Ionik network based on a low cost scintillation monitor for continuous monitoring of ionosphere

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Introduction

The Global Navigation Satellite System (GNSS) signal is an important tool for monitoring the ionosphere. The ionosphere under low latitudes has a particular dynamics with generation of plasma irregularities bubbles. This phenomenon affects the communication near the geomagnetic equator region. The Brazilian territory is the major one in South America (Figure 1), located in the eastern part bordering the Atlantic Ocean; it occupies almost 50% of this region of the continent. This expansive territory is mainly belonging to the low latitude and equatorial regions and therefore is directly affected by the ionospheric irregularities. This large territorial size is a challenge for monitoring and mapping the ionospheric characteristics and consequently its effects for GNSS users, more specifically for aviation and precision agriculture.

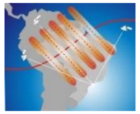

Figure 1: Bubble mapping over South America

Goal

In this work it is presented a low cost scintillation monitor developed under requirements of low complexity and simple interface. This monitor does not need computer interface for operation and the acquired data is transmitted by internet to a remote server that will process and store the data. This kind of device is nowadays feasible because in the past two decades the advances in semiconductor technology resulted in microelectronics systems more integrated, which also resulted in a low-power consummation, substantial dimension and weight reductions, with increasing of reliability and signal processing capability.

Project overview

The prototype hardware (Figure 2) of the scintillation monitor: uses Arduino with GPS Adafruit Breakout, gets data at 10 Hz as NMEA sentences, receives about 100 Mb each 8 hour recording and costs about $100,00. The software and web development are shown at Figure 3.

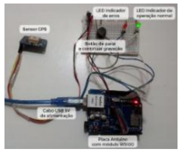

Figure 2: Arduino prototype

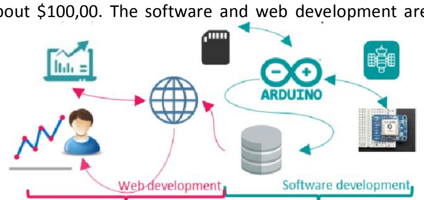

Figure 3: Project overview including the software and web development

The web project has been developed with HTML, CSS, Javascript, PHP and SQL database using Bootstrap and Chart.js. The image (to the right) represents the querying platform.

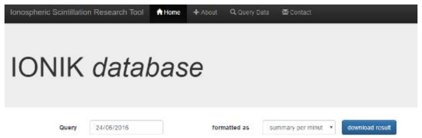

Figure 4: web interface

Data processing

At each 10 seconds the GPS sensor gets 10 frames of 6 NMEA sentences that contains mixed information as lat/long data, GMT time, satellite PRN, azimuth, elevation and SNR for each satellite in view. To calculate the ionospheric coefficients, the NMEA data is prepared and each satellite information is organized as "HrMinSec(UTC); Day; Month; Year; Satellite PRN number; Elevation; Azimuth; SNR". Finally S4 index can be calculated for each satellite per minute (using about 600 different SNR samples) as

$$S_4 = \frac{std(I)}{mean(I)} \text{ where } I = 10^{\frac{SNR}{10}}$$

Based on the measurements of this monitor, a series of scintillation parameters like, scintillation index S_4, decorrelation time τ_0, fading coefficients α and μ, besides positioning are acquired. The first prototype was deployed at São José dos Campos (23.21° S, 45.95° W, -19.5° dip latitude, declination 21.4° W), Brazil, on November 2016 and the results were validated against a Septentrio scintillation monitor that is available in the market. The validation results showed a good agreement between the monitor developed and the commercial receiver, including for strong scintillation conditions.

Validation and preliminar results

The project concept of a low cost scintillation monitor has been successfully proven based on 2 months of observation between November 2016 and January 2017. The second phase of the project was the network tests. Currently, the challenge involves the installation of eleven stations distributed over the Brazilian territory with planning of expansion for more thirty units. Figure 5 showns one example of Ionik raw scintillation data. The main results that validated the Ionik project are shown in the Figures 6 and 7.

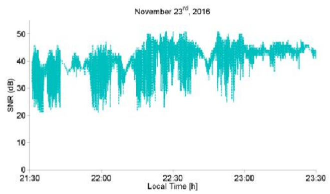

Figure 5: Example of raw scintillation data

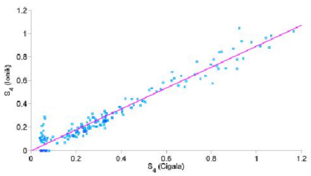

Figure 6: Ionik and Cigala/Septentrio S_4 comparision

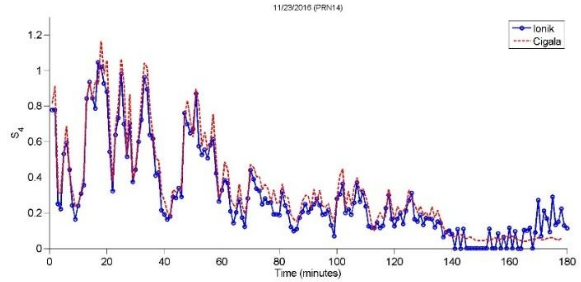

Figure 7: Comparison between the proposed and the Cigala/Septentrio scintillation monitors for different levels of S4 data

Finally, after the Ionik prototype validation with Cigala/Septentrio, data web plotting using Chart.js was done, including satellite elevation (in degrees) and 100 $* S_4$ versus time on the same chart (see Figures 8 and 9 below).

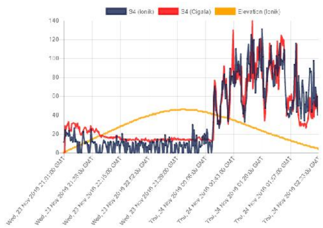

Figure 8: satellite PRN=26 in Nov. 23,24 2016

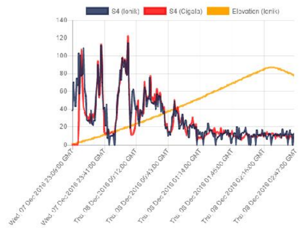

Figure 9: satellite PRN=14 in Dec. 07,08 2016

Next steps

These low cost scintillation monitors are expected to integrate the CIGALA/CALIBRA network and the corresponding database. In the future, it is planned to have a system for real time monitoring, imaging and warning of bubble structures that may affect GNSS applications, more specifically for aviation users. The Ionik project is based in a collaborative and open source environment and in the future we expect to provide the firmware for users that will be able to integrate their prototypes in this network.

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