the corresponding alarm limits, HAL and VAL respectively (this is, HPE < HAL and VPE < VAL).
Next plot provides the percentage of time (monitored epochs + not monitored epochs) for which the protection limits are enclosed by their corresponding alarm limits for APV-I.

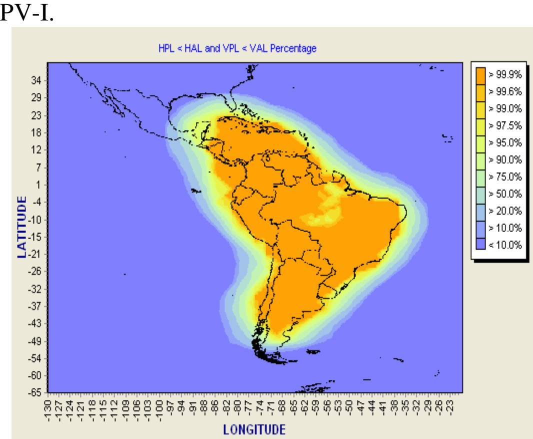

Figure 9 ECLAYR: User´s level Availability for APV- I: HPL < 40m and VPL < 50m (%).

As observed, most of the CAR/SAM regions are compliant with the APV-I[1] availability requirements.

The integrity concept at user´s level can be estimated by means of the percentage of the monitored epochs for which the horizontal and vertical position errors are below the corresponding protection limits (HPE < HPL and VPE < VPL). The next map shows how both the horizontal and vertical positions errors are below their corresponding protection limits for the 100% of the monitored epochs in the CAR/SAM regions.

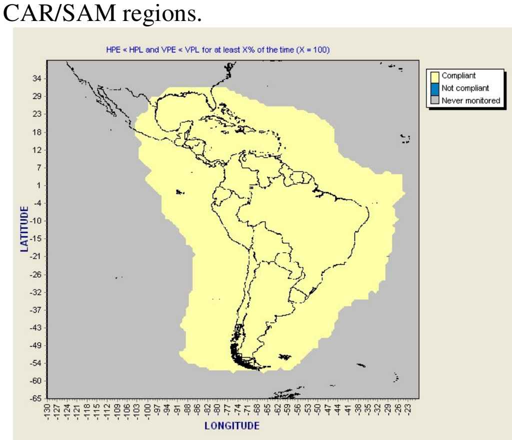

Figure 10 User´s Level Integrity: yellow: region for which HPE < HPL and VPE < VPL for the 100% of the monitored epochs.

As observed, at user´s level the system is compliant with the integrity requirements in the Service area.

In addition to the integrity´s analysis at user´s level, it is also important to analyze the integrity at satellite and ionospheric levels, in order to ensure the adequate behavior of the UCP for this scenario.

Next plot shows a histogram representing the relative frequency of time for which the SREW/UDRE ratio is between certain safety indexes. It is important to notice that the UDRE values are scaled to 0.9999999 (5.33σ) and therefore the reference factor of the safety index is 1/5,33=0,18. The higher the percentage for low SREW/UDRE ratio, the better integrity behavior the system has.

[1] It is important to point out that the availability performances at some regions in the centre of the continent are affected by the lack of stations in that region, and therefore are not representative of the integrity conditions: a new stations´ distribution would solve the integrity problem.

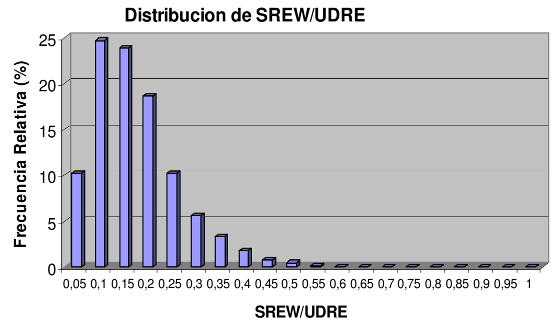

Figure 11 SREW / UDRE Distribution.

As observed, the SREW/UDRE ratio is always smaller than 1 and therefore there are no integrity failures.

Integrity is also a key element in terms of ionosphere and has a special importance in this region where the ionosphere is a critical aspect. At IGP´s level, integrity is achieved when the confidence levels given by the corrections (GIVE values for each IGP) limit the corresponding GIVDerrors, being compliant with the specified confidence level. Therefore if we represent the histogram of the relative frequency of the GIVDerror/GIVE (5.33σ) ratio for all IGPs and for all the epochs, in case this ratio is smaller than 1, the integrity at IGP´s level is compliant. On the other hand, the smaller this ratio is, the higher the integrity is.

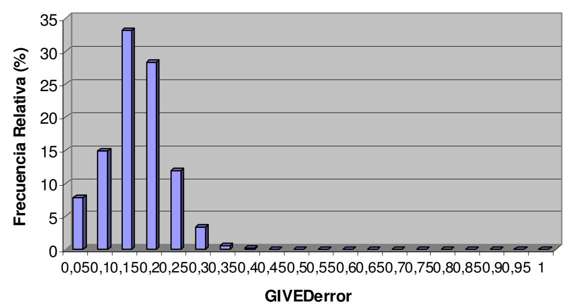

Figure 12 GIVDerror / GIVE distribution.

Again, there is no integrity failures, since the GIVDerror/GIVE ratio is always smaller than 1.

Performances for Degraded Scenario

This section presents the results obtained in the performance´s analysis for the degraded scenario defined as part of the SACCSA´s ionospheric study.

Three days of simulations (13, 14 and 15th of September 2001) have been run and analyzed. Results achieved for the third day (15th September 2001) are shown here.

Taking into account the occurrence probabilities, priority and SBAS system requirements´ compliance for a degraded scenario, this analysis is focused on the integrity´s compliance with reasonable values of the availability.

Following the nominal scenario´s procedure, the horizontal and vertical protection levels (HPL and VPL, respectively), as well as the horizontal and vertical position´s errors (HPE and VPE, respectively) at user´s level have been analyzed using ECLAYR tool in the SACCSA Service Area.

Next map shows that the horizontal and vertical protection's limits are higher than the corresponding position´s error for all analyzed epochs, and therefore the user is always protected and the system shows good integrity´s performances.

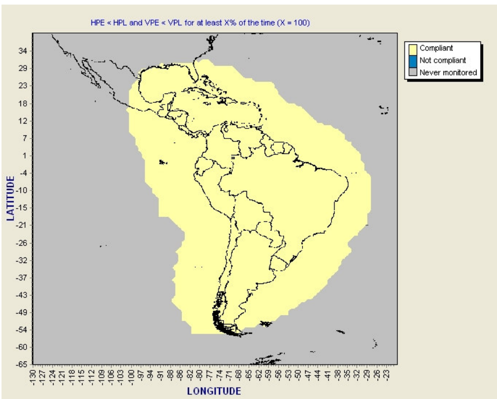

Figure 13 Integrity at user´s level: time for which it is verified that HPE < HPL and VPE < VPL.

In addition to the integrity´s analysis at user´s level, the integrity at satellite and ionospheric level has also been analyzed, in order to ensure the adequate behavior of the UCP also for the degraded scenario.

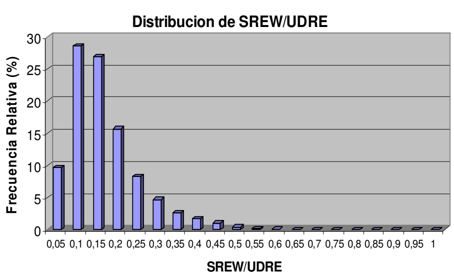

Figure 14 SREW/UDRE Distribution for the degraded scenario.

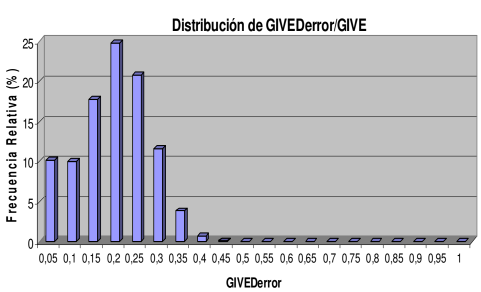

Figure 15 GIVEDerror/GIVE Distribution for the degraded scenario.

As observed, the integrity is preserved at user´s level and also at satellite/ionosphere level within the Service Area. It is also important to point out that the SBAS system´s objective is achieving the higher availability but always maintaining the integrity. Therefore, the conclusion shown here is an important result that has to be highlighted.

SACCSA PROTOTYPE PERFORMANCE ANALYSIS USING REAL DATA

As commented previously, ***magicSBAS***, a SBAS demonstrator developed by GMV, will be used as the core of SACCSA prototype. SACCSA UCP will be based on magicSBAS and will be modified to customize it to the CAR/SAM regions. In particular SBAS Ionosphere algorithms will be modified with the solutions proposed as part of the project.

At the time of preparing this paper there were no results available of the SACCSA prototype, as operations are expected to begin at the end of this year. Fortunately, some preliminary results with magicSBAS are available in South-America with real data running in Real Time from previous magicSBAS prototype campaigns in South-America.

Previous to entering details on the performances obtained hereafter, a high level view of what magicSBAS is will be provided.

magicSBAS high level view

The ***magicSBAS*** scheme is based on the collection of measurements and data from existing reference stations in the Internet in a protocol called NTRIP (for real time processes). Then ***magicSBAS*** computes corrections, confidence levels and all additional information required by an SBAS system, using enhanced EGNOS **[6][7]** algorithms, and broadcasts this information to the final user via Internet using the format SISNET. Thus, the ***magicSBAS*** system is composed of:

i. NTRIP data + ***magicSBAS*** as ground infrastructure;
ii. SISNET broadcasts over the Internet – which can be accessed via GPRS – replacing the SBAS geostationary satellites and
iii. SBAS receiver processing SISNET format – such as GMV I-10 – Septentrio or standard non-SISNET receivers complemented with SW tools.

In this way, ***magicSBAS*** does not require a dedicated space segment or deployed stations and the transmission can be achieved with full independence from other systems. This leads to a more efficient management and decision driving.

Figure 16 provides a graphical representation of ***magicSBAS*** elements. It can be seen that ***magicSBAS*** consists of just one PC with ***magicSBAS*** SW receiving data from stations in Internet through NTRIP casters. Then, it computes the corrections and integrity and provides the SBAS message to Internet for a later access through mobile technology. Dedicated receivers and ***magicSBAS*** monitoring are optional enhanced capabilities.

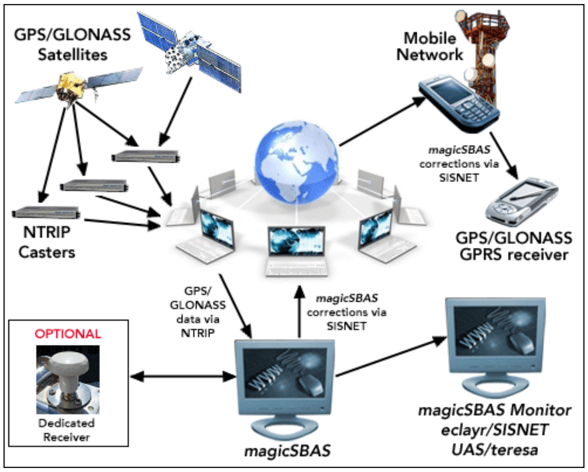

Figure 16 magicSBAS Overview

The real time NTRIP data available at present world-wide and shown in Figure 17 are daily updated from (http://igs.bkg.bund.de/root_ftp/NTRIP/maps/networks/All-World.png):

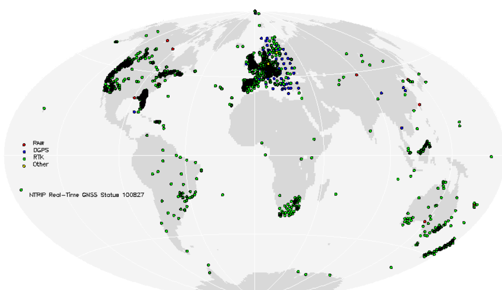
Figure 17 NTRIP stations world-wide

The full list of the available NTRIP stations with their characteristics (receiver model, system, carrier, position, NTRIP broadcaster …) can also be seen at http://igs.bkg.bund.de/root_ftp/NTRIP/streams/streamlist_world-wide.htm.

magicSBAS obtained performances in South America

magicSBAS has been adapted to South America with excellent results. magicSBAS Data Processing algorithms has also be modified to customize algorithms to equatorial regions.

magicSBAS has been run with the available NTRIP data in South-America during June-July-August 2009. The stations used were GPS-only, double frequency geodetic receivers and their location is shown in Figure 18. Please note that this period is considered of low ionosphere activity.

The number of stations at the time of the demo was very limited in South America except for Brazil, and the NTRIP data were frequently lost for some stations due to internet problems, therefore the maximum number of stations available was configured for evaluation.


Figure 18 NTRIP-Stations used in South America

Typical results with magicSBAS performances when most of the NTRIP stations were available are shown below. Similar results were obtained during other periods of the day. Should you require further analysis, please send an e-mail to magicSBAS@gmv.com.

It is important to remark that the performances provided by ECLAYR are independent from the GPS measurements availability at receiver´s level and give an estimation of the levels of availability, continuity, accuracy and integrity that could be achieved by a fault-free receiver in the Service Area using only the GPS ephemera and the SBAS corrections broadcast by the corresponding GEO satellite.

Figure 19 represents for each user position, the percentage of time that the protection level is lower than the APV-I 99% alarm limit (HAL=40m, VAL=50m). This percentage has been computed with respect to the monitored epochs.

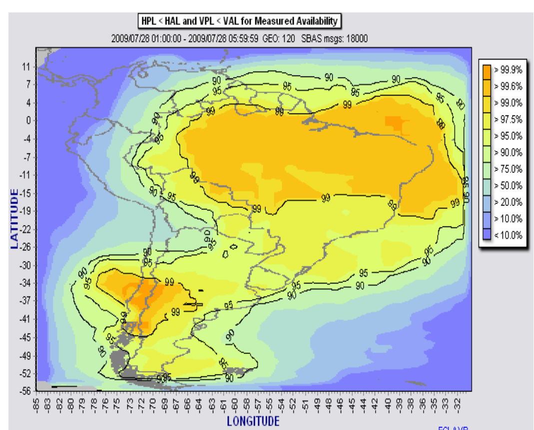

Figure 19 South-America magicSBAS availability

Performance figures highly depend on NTRIP station availability, as it can be seen in Figure 20 where availability performances are analyzed in a different time period:

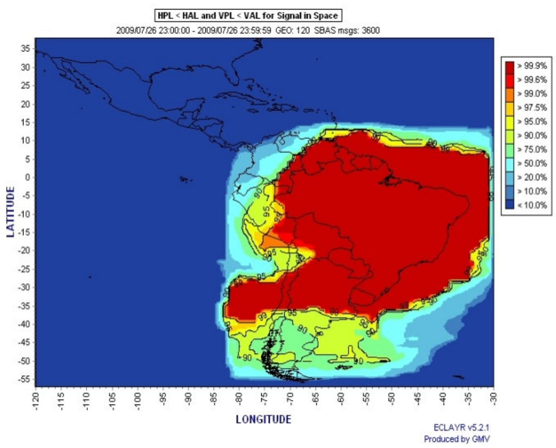

Figure 20 South-America magicSBAS availability

The following figures represent both the Horizontal and Vertical Accuracy measured at percentile 95%. As it can be seen, it is in the order of 1-2 meters.

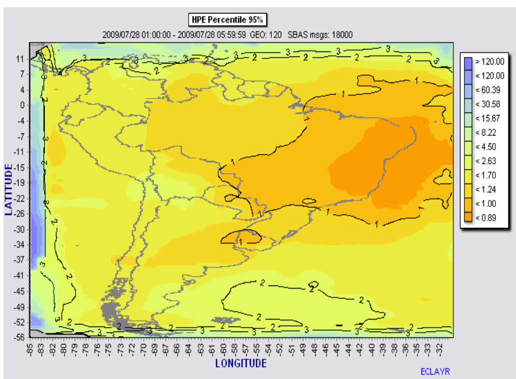

Figure 21 South-America magicSBAS horizontal accuracy

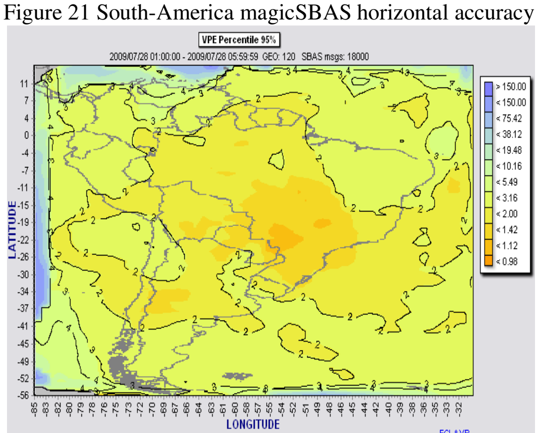

Figure 22 South-America magicSBAS vertical accuracy

The Safety Index for each position represented in Figure 23 and Figure 24 is defined as the ratio between the position´s error and the protection level for each epoch. As can be seen, integrity is preserved as the index is always below 1. Protection levels are about 5 times higher than user errors. Note that Safety Index also represents the margin between integrity and availability.

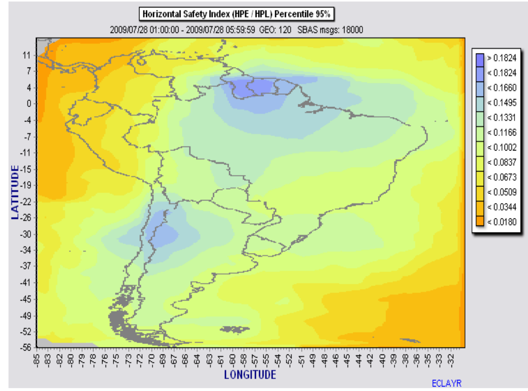

Figure 23 South-America magicSBAS horizontal Integrity

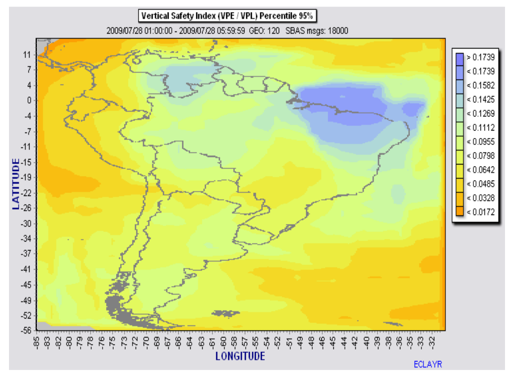

Figure 24 South-America magicSBAS vertical Integrity

The following figure represents the Continuity Risk factor for each position. Continuity Risk is defined as the probability of having the service unavailable (PLs > ALs) during the aircraft landing operation provided the system was available at the beginning of the operation. Notice that continuity risks lower than 1e-5 are better than the qualified EGNOS continuity risk and thus a major performance indicator of the SBAS service.

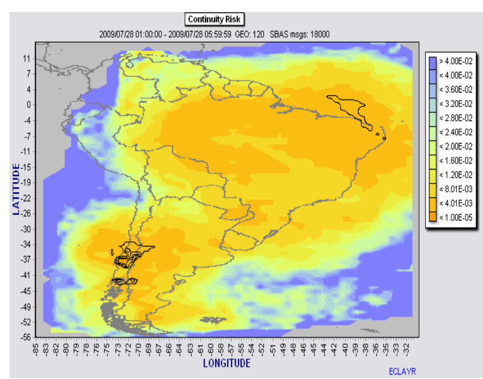

Figure 25 South-America magicSBAS continuity

The figure below was obtained with TERESA in the Concepción station (CONZ) located in Chile, inside the coverage area. After magicSBAS initialization (which takes about 3600 epochs) magicSBAS gets similar performances than a "GPS-only" system in terms of Navigation System Error (North, East and Vertical Error) – note that SBAS systems are not designed for the provision of accuracy performances but rather for the stringent integrity requirements, 1e-7 -.

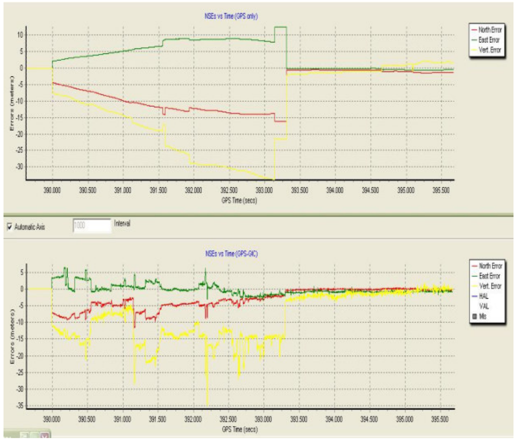

Figure 26 Navigation System Error comparison

TERESA also provides real-time Protection Levels information as can be seen in Figure 27.

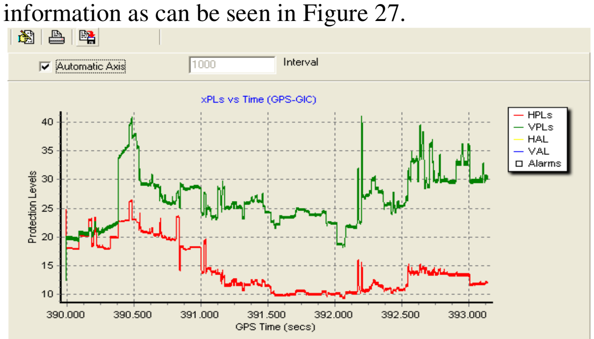

Figure 27 Protection Levels in CONZ

Note that magicSBAS also provides other real-time products, such as ionosphere corrections and integrity. The next figure shows the differences in ionosphere corrections provided by magicSBAS when compared to the “igsg” IONEX **[11]** for the same day and locations. Ionoe Real Time Estimation error (RMS) is always below 0,75m (4,5 TECUs).

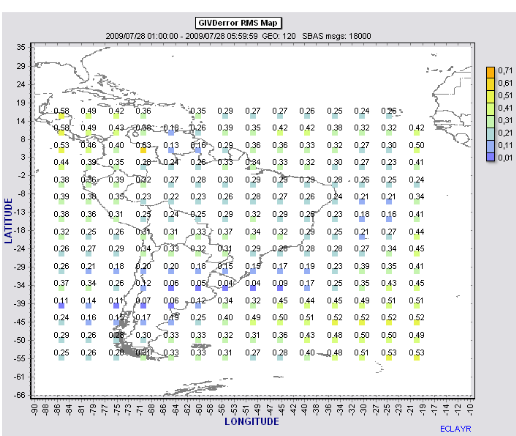

Figure 28 magicSBAS real-time ionosphere

At magnetic equatorial latitudes (±10º-15º from magnetic equator) the ionosphere activity can become a limitation on GNSS augmentation systems, and therefore special attention has to be paid to the estimation of ionospheric delays through SBAS-like algorithms and its performances.

From the figures included in this paper, it can be observed that magicSBAS performances in the targeted zone are in line with any other operational SBAS systems (like WAAS) or yet to be operational (EGNOS).

CONCLUSIONS

The main objective of this paper is to describe the SACCSA project phase III and to provide the obtained performances.

SACCSA performances have been analyzed through simulated and real data. End-to-End simulations have been used to evaluate the expected performances in different representative scenarios and with realistic measurement models and based on the ionosphere studies done also as part of the project. On the other hand, analyses with real data using SACCSA prototype have also been shown.

Two representative simulated scenarios have been defined in SACCSA to analyze the nominal and degraded cases performances.

With regard to the nominal scenario´s performances, most of the CAR/SAM regions are compliant with the APV-I availability requirements. On the other hand, the system is compliant with the integrity requirements at user´s level for all the monitored regions in the Service area. In addition to the integrity´s analysis at user´s level, it was also verified that the integrity is also preserved at satellite and ionospheric levels.

As far as the degraded scenario is concerned, it was verified that the user is always protected and the system shows good integrity´s performances. In addition to the integrity´s analysis at user´s level, the integrity at satellite and ionospheric levels has also been analyzed. As observed, the integrity is preserved at user´s level for all monitored regions within the Service Area.

Preliminary results using magicSBAS in South-America with real data (running in Real Time from previous magicSBAS prototype campaigns in South-America) have also been shown. The main conclusion of these results is that magicSBAS performances in the targeted zone are in line with any other operational SBAS systems (like WAAS) or yet to be operational (EGNOS).

Finally, and taking into account the performance analysis results, it can be concluded that at the moment it is not possible to be compliant with APV-II requirements, and that it is necessary to focus the analysis on APV-I and LPV-200.

It is also important to point out that the aforementioned analysis was developed using a *magicSBAS* version minimally adapted to the CAR/SAM regions. Several modifications have been identified to improve the obtained performances. The analysis of these modifications is being developed in the frame of the third phase of SACCSA. This strategy is compliant with the "own system hypothesis", in other words that it is not possible to directly use existing SBAS data processing (EGNOS or WAAS) and a customization and/or adaptation, mainly related to iono aspects, is needed for the CAR/SAM regions.

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