Characteristics and Performance of Algerian Satellite Based Augmentation System (AL-SBAS)

Lahouaria Tabti
Department of Space Geodesy, Centre of Space Techniques,
Algerian Space Agency
Email: ltabti@cts.asal.dz

Salem Kahlouche
Department of Space Geodesy, Centre of Space Techniques,
Algerian Space Agency
Email: skahlouche@cts.asal.dz

Abstract— The Algerian Satellite Based Augmentation System (AL-SBAS) is developed by the Algerian Space Agency (ASAL) and is based on Algerian geostationary satellite Alcomsat-1. AL-SBAS permits to transmit SBAS messages according to the international standards defined by the International Civil Aviation Organization (ICAO). Compared to existing SBAS, currently the service area of AL-SBAS is limited to Algeria only. Thus, the number of Ionospheric Grid Points (IGP) and satellites "to be increased " is lower than the existing SBAS, in particular the European Geostationary Navigation Overlay Service (EGNOS). The Al-SBAS correction messages are calculated by the Data-Processing Center (DPC) using GPS satellite data collected from a terrestrial network of 18 Reference Stations (RS), which are geographically distributed over the entire country. This work presents the main characteristics and preliminary performance tests of the AL-SBAS System. The analysis concerns in particular the parameters of pseudo-range and ionospheric correction, as well as the integrity transmitted by the system. Very promising results have been achieved considering the number of currently available reference stations in the south of Algeria, which is a region EGNOS does not cover. The ionospheric indicators using EGNOS are between 8 and 15, while the AL-SBAS allows to have indicators ranging between 6 and 13.

Keywords-GPS; AL-SBAS; EGNOS; Indicators of Precision; Integrity.

I. INTRODUCTION

A Satellite Based Augmentation System (SBAS) is an augmentation system that transmits the complementary information to correct errors of measurements and to ensure integrity. SBAS broadcasts corrections of the Global Navigation Satellite System (GNSS) satellite clock, satellite orbital error and corrections of ionospheric delays related to the signal propagation to improve positioning performance [1].

Many countries have established their own SBAS's. Currently, there are four operational SBAS, including the US Wide Area Augmentation System (WAAS), the European EGNOS system, the Indian GPS Aided Geostationary Augmented Navigation (GAGAN), and the Japanese Multi-functional Satellite Augmentation System (MSAS). Russia has also deployed its SBAS system, named the System for Differential Corrections and Monitoring (SDCM). In addition, some countries, such as Australia, Nigeria, and Korea, are testing their SBASs named the Southern Positioning Augmentation Network (SPAN), Nigerian Satellite Augmentation System (NSAS) and Korea Augmentation Satellite System (KASS) respectively**.** China is planning to broadcast SBAS messages via BeiDou Satellite-Based Augmentation System (BDSBAS) [2] [3].

Algeria is also one of the countries that is implementing a similar augmentation system based on the geostationary satellite Alcomsat-1, in order to provide services for Algeria and the surrounding area.

Alcomsat-1 communications satellite was launched on December 11, 2017, and is located at 24.8° W in a geostationary orbit. Figure 1 illustrates the coverage of Alcomsat-1 Navigation Overlay Services named AL-SBAS. The coverage of Alcomsat-1 includes the entire Africa, South America and part of Europe. Alcomsat-1 Communications Satellite is equipped with 33 transponders, including L1&L5 signals navigation augmentation (the other bands are Ku and Ka) [4]**.**

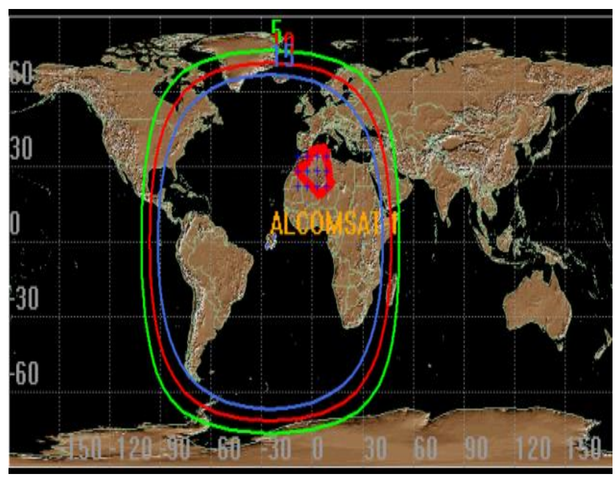

Figure 1. Coverage of Alcomsat-1 Navigation Overlay Services.

The AL-SBAS permits to improve the positioning accuracy and integrity in Algeria and the nearby countries. The system aims to provide SBAS services not only for aviation users but also for other general users, such as surveying, transportation and railways, etc.

The AL-SBAS collects GPS observations and corrects GPS satellites ephemeris errors, clock errors, and ionospheric errors together with the corresponding integrity parameters in real-time. The system broadcasts differential corrections through geostationary satellite (Alcomsat-1) with a high accuracy and a significant capability for integrity augmentation.

The mathematical model of the corrected observation equation using AL-SBAS messages is defined as follows [5]:

$$l_{corr} = l_{mes} + RC_{fast} + RC_{clock} - RC_{iono} + RC_{tropo} \quad (1)$$

where l_{corr} is the pseudo - range for position determination application, l_{mes} is the measured pseudo - range, RC_{fast} is the fast corrections, RC_{clock} is the clock corrections, RC_{iono} is the ionospheric corrections and RC_{tropo} is the tropospheric corrections.

The main objectives of this work consists of analysing the evaluation of AL-SBAS corrections in Algeria and comparing the results with EGNOS.

The rest of the paper is structured as follows. Section II presents the Algerian augmentation system. Section III shows the results of the study. We conclude our work in Section IV.

II. OVERVIEW OF THE ALGERIAN AUGMENTATION SYSTEM (AL-SBAS) BASED ON ALCOMSAT-1

The AL-SBAS system functionality is similar to the SBAS, where a number of ground reference stations monitor the GPS satellites signals and provide their observations to one or more Master Control stations. An augmentation message is generated and transmitted via uplink stations within the uplink the coverage area of the geostationary satellite. Finally, this satellite broadcasts these signals regionally to users with messages to improve positioning accuracy and integrity.

AL-SBAS consists of 18 RS that are installed only in Algeria and are covering all the Algerian territory, one DPC and one Ground Uplink Land Station in Algiers (GULS) [6].

A summary description of the AL-SBAS architecture is provided in Figure 2.

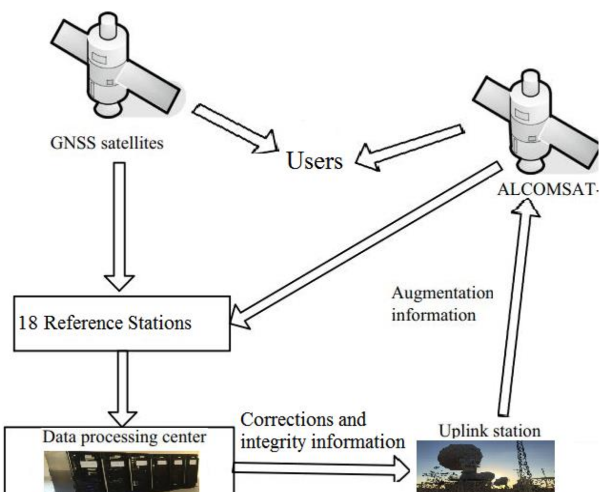

Figure 2. AL-SBAS system description.

A. Overview of AL-SBAS L1 Signal

The structure of AL-SBAS signal is defined to have full compatibility with the SBAS signal. The generator of Pseudo-Random Noise (PRN) code for spreading spectrum is the same as GPS/SBAS L1 (1575.42 MHz).

The following PRN code number 148 is allocated to AL-SBAS for use on L1 C/A code; Table 1 presents the PRN assignments for the AL-SBAS system published in October 2021 [7].

TABLE 1. PRN ASSIGNMENT TO AL-SBAS FOR USE ON L1 C/A CODE

PRN Code Number	PRN Allocations	Orbital Slot
148	ASAL (Alcomsat-1)	24.8 W

The AL-SBAS message structure is like other SBAS composed of 8-bit preamble (to ensure the synchronization of frame), 6-bit to define the Message Type (MT), 212-bit data field to provide corresponding data, and 24-bit Cyclic Redundancy Check (CRC) parity. Figure 3 illustrates all the correction parameters and integrity information that are included in 250-bit data every second [8].

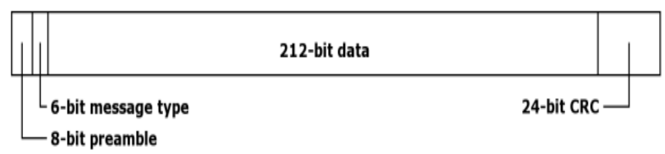

Figure 3. AL-SBAS message structure.

B. Overview of AL-SBAS L1 Correction

AL-SBAS transmits messages in hexadecimal format; an example of the AL-SBAS raw message is given by Figure 4 on 1 December, from 1:00:01 to 1:00:10 with message type MT: 0, 2, 3, 4, 0, 25, 0, 2, 3 and 4.

```
148 22 12 01 00 00 01 0 5302000000000000000000003FC4000003FC0000000003BBBBBBA797BBB7E30DC0
148 22 12 01 00 00 02 2 9A08000000000000000000003FC4000003FC0000000003BBBBBBAB97BBA939C300
148 22 12 01 00 00 03 3 C60E0003FD3FD4003FE4000003FC8003FDC000003FDBB97B3BAF9FB9B57D65C0
148 22 12 01 00 00 04 4 53113FD000000000000000000000000000000000000017BBBBB80000165F9140
148 22 12 01 00 00 05 0 9A00000000000000000000003FC4000003FC0000000003BBBBBBAB97BBA4C03A00
148 22 12 01 00 00 06 25 C6664098060100000000000094AC01FFE7F10000000000000000000027B04180
148 22 12 01 00 00 07 0 5302000000000000000000003FC4000003FC0000000003BBBBBBAB97BBBAB905C0
148 22 12 01 00 00 08 2 9A08000000000000000000003FC4000003FC0000000003BBBBBBBBBBBB9EAA01C0
148 22 12 01 00 00 09 3 C60E0003FD3FD4003FE4000003FC8003FDC000003FDBBBBBBBBBBBBBA1CC20C0
148 22 12 01 00 00 10 4 53113FD00000000000000000000000000000000000003BBBBBB8000013C31280
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Figure 4. AL-SBAS raw message on December 1, 2022.

AL-SBAS generates three types of differential corrections that are summarized in Table 2.

TABLE 2. DIFFERENTIAL CORRECTION MESSAGES FOR AL-SBAS

MT	Data Type
1	PRN Mask
2-5	Fast correction
24	Mixed fast/long-term satellite correction
25	Long-term satellite error corrections
18	Ionospheric grid point masks
26	Ionospheric delay corrections

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In addition to differential corrections, the SBAS also monitors and broadcasts the integrity of GPS satellite signals. The user can determine which satellites and IGP are usable for reliable positioning computation.

C. AL-SBAS Transmission Test

The test transmission of AL-SBAS with code PRN 148 on Alcomsat-1 geostationary satellite was started in July 20, 2020. Currently, this system is intended for test and development purposes only, which will be refined and developed to become a fully certified and operational SBAS for the Algerian region.

The AL-SBAS transmission was not permanently available for each day of year 2021 and during daytime until 21 May (DOY 142). To observe the function of the AL-SBAS in 2021, an analysis of transmitted messages has been performed for that year. These messages are available on the CNES Navigation and Time Monitoring FTP Service [9]. It gives access to AL-SBAS, which allows in an easier way to find and download files, which allows in an easier way to find and download files, regarding the AL-SBAS historical data. Figure 5 shows the number of messages transmitted by AL-SBAS for each day of the year 2021.

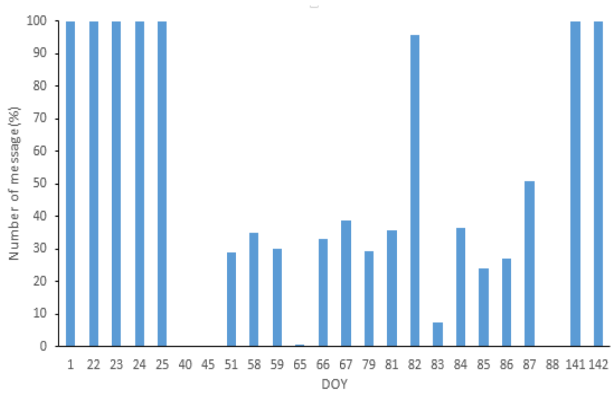

Figure 5. Histogram of Availability and the number of messages transmitted by AL-SBAS during year 2021. The Histogram is based on data from CNES site [9]. The days where no message is transmitted are not presented.

For 2021, there were days and times in which the system did not send any messages. The AL-SBAS satellite broadcasts one message per second and thus the number of SBAS messages during a period of 24 hours is 86400 (100%).

The total message count for AL-SBAS messages varies for each day of the year and (from) hour-to-hour. In particular, the total message count for day 22, 23, 24, 25, 82, 141 and 142 was close to 100%.

III. PURPOSE AND STUDY RESULTS

The main purpose of this work is to test the current AL-SBAS performance and compare these results with EGNOS in Algeria without Ranging and Integrity Monitoring Stations (RIMS).

The corrections of AL-SBAS and EGNOS are downloaded from the CNES FTP server [9]. These files are provided in the RINEX - B format [10]. The analysis was performed for the time period December 1st to 6th, 2022.

A. Analysis Result of Satellite Status

The augmented information related to satellite orbital and clock errors is calculated using MT 1, 2 to 5, 24 and 25. MT 1 provides a Pseudo Random Noise (PRN) mask that specifies the PRN number of the augmented satellite. MT 2 to 5 and 24 provide fast corrections and User Differential Range Error Indicators (UDREI). The UDREI values range from 0 to 15. UDREI equal to 14 means that the satellite is not monitored, while if it is equal to 15 means that it is not used [11], MT 24 and 25 provide long-term correction. Histograms of UDREI parameters for 32 GPS satellites using EGNOS are presented in Figure 6.

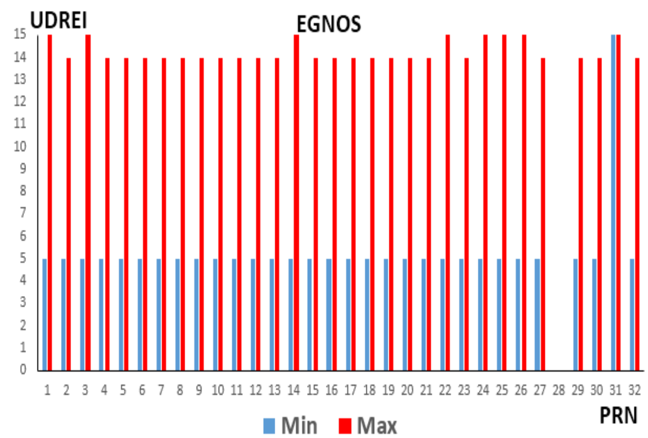

Figure 6. UDREI indicators of each satellite GPS using EGNOS.

By analyzing the indicators of precision transmitted by EGNOS, we notice that these indicators vary between 5 and 15, which means there are some satellites that are not monitored by the system and that the system recommends not to use some satellites. On the other hand, the indicators transmitted by AL-SBAS vary between 5 and 14, as shown in the histogram of the Figure 7.

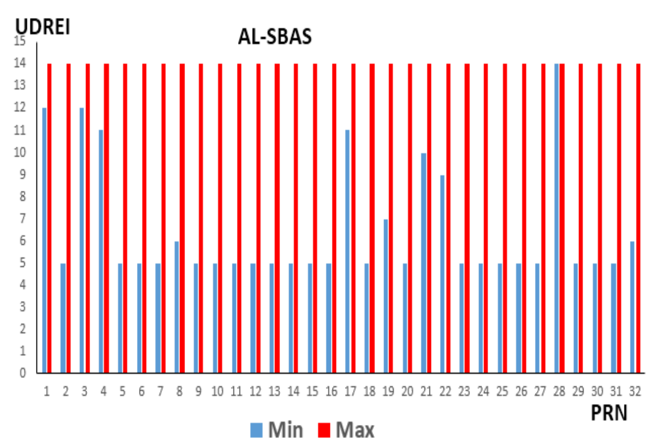

Figure 7. *UDRE* indicators of each satellite GPS using AL-SBAS.

B. Analysis Result of Ionospheric Error

The ionospheric correction is calculated using the information from MT 18 and 26. MT 18 provides the IGP mask that indicates the position of IGP and MT 26 provides ionospheric correction GIVD (Grid Ionospheric Vertical Delay) and indicators GIVEI (Grid Ionospheric Vertical Error Indicator) for each IGP. The GIVEI values range from 0 to 15. GIVEI equal to 14 means that the status of the IGP is not monitored, while if it is equal to 15 means that it is not usable [12].

The analysis result of MT 18 and 26, which are related to the ionospheric error correction shows that the AL-SBAS and EGNOS broadcast ionospheric corrections in the area [-25, +25] degree in longitude and [+5 ,+50] degrees in latitude and [-80, +80] degrees in longitude and [+10,+85] degrees in latitude, respectively. Figures 8 and 9 present the IGPs covered by AL-SBAS and EGNOS transmissions.

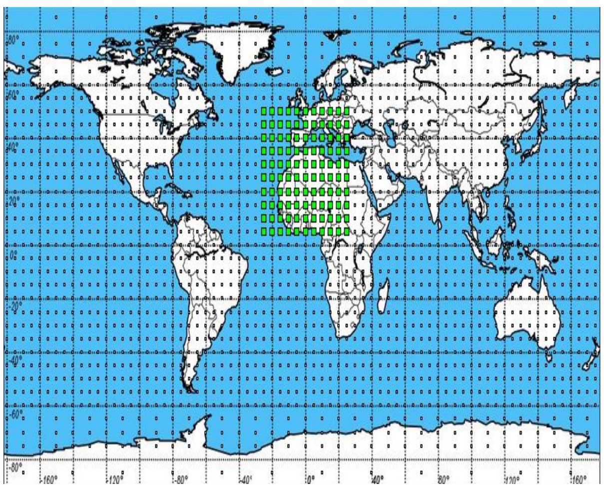

Figure 8. IGPs covered in AL-SBAS transmissions.

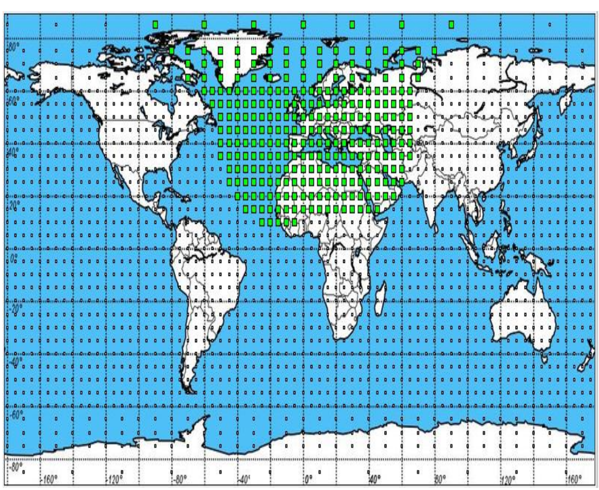

Figure 9. IGPs covered in EGNOS transmissions.

The vertical delay and indicators transmitted by AL-SBAS and EGNOS for two IGP of Lat 35 N, 25 N and long 0 E are given in Table 3.

TABLE 3. VERTICAL DELAY AND GIVDI TRANSMITTED BY AL-SBAS AND EGNOS FOR 2 IGP (LAT 35 N, 25 N AND LONG 0 E)

	AL-SBAS		EGNOS	
	Lat 35 N	Lat 25 N	Lat 35 N	Lat 25 N
GIVD(m)	2.22	4.59	2.48	32.21
GIVEI	[6 13]	[6 13]	[6 11]	[8 15]

For the AL-SBAS system, both IGPs are used to calculate an augmented position, however, for EGNOS the IGPs at 25° range from 0 m to 63.875 m, which indicates that this IGP is not monitored, or it is marked Do Not Use. The GIVEI is an indicator of the vertical ionospheric error.

It can be noted that for some IGP points, EGNOS cannot calculate the ionospheric delay, due to the lack of RIMS in Algeria.

The implementation of a RIM in the country will permit further improvement of the corrections transmitted by the EGNOS system, particularly ionospheric correction [10].

To better analyze the impact of the reference station to modelling ionospheric error, a comparison of the temporal variation of ionospheric delay over 24 hours for IGP at 25° in latitude and 0° in longitude was performed. The variation of this correction is presented in the two Figures 10 and 11 for EGNOS and AL-SBAS.

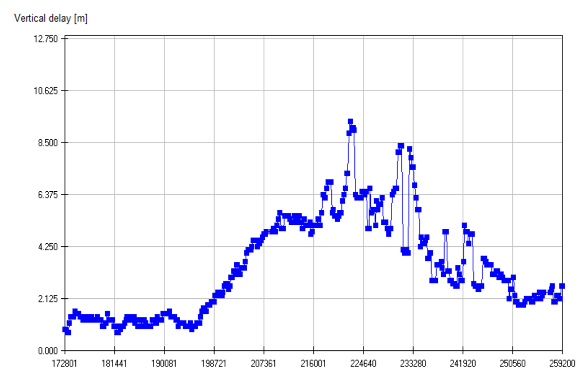

Figure 10. Variation of ionospheric delay over 24 hours for IGP (25° in latitude and 0° in longitude) using AL-SBAS

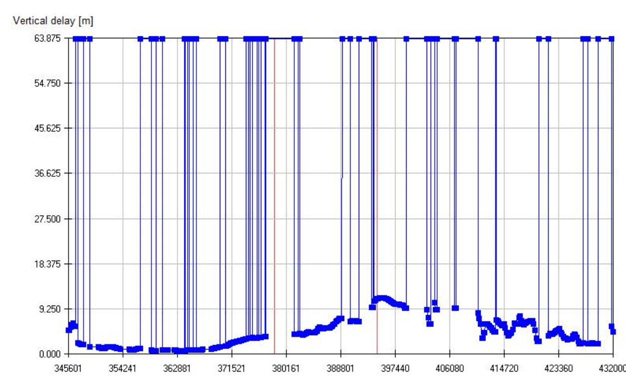

Figure 11. Variation of ionospheric delay over 24 hours for IGP (25° in latitude and 0° in longitude) using EGNOS

For latitude 25°, it is clear to see the lack of data, related to the "Not Monitored" state of EGNOS, while for AL-SBAS, this value varies between 1 m and 9 m.

IV. CONCLUSION

Algeria has been developing a satellite-based augmentation system called Algerian Satellite Based Augmentation System (AL-SBAS). The service area is limited to Algeria and nearby countries. The AL-SBAS augments the GPS standard positioning service by providing differential GPS corrections and integrity monitoring information.

The main objective of this work is to analyse and compare the corrections transmitted by AL-SBAS and EGNOS in Algeria. The major conclusions reached of the analysis performed are:

- The augmentation of AL-SBAS covers the entire country of Algeria, while the EGNOS system covers only the northern part of the country.
- Results of the AL-SBAS performance confirmed that ionospheric corrections from the currently available reference stations are more accurate than EGNOS, particularly in the southern part of Algeria.

These encouraging results open the possibility of a better application of the Algerian SBAS corrections in the future. In addition, it is recommended to test the availability and the effectiveness of AL-SBAS corrections by using a low cost receiver in real time.

As a perspective, we encourage the cooperation between the African air navigation services to accelerate the SBAS services deployment and provision to meet requirements of the aviation and extend the coverage of AL-SBAS system by adding reference stations in neighboring countries in order to improve the system performance.

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