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Ionospheric scintillation effects on DGPS positioning

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Abstract

Dynamic position vessels (semi, drill ships, tug boats) performing deepwater petroleum exploration and production works at Campos Basin (22.46º S, 40.06º W), use DGPS (Differential Global Positioning System) as one of two available reference positioning system. A loss of one system degrade the DP vessels and could interrupt the operation. From middle of September 1998 up to February 1999 scintillation on GPS satellite radio signal and differential satellite signal, at the Campos Basin (Petrobrás-Macaé-RJ), caused deterioration and even loss of the GPS positioning system, from about 2030 up to 2400 LT. As this coincides with the time interval of ionospheric irregularities occurrence, we analysed the signal amplitude using Cornell University GPS receiver, specially developed to detect scintillations during such irregularities, which is operational at São José dos Campos (23^o S, 45^o W, dip latitude 13^o S) since September 1997. Good correlation was observed between these events, using this methodology.

INTRODUCTION

The ionospheric plasma irregularities, which are called spread F, are generated after sunset in the equatorial region by plasma instabilities. After the generation at the F region base, they can grow in altitude and extend about 10,000 km along the magnetic field lines, configurating what is called an ionospheric plasma bubble (Sobral et al., 1980 a; 1980b; 1998), which can reach low latitudes like São José dos Campos and Campos. These bubbles are characterized by a depleted plasma density and intensified zonal electric field in its interior and large range scale instabilities are observed at their boundaries. The occurrence of the irregularities can be detected by distinct instruments such as digisondes, photometers, radars, payloads on board of rockets and satellites and GPS receivers. Many works (Klobuchar,1996, Campos and Wanninger,1997) showed that the GPS receiver performance can be deteriorated by the ionospheric scintillations, reducing the signal strength, increasing the number of cycle slips and even causing inability to perform measurements. In this work we use the signal amplitude of the GPS receiver developed by Cornell University to identify the irregularities and try to correlate them with the DGPS failures over the brazilian region (Campos basin), provided by Petrobrás on data sheets. The Cornell GPS card is a modified GEC-Plessey that has the ability of measuring the signal power and noise at a high rate. This card has 12 channels which process digitally the received signal and is inserted in a PC, which performs low level operations like achieving lock and maintaining tracking of the satellite signal at the L1 band (1.57542 GHz). Beach(1998) describes the detailed modifications in the Plessey system including softwares to study the equatorial scintillations. Since September 1998, many cases of loosing the positioning were reported by the DGPS system at the Campos basin and these informations were compared with our GPS receiver data in São José dos Campos.

DATA PRESENTATION

Figure 1 shows satellites azimuth-elevation plots(upper part) and of the projections of GPS signal subionospheric points at 300 km (lower part), for the night of January 29, 1999. In the uper part of this figure the big circles represent the elevations of 0, 30 and 60^o , the center is the zenith for the receiver site and in the lower part the receiver site is located at the center of the linear grid. Also in this figure the dashed lines represents the satellite tracks and the diameter of the small circles indicates the amount of signal strength variance over a one minute period, relative to the mean value of signal strength for that period. Signal strength variance over one minute intervals is caused by ionospheric scintillations. Figure 2 shows the wide band power of the received signal for October 04, 1998. This figure shows that the power of many satellites in various positions in the sky suffers strong scintillations what can cause deterioration and even loss of positioning by the GPS receivers. Figure 3 shows the periods of ocurrence of ionospheric scintillations at São José dos Campos and failures in the positioning of DGPS at the Campos basin, for the period September 29 to October 19, 1998, and a good correlation between them was observed. It was reported vertical positioning errors of about 25 m in the vertical positioning of these DGPS and complete lack of positioning at the Campos basin,during ionospheric bubbles.

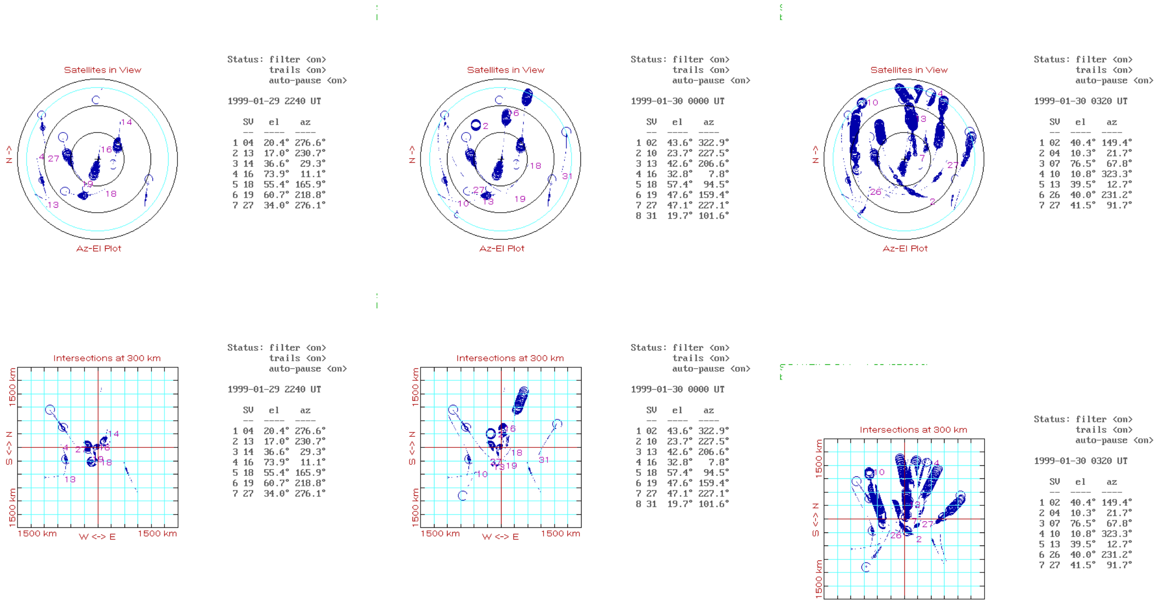

Figure 1 – Satellites azimute-elevation and signal subionospheric points projections

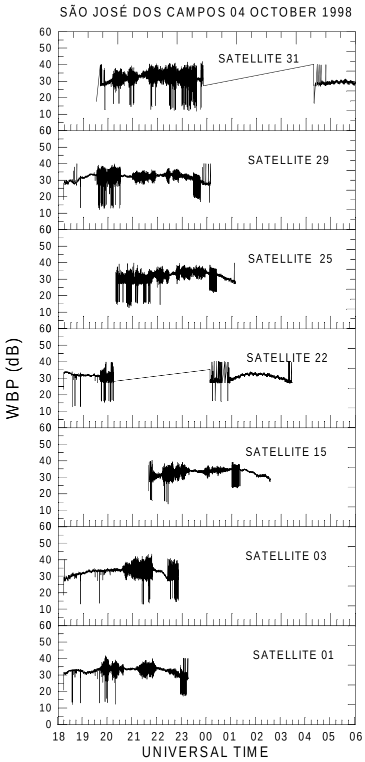

Figure 2 – Received signal wide band power

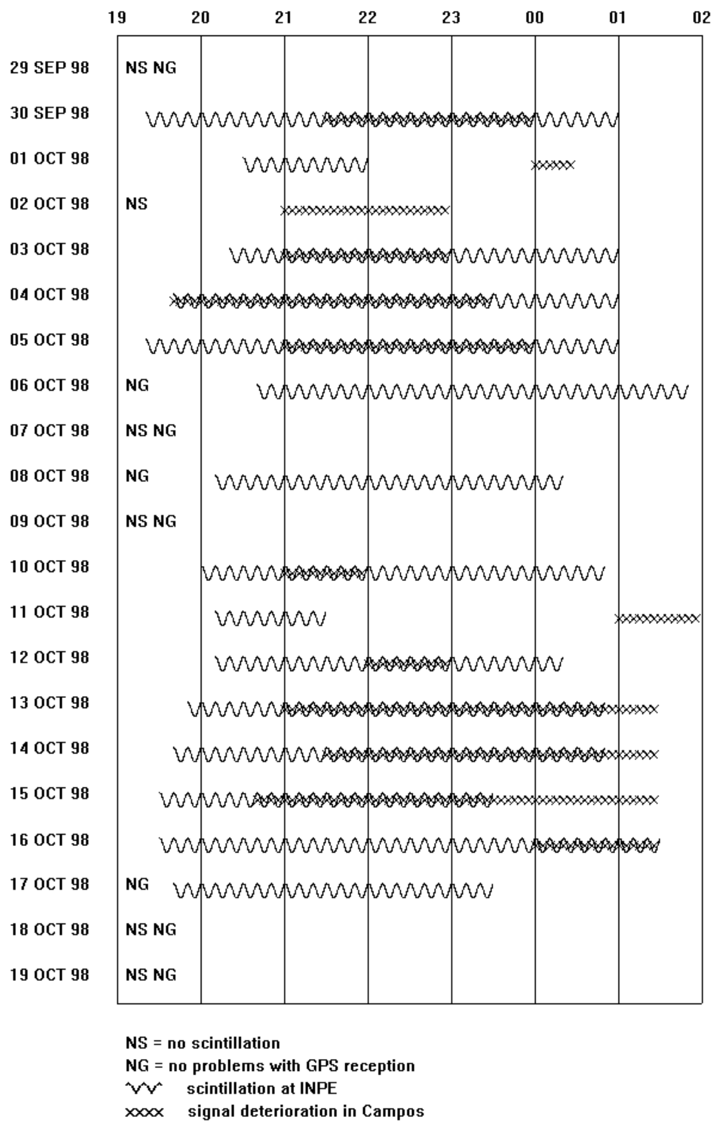

Figure 3 – Periods of occurrence of scintillations at São José dos Campos and failures in the DGPS positioning at Campos basin in function of the local time.

DISCUSSION AND CONCLUSIONS

Analysing the GPS receiver signal scintillations during ionospheric bubbles at São José dos Campos and simultaneous failures of DGPS positioning at the Campos basin we could observe strong evidences that the phenomena are correlated. As the ionospheric irregularities occur mainly from September to March over the brazilian region and knowing that their occurrences vary periodically with solar cycle, that probably will reach the maximum in about 2 years, the DGPS users for positioning over our region should be aware of interferences and they should think about alternative positioning systems during the time interval of about 2030 to 2400 LT. Strong magnetic storms, like the storm of 26th of August 1998, can also trigger strong ionospheric scintillations and they can occur at any season and at any time of the solar cycle.

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