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magicSBAS: A SOUTH-AMERICAN SBAS WITH NTRIP DATA

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BIOGRAPHY

I. Alcantarilla, J. Caro, A. Cezón and J. Ostolaza are part of GMV GNSS team. GMV is responsible for the computing centers in EGNOS – CPFPS – and Galileo programmes – OSPF and IPF – in charge of the computation of the corrections for SV orbits & clocks and ionosphere and integrity.

ABSTRACT (ENGLISH)

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).

The development and deployment of a complete satellite navigation system for a given region is a serious technological challenge that requires a significant investment and a relatively long process, which may last many years. Systems like WAAS or EGNOS have required around a decade from their original concept design to the final achievement of the operational status.

In this context, GMV (www.gmv.com), a reference Spanish company in the domain of GNSS ground segment computation facilities, has developed ***magicSBAS*** . ***magicSBAS*** takes advantage of the technology already developed both in the frame of satellite navigation and in the area of personal communications in order to propose an alternative for new regions to a full development of a new system. Moreover, it represents the first multi-constellation SBAS integrity provider by augmenting not just GPS, but GPS and GLONASS satellites.

magicSBAS collects real-time pseudorange measurements and ephemeris in RTCM format from existing reference stations in the Internet via the NTRIP protocol (www.rtcm-ntrip.org). Then ***magicSBAS*** computes corrections (SV orbits & clocks, ionosphere), integrity and all additional information required by a SBAS system in real-time and broadcast this information to the final user using SISNET format (http://www.egnos-pro.esa.int/sisnet/index.html). The SISNET broadcast information can be accessed via Internet or GPRS/3G technology by user receivers to navigate safely.

magicSBAS has been adapted to the real-time processing of the NTRIP data in South America with excellent results. It will be shown how a SBAS service can be provided in South America in real time with the same performances as any other SBAS system. Accuracy, availability, continuity and integrity will be evaluated in South America with NTRIP data + ***magicSBAS***. Moreover, the performances of the real-time SV orbits & clocks and ionosphere corrections will be shown.

ABSTRACT (ESPAÑOL)

El mapa actual de sistemas de navegación por satélite incluye sistemas globales sin provisión de integridad (GPS y GLONASS), sistemas regionales con provisión de integridad (WAAS, EGNOS, MSAS), y los futuros sistemas de navegación con provisión de integridad y con cobertura mundial (Galileo).

El desarrollo y despliegue de un sistema completo de navegación por satélite para una determinada región es un serio desafío tecnológico que requiere una inversión importante y un proceso relativamente largo, que puede durar muchos años. Sistemas como EGNOS o WAAS han requerido en torno a una década desde su concepción inicial hasta la consecución del estatus operacional.

En este contexto, GMV (www.gmv.com), una empresa española de referencia en el ámbito del segmento de tierra GNSS, ha desarrollado ***magicSBAS***. ***magicSBAS*** aprovecha las ventajas de

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la tecnología ya desarrollada, tanto en el marco de la navegación por satélite y en el área de las comunicaciones personales con el fin de proponer una alternativa para las regiones frente al desarrollo de un sistema completo. Además, representa el primer SBAS multi-constelación al aumentar no sólo los satélites GPS sino los satélites GPS y GLONASS.

magicSBAS recoge de Internet en tiempo real las medidas de pseudocódigo y las efemérides en formato RTCM de las estaciones de referencia a través del protocolo NTRIP (www.rtcm-ntrip.org). Luego ***magicSBAS*** calcula correcciones SBAS (órbitas y relojes de satélites e ionosfera), junto con su integridad y toda la información adicional requerida por un sistema SBAS en tiempo real y transmite toda esta información al usuario final utilizando el formato SISNET (http://www.egnos-pro.esa.int/sisnet/index.html). Esta información SISNET se puede acceder a través de Internet o con la tecnología GPRS/3G por receptores de usuario para poder navegar con total seguridad.

magicSBAS se ha adaptado para procesar en tiempo real datos NTRIP en Sudamérica con excelentes resultados. Se mostrará cómo un servicio SBAS en tiempo real en Sudamérica es posible con las mismas prestaciones que cualquier otro sistema SBAS. La precisión, disponibilidad, continuidad e integridad serán evaluadas para Sudamérica.

INTRODUCTION

A SBAS (Space 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 geostationary satellites. Thus, the system is composed of:

i. Ground infrastructure,
ii. SBAS geostationary satellites, and
iii. SBAS receivers.

The ground infrastructure includes the monitoring and processing stations, which receive the data from the navigation satellites and compute integrity, corrections and ranging data which form SBAS signal-in-space (SIS). The SBAS satellites relay the SIS from the ground infrastructure to the SBAS user receivers, which determine position and time information from core satellite constellation(s) and SBAS satellites (via GEO). The SBAS receivers acquire the ranging and correction data and apply these data to determine the integrity and improve the accuracy of the derived position.

The SBAS ground system measures the pseudorange between the satellites and a set of SBAS reference receivers at known location and provides separate corrections and levels of confidence for satellite position errors, satellite clock errors and ionospheric errors. The user will apply these corrections to improve its estimate of its position and its level of confidence.

WHAT IS *MAGICSBAS*?

The ***magicSBAS*** scheme is based on the collection of measurements and data from existing reference stations in the Internet in a protocol called NTRIP, then ***magicSBAS*** computes corrections, confidence levels and all additional information required by a SBAS system and broadcast this information to the final user via Internet using the format SISNET[3]. Thus, the ***magicSBAS*** system is composed of:

i. NTRIP data + ***magicSBAS*** as ground infrastructure
ii. SISNET broadcast 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, which leads to a more efficient management and decision driving. The region keeps full control and sovereignty on the ***magicSBAS*** operations. Moreover and since ***magicSBAS*** follows standard protocols, it can be easily complemented with dedicated receivers to enhance the performances in the target region.

Figure 1 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

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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.

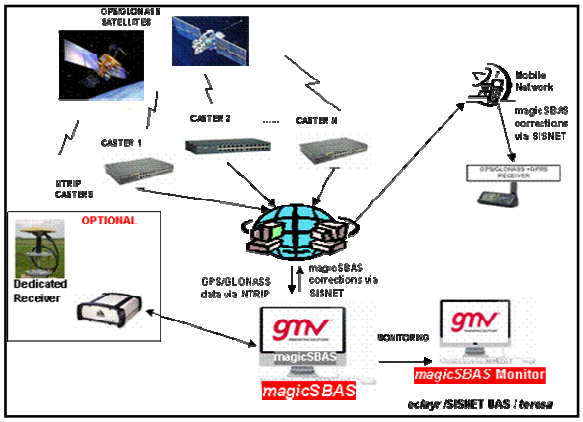

Figure 1 magicSBAS Overview

The ***magicSBAS*** Monitor provides the necessary real-time and post-processing performance analyses tools (used in EGNOS validation):

i. ***teresa*** [2] (TEsting Receiver for EGNOS using Software Algorithms) is a software tool that fully implements User Receiver Algorithms providing real-time and post-processing GNSS performance (GPS, GLONASS and SBAS Systems).

ii. ***eclayr*** [1] (EGNOS Continuous Logging Analyser) is a SBAS performance analyzer that provides very detailed post-processing performance analyses at range (SV and ionosphere) and user levels. ***eclayr*** is fully automatable.

The NTRIP data available at present world-wide are shown in ***Figure 2*** (http://igs.bkg.bund.de/root_ftp/NTRIP/maps/networks):

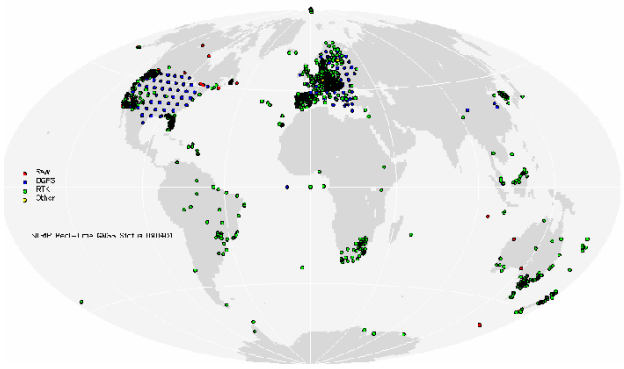

Figure 2 NTRIP stations world-wide

SBAS PERFORMANCE EVALUATION

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) do not exceed the alarm limits (HAL and VAL) 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 the better) provided that the integrity of the system is maintained (accuracy is generally met and continuity generally not met).

magicSBAS PERFORMANCE AROUND THE WORLD

Figure 3 and ***Figure 4*** provide the real-time availability maps for two cases where there is no SBAS service currently available. The first one corresponds to Eastern Europe where EGNOS (the European SBAS) does not provide service yet while the second one is the New Zealand (NZ) case, where no SBAS is currently deployed.

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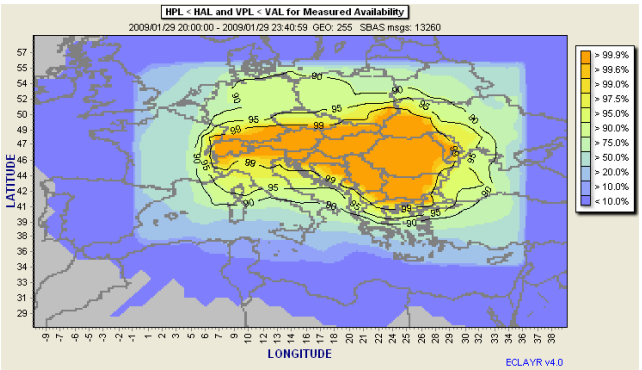

Figure 3 Eastern Europe magicSBAS availability

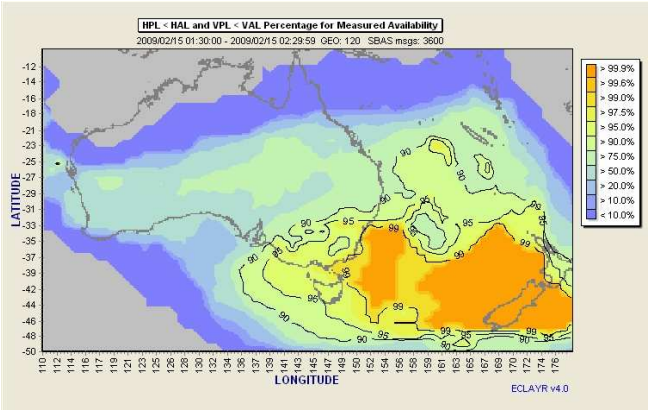

Figure 4 New Zealand magicSBAS availability

It is possible to observe from these figures that 99% APV-I availability is reached for the targeted zones which imply that ***magicSBAS*** performances are in line with those of the current SBAS in the world (e.g., WAAS, EGNOS).

magicSBAS PERFORMANCE IN SOUTH-AMERICA

magicSBAS has been run with the available NTRIP data in South-America (the location of used stations is shown in Figure 5). The results with ***magicSBAS*** performances are shown next.

Figure 5 Ntrip-Stations used in South America

Figure 6 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 respect to the monitored epochs.

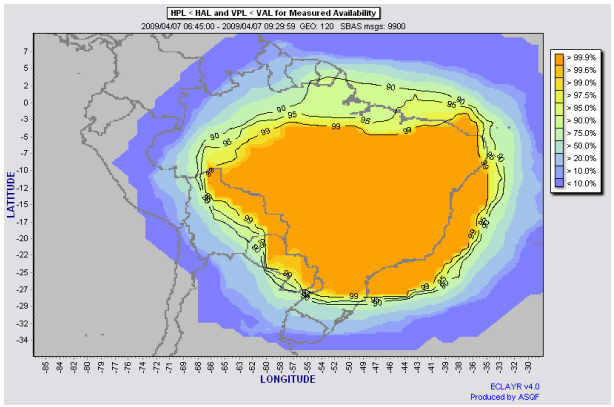

Figure 6 South-America magicSBAS availability

Figure 7 represents the Horizontal Accuracy measured at percentile 95% and defined by the difference between estimated and real user position. As it can be seen it is less than 1 meter.

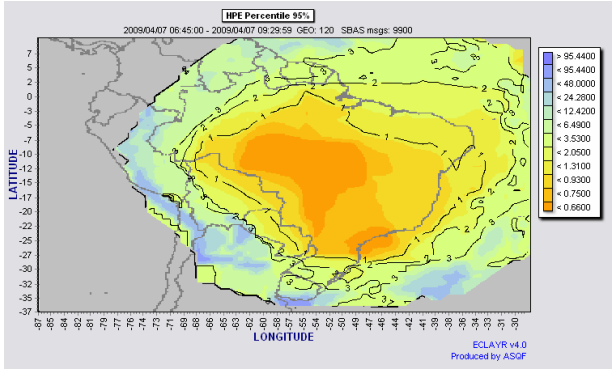

Figure 7 South-America magicSBAS accuracy

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The Safety Index for each position represented in Figure 8 is defined as the division between the position error versus the protection level for each epoch. As it 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 represents also the margin between integrity and availability.

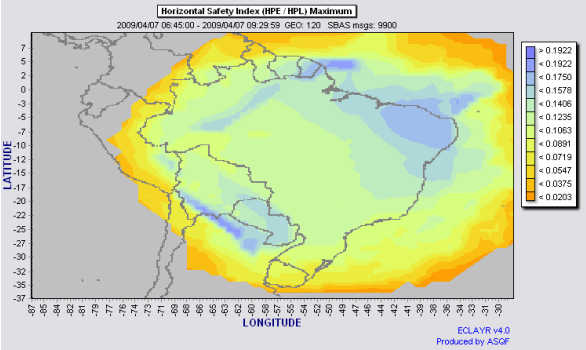

Figure 8 South-America magicSBAS integrity

Figure 9 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. Observe that continuity risks lower than 1e-5 are better than the qualified EGNOS continuity risk and then a major performance indicator of the SBAS service

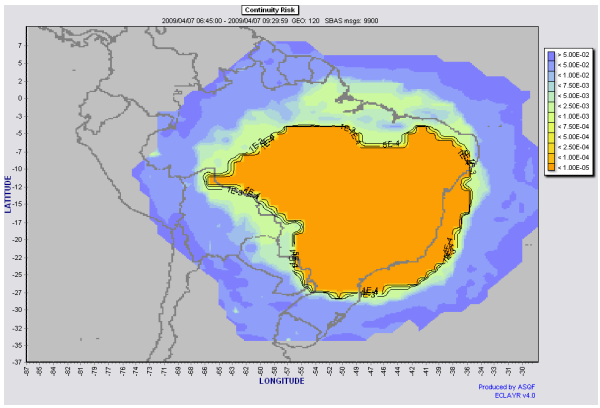

Figure 9 South-America magicSBAS continuity

Note that magicSBAS provides also other real-time products, such as ionosphere corrections and integrity. Figure 10 shows the differences in ionosphere provided by magicSBAS when compared to the "igsg" IONEX [4] for the same day and locations. Ionosphere Real Time Estimation error (RMS) is always below 0,75m (4,5 TECUs).

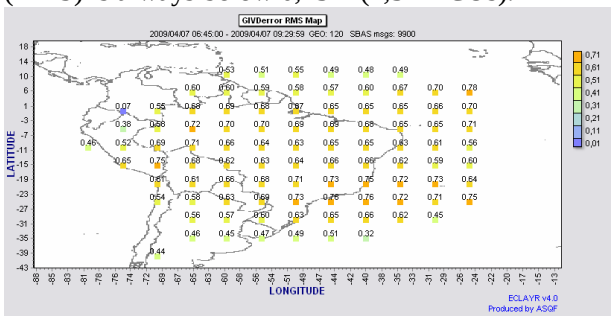

Figure 10 magicSBAS real-time ionosphere

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 (WAAS) or yet to be operational (EGNOS).

SUMMARY

The ***magicSBAS*** service can be provided as far as NTRIP data is available without the need of the deployment of a dedicated infrastructure. A real-time SBAS is **ALREADY** running in South-America with 22 Ntrip Stations located in Brazil. The APV-I 99% coverage area will be extended as soon as further NTRIP stations will be available.

magicSBAS performances are shown to be as any other operational SBAS (WAAS, EGNOS).

Due to the characteristics of the region (Brazil) in terms of ionosphere perturbations, special attention has to be paid on this aspect. Therefore for an operational SBAS, ***magicSBAS*** should be customized to the ionosphere of the region.

For a monitoring of that SBAS service, please email at ***magicSBAS***@gmv.com for a username, password and instructions to access this real-time SBAS.

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[3] ESA SISNET User Application Software: http://www.egnos-pro.esa.int/sisnet/uas.html
[4] Ionospheric delays in IONEX format: ftp://cddisa.gsfc.nasa.gov/pub/gps/products/ionex/

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