

A FACILITY FOR GPS/EGNOS SIGNAL MONITORING

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The imminent implementation of the final EGNOS version will allow users to obtain not only an improved GPS position, but also better integrity and availability capabilities than the standard GPS. A detailed observation of both the GPS and the EGNOS positioning systems enables the study of the incoming GPS+GALILEO potential features. Thus, our work has been focused on the development of a hardware/software environment for displaying in an intuitive manner a complete set of real time GPS/EGNOS parameters, such as satellite status information, HPL_{SBAS} , GDOP or HPE values. Additionally, some results obtained in real tests performed in urban areas are shown. These results allow the analysis of the services offered by EGNOS.

1. INTRODUCTION

Most of the GPS manufactures provide GPS information software for monitoring purposes included in the sensors. Real time satellite status information, satellite position, type of GPS solution and its quality are usually supplied. Unfortunately, these software programs are proprietary and depend on every GPS receiver.

In terms of the integrity parameters of the current position, most of the receivers are based on GDOP (*Geometry Dilution Of Precision*) calculations. Various parameters are based on this concept: PDOP (*Position Dilution Of Precision*), TDOP (*Time Dilution Of Precision*), HDOP (*Horizontal Dilution Of Precision*), and VDOP (*Vertical Dilution Of Precision*). The algorithms used to calculate these values can be found in [1]. All of them are based exclusively on the satellite constellation geometry used in the GPS solution, and errors caused by a wrong measure of the distance to each satellite are not considered. In order to

mitigate this lack, EGNOS offers to their client equipments the possibility of calculating an indicative value of position integrity which considers pseudorange errors. This factor, named the *Horizontal Protection Level*, or HPL_{SBAS} ¹, can be calculated as explained in [2]. The relevance of the HPL_{SBAS} factor in order to apply GPS/EGNOS to the problem of precise positioning in vehicles can be seen in [3].

Although the GPS/EGNOS monitoring in static stations is useful for researching and control tasks, probably its main benefit is in the dynamic field. For dynamic applications, the navigation software and recently, the freight tracking solutions are more and more considered as fundamental tools for travel guidance and remote management in the road transportation area. An example of a road pricing application which can benefit the resultant GPS/EGNOS system can be found in [4].

The work presented in this paper is based on a GPS/EGNOS monitoring station extensible to any type of receiver, where information of all satellites in orbit, state of the current position, and an historic of the integrity parameters for the solution, included the HPL_{SBAS} , are displayed (section 2). Additionally, an application of EGNOS to a land vehicle navigation system and real results in city environments are also shown in this paper (section 3). The main conclusions of our work are discussed in section 4.

2. GPS/EGNOS MONITORING

The monitoring station is situated in one of the external laboratories of our research group, located in the Campus of Espinardo in the city of Murcia. Next, a description of the components and software used is presented.



Fig. 1: Hardware used in the monitoring station.

2.1. The hardware deployment

As can be observed in Fig. 1, the GPS antenna has been situated over the roof of the laboratory to maximize the reception of signal. The GNSS sensors used are: Novatel Millennium OEM3 Fw 4.521/2.03, Novatel Millennium OEM3 Fw 4.521S1/2.03, Novatel Millennium OEM4 Fw 2.210, Thales DG16, San Jose Navigation FV-21, and Trimble Lassen iQ. The antenna used was included in the Thales kit with the DG16 receiver. By using a power splitter, we can duplicate the signal coming from the antenna and perform test with two sensors at the same time. The computer used is a PC with a Pentium 4.2 GHz processor, 512 MB of RAM and 70 GB of hard disk. The operating system used is Linux Fedora Core 4.

¹ This value is usually called HPL_{WAAS} , but the term HPL_{SBAS} expresses better the algorithm capability to integrate any Satellite Based Augmentation System (SBAS) correction.

2.2. The GPS Control Station Application

GPS Control Station is a software tool developed in Java 1.5 with an intuitive interface which displays the current state of the GPS/EGNOS system. The implementation developed allows us to extend the amount of receivers supported with a low programmatic complexity. Actually, the receivers included in the application are all listed in section 3. Due to the great amount of information which is required by the receiver, it is not possible to use a standard communication protocol, as NMEA, so the access to the device must be implemented.

An interesting feature of the software is its capacity of saving logs at specified rate in the same unified format for all the devices, quite useful in postprocess studies. This format registers all the information available every epoch, including all the data concerning current position, GDOP values, HPL_{SBAS}, and information of GPS and SBAS satellites tracked.

2.3. Controlling the current state of GPS

Fig. 2 shows two screen shots and a zoom of the upper zone of the main window. In the upper zone the current position data is shown. On the left, the current position in latitude/longitude and ECEF and the type of position can be seen, and on the right side, the DOP (*Dilution Of Precision*) values and the GPS time are displayed.

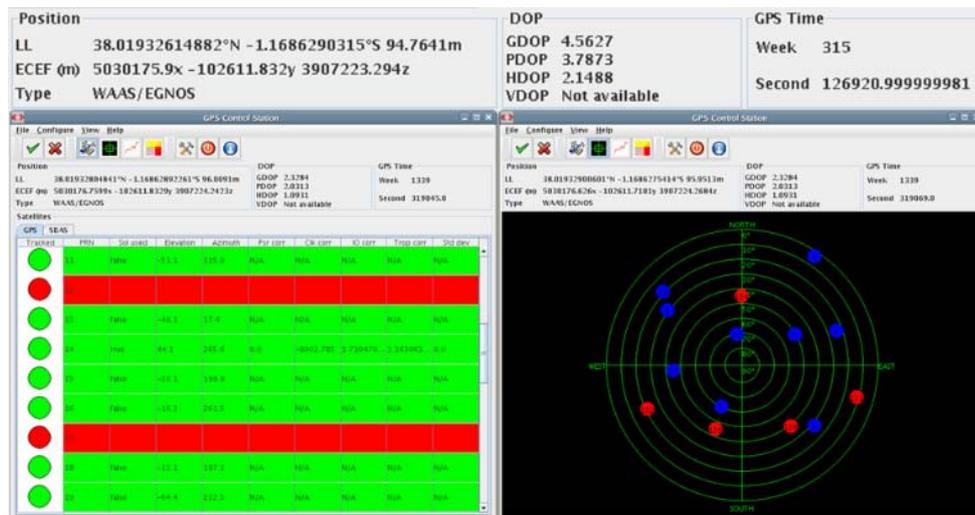


Fig. 2: Satellite information and calculated position.

The lower side of Fig. 2 shows two modes of GPS, EGNOS and WAAS constellation satellite tracking. The left window provides information in text mode concerning the tracked satellites. On the right window the satellites are plotted in a polar diagram, being the red ones SBAS satellites.

2.4. Monitoring the quality and integrity of position

As seen in section 2.3, continuous information about the quality of the position is obtained by the GDOP calculations. However, some other parameters can show the reliability of the

solution calculated by the receiver in a more complete manner. Thus, HPE, VPE and HPL_{SBAS} indicators have been also included.

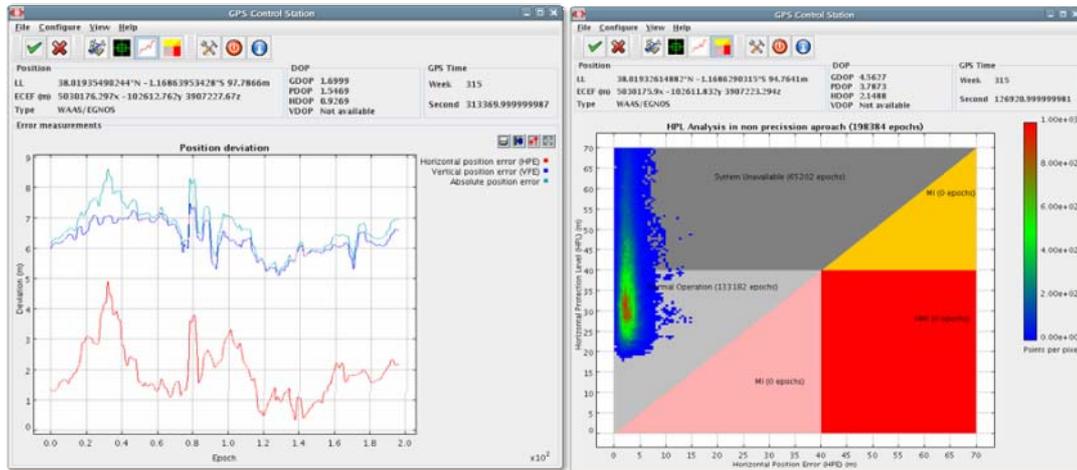


Fig. 3: Position error and HPL graphs.

The HPE (*Horizontal Position Error*) and the VPE (*Vertical Position Error*) values are shown in the left side of the Fig. 3. To calculate the HPL_{SBAS} integrity factor it is necessary to determine, not only the situation of each satellite used and the current position of the receiver, but also information of the pseudorange measurement precision, which is included in the EGNOS messages [2]. Due to this, a continuous flow of EGNOS messages has to be maintained, and a WAAS client must be used to process this information.

Fig. 4 shows the whole system proposed in this paper. Since some receivers can not provide the EGNOS messages, we have considered an alternative approach. On one hand, our software owns functionality to receive EGNOS messages from a capable receiver with an additional communication port (*Local GPS/EGNOS Sensor*). On the other hand, the local PC (Fig. 4) runs a SISNeT client implemented in the GPS Control Station application, allowing the reception of the messages via Internet [5]. As result, the HPL_{SBAS} value can be displayed.

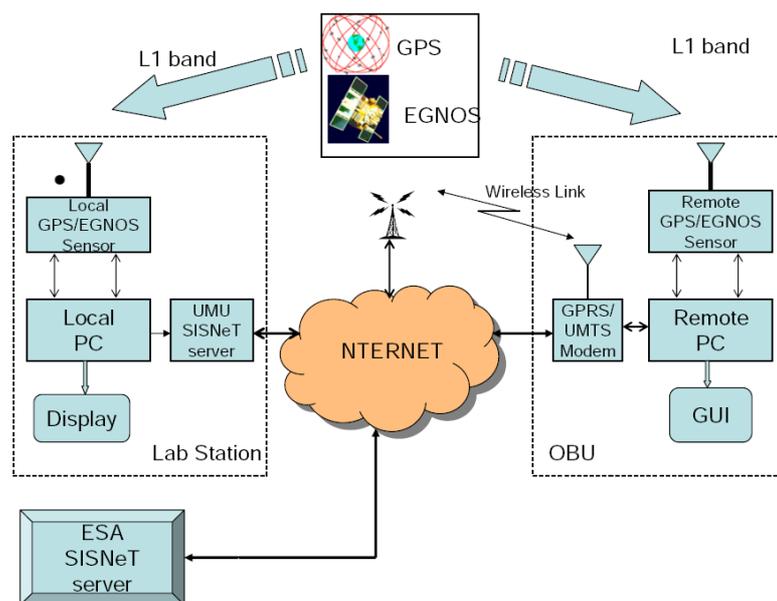


Fig. 4: System architecture.

Equations (1), (2) and (3) show intuitively the iterative calculations required for obtaining the HPL_{SBAS} value. In (1), the $K_{H,NPA}$ parameter is a constant for *Non Precision Approach* mode (NPA) of EGNOS. As observed in (2), the d_{major} value is calculated in a set of operations whose input is the geometry of the satellites used in the solution (ϕ_i), and a value of the error variance in the pseudorange measurements (σ_i^2). As shown in (3), the parameters used to calculate this variance are the fast and long term correction residuals, ionospheric delay, airborne receiver errors, and the tropospheric errors variances, $\sigma_{i,flt}^2$, $\sigma_{i,UIRE}^2$, $\sigma_{i,air}^2$ and $\sigma_{i,tropo}^2$ respectively. Details about the complete calculation can be read in [2].

$$HPL_{SBAS} = K_{H,NPA} \bullet d_{major} \quad (1)$$

$$d_{major} = \phi_i \times \sigma_i^2 \quad (2)$$

$$\sigma_i^2 = \sigma_{i,flt}^2 + \sigma_{i,UIRE}^2 + \sigma_{i,air}^2 + \sigma_{i,tropo}^2 \quad (3)$$

The right side of Fig. 3 shows a screen shot of our application when the HPL_{SBAS} view is selected. This historic shows the Stanford graph, where horizontal axis are HPE values and vertical axis the HPL_{SBAS} . In this graph, an intensive colour represents a big concentration of points with similar parameters. In *non precision approach mode* of EGNOS, the HAL (*Horizontal Alert Limit*) value is set to 40 for the HPL_{SBAS} parameter.

3. EGNOS CORRECTIONS IN ROAD TRANSPORT

In addition to the monitoring station, road application issues have been also investigated. For this purpose, the OBU shown on the right side of Fig. 4. has been developed.

A standard car was equipped with a laptop used as onboard computer. A PCMCIA UMTS card enables the connection of the computer to the Internet. The GPS sensor used in the trials was the San Jose Navigation FV-21 model, with a portable antenna easy to fix on the vehicle's roof. The sensor is powered by the car lighter. The positions are logged into the hard disk of the laptop for postprocess studies. The software developed by our group permits the provision of the EGNOS corrections, whether directly to the receiver, or performing a previous conversion to RTCM (a standard supported by many GPS receivers). Thus, a low cost receiver can be used as a *Remote GPS/EGNOS Sensor* (Fig. 4). In both cases, the EGNOS messages are received from SISNeT via the Internet, so the HPL_{SBAS} value can be monitored by using the method explained in section 2.4.

A simple implementation of a SISNeT server has been developed following the guidelines exposed in [6]. This server, named *UMU SISNeT server* (Fig. 4), is connected to the receiver in the test laboratory and provides controlled and small delay communications. Fig. 6 shows a test of three trajectories following the same itinerary with different configurations: single position, EGNOS, and EGNOS obtained from SISNeT through a RTCM interface. Results can be whether plotted on GIS maps, or superposed on real photos of the trial zone.

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Fig. 5: Test performed in Murcia, Spain, (photograph by Google Earth®).

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