International Beacon Satellite Symposium BSS-2016
Trieste, Italy

An Educational Commercial off-The Shelf GNSS Receiving Station for Monitoring Ionospheric Effects on Positioning Systems

Raydel Abreu Espinet*[1], Guillermo Ayran Torres Lores[1] and Ramón Carrasco Duboué[2]

[1] Space Geophysics Department, Instituto de Geofísica y Astronomía, Calle 212 No. 2906 Reparto La Coronela, La Lisa, Havana, Cuba.
(E-mail: raydel@iga.cu, guille@iga.cu)

[2] Astronomy Department, Instituto de Geofísica y Astronomía, Calle 212 No. 2906 Reparto La Coronela, La Lisa, Havana, Cuba.
(E-mail: ramon@iga.cu)

ABSTRACT

The Earth's Ionosphere represents one of the main error sources on GNSS. While the satellite's signal travels through the ionized media, its travel speed is slowed according to the electron density in the path. Such changes in the speed implies the increase of unknown positioning errors due to the incorrectly measured pseudo-range between the satellite and the receiver. Although many modelling methods for minimizing the ionosphere contributed errors have been developed, not all GNSS receiving stations, especially those that are small, portable and daily used, are capable of having high precision. Still, the Ionosphere can negatively impact on the navigation and general satellite services in a different way; turbulent areas can produce electron content irregularities of small, medium and large size which are responsible for the creation of phase and amplitude scintillations that affects the strength and quality of the received signal, and can even take to the entire loss of track or sync. The ionosphere induced scintillations are most severe at low geomagnetic latitude, while being moderate at high latitudes and little at middle latitudes.

Even though it is quite well known for the scientific and GNSS community the negative impact the ionosphere can have on these system, it is still not highly considered by most users due to the lack of information or interest. This poor recognition of the existence of that considerable source of error can be quite negative in life threatening situations.

Therefore, a simple low budget GNSS receiving station based on Commercial off-The Shelf (COTS) hardware with the purpose of demonstrate the effects of the Ionosphere on these platforms could be a great asset to introduce young students and general public on this topic. While keeping the low cost perspective, such kind of station can be simply built and deployed in a single or network architecture by a local University or Research Facility from a developing nation, as well as in any other place where the available budget could not afford a more professional (and expensive) unit. Despite the fact of being a simple GNSS station based on available commercial hardware, if the inherent limitations are kept into account, some very basic

while yet productive science can be done. It is important to consider that the main limitation for this project is on the quality and capabilities of the chosen receiver,

As a first approach it was used a Jupiter Telit JN3 integrated GPS board which was recovered from a GRAW DFM-06 weather radiosonde which, in this case, decreased the cost of the receiver to zero. The JN3 receiver outputs navigation data at 5 Hz rates. While the current data rate is slow for typical S4 calculations, other commercial receivers on the market like the MTK3339 (e.g.) which supports tracking 22 simultaneous satellites at 10 Hz rates that is the minimum data rate used on many professional GNSS receivers for ionospheric research.

For the development of this prototype a B+ model Raspberry Pi (Rpi) was used as a microcomputer. The Rpi is a low cost, high performance embedded system that uses a Linux platform, so it is not needed to pay for using the operative system. Therefore, it can be used for advanced and complex data processing at low expenses.

The following table shows the overall costs for the construction of the hardware part for a similar station. The price is dependent of the components availability and the desired final performance; highest quality GNSS receiver board and antenna equals to better data quality. Other costs derived from cables, enclosures, waterproofing, etc. are not included.

Part Name	**Typical Price (USD)**
Raspberry Pi B+ microcomputer	~35.00
Integrated GPS/Antenna Board	39.95
5V, 2A AC-DC adapter	~6.00
16 GB USB Flash drive for data store	~20.00
TOTAL	100.95

Table 1 Approximate costs for the main components on hardware side. Excluding cables, cases and waterproofing

The software application architecture is structured by layers that helps to create good software as well to write clearly and legibly source code. Furthermore, object oriented programing with the principles of SOLID (Single responsibility, Open-closed, Liskov substitution, Interface segregation and Dependency inversion) was used. When applied together, a programmer can create a system that is easy to maintain and extend over time. The philosophy of the project is Open source, so it respects the user essential freedoms: the freedom to run it, to study and change it, and to redistribute copies with or without changes.

The Diagram of the project is depicted on the figure below. Basically the system is structured on: A Receiver, three fundamentals layers, a data base and a web interface. The Acquisition Layer Frame, receives the data generated by the Receiver and send specific frames to the next layer. Data Handling & Verification handles the parsing of frames and Data Base management. The Analysis Layer deals with the implementation of Data Mining algorithms and Exploratory Data Analysis.

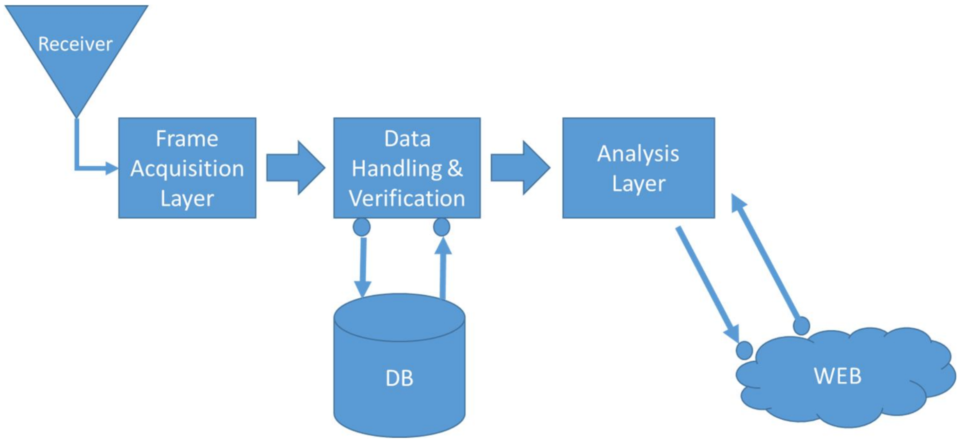

Figure 1. Block diagram of the main components in the system's software.

The code is written in Python 2.7, a programming language that allows agile software development. Python's community is vast, diverse and growing. It also has high power calculation scientific libraries. This language also contributes to the development, extensibility and maintenance of the system. The development of the web interface was implemented using Django, a free and open-source web framework, written in Python as well, which follows the Model–View–Template (MVT) architectural pattern based in the Model-View-Controller (MVC) architectural pattern.

On the current step of the development, the web page shows the positioning error measured for each time interval and generates the S4 index graph for every available satellite arc. The plotted data can be shown either in real time or from a selected time frame.

Key words:
GNSS, Ionosphere, Scintillation, Positioning Errors, Education, Raspberri Pi

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Acknowledgements: The authors would like to acknowledge the help of Mr. Valentino Morandini for the donation of the Rpi microcomputer, Mr. Alex Zinken who kindly sent us the GPS board used and Mrs. Katy Alazo Cuartas for several years of teaching and support.