A DISCUSSION ON GPS ERRORS DUE TO IONOSPHERIC SCINTILLATIONS BASED ON HF MEASUREMENTS

Mauro S. Assis[(1)], Ângelo A. C. Canavitsas[(2)] and Giuseppe Amendola[(3)]

[(1)]*Fluminense Federal University – UFF - Rua Coelho Neto, 17 Apt.301*
Rio de Janeiro – RJ, 22231-110 – Brazil - msassis@openlink.com.br

[(2)]*Air Space Control Department – DECEA -* canavitsas@openlink.com.br

[(3)]*Military Institute of Engineering – IME - Praça Gen. Tibúrcio, 80*
Rio de Janeiro – RJ, 22290-270 –Brazil - gamendola@uol.com.br

ABSTRACT

Based on the physical evidence that signals in different frequencies are equally affected by the presence of the ionosphere, this paper investigates a possible correlation among GPS errors and HF multipath fading. This correlation could be the basis for the development of an adaptive algorithm for correcting GPS errors in equatorial regions. In this context, HF measurements in a 1500 km long radio link, between Cuiabá (19.02S ; 57.65W) and Rio de Janeiro (22.88 ; 43.28W), were carried out simultaneously with GPS signals from a station located near the middle point of this path in Presidente Prudente (22.12S ; 51.37W). The preliminary analysis of the acquired data was shown to be promising enough.

INTRODUCTION

Nowadays, the Global Positioning System (GPS) evolved into a widely accepted tool for a variety of applications in different areas. Geodesy, agriculture, fishing, atmospheric studies and radio-navigation are examples where the use of this technology has had a major impact. Emphasis on the use of GPS has increased after the disabling on 02 May 2000 of the S/A (Selectivity Availability) signal which was conceived for introducing errors in the information from GPS satellites for civilian users. However, depending on the degradation of the satellite signals after crossing the ionosphere, the accuracy of GPS could be seriously affected. This problem is particularly important in the equatorial region where, due to the ionospheric equatorial anomaly, small-scale irregularities within ionospheric bubbles or patches are sources of intense scintillation effects in the post-sunset period. On the other hand, there is a physical evidence that these irregularities are the common source of HF multipath fading and GPS errors. Consequently, simultaneous measurements of these two phenomena, associated to ionosonde predictions, could give an adequate information for the development of an adaptive algorithm for correcting GPS errors. The first path in this process, i.e., a possible correlation among GPS errors and HF multipath fading is investigated in this paper.

IONOSPHERIC SCINTILLATIONS

Ionospheric scintillations refer to random amplitude and phase shifts of radio waves due to propagation through small-scale non-homogeneities of the ionosphere. These scintillations may cause significant errors in the GPS measurements, as well as loss of lock on GPS satellites. Small-scale scintillation effects are observed in the high latitude auroral region and in the equatorial anomaly region (see Fig. 1). In low latitude areas, this anomaly consists of two maxima in electron density, located approximately 15^0 North and South of the magnetic equator. The daily equatorial anomaly generally begins to develop near 9:00 - 10:00 hours local time, and reaches its maximum around 14:00 - 15:00 hours and persists until after the sunset, when no more ionization is produced by the sun. The cause of this phenomenon is the combined action of electric and magnetic fields. First, there is a shift of electrons upward followed by a diffusion downward along the lines of the geomagnetic field where it intersects the normal F2 layer. This movement is called fountain effect. A developed equatorial anomaly in the afternoon hours may be taken as a precursor of scintillations in the post-sunset hours [1].
In the early evening, while the enhanced ionization is decreasing, vast irregularity regions with the shape of expanding bubbles appear near the altitude of 250 km (F2 layer). These bubbles are generated by a dynamic process named Rayleigh - Taylor instability and during the evening hours they grow up to 1000 km. The bubbles form holes in the local ionization and radio waves are refracted by these discontinuities.

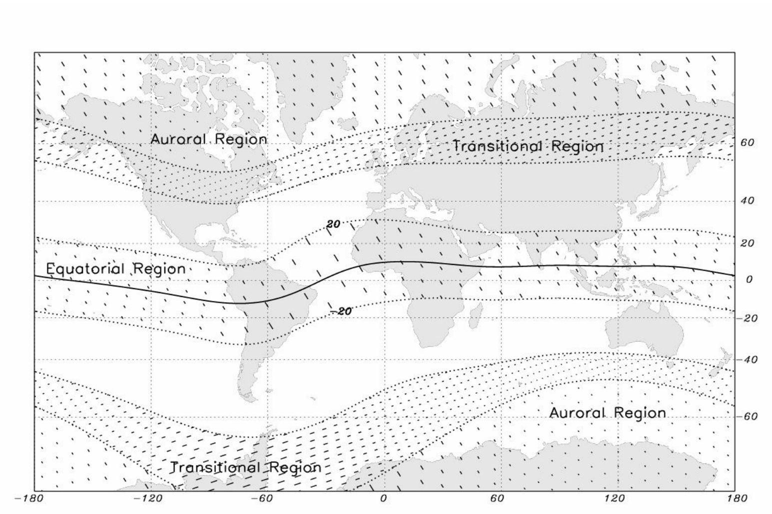


Fig. 1 – The regions of the ionosphere

The scintillation effect is due to the multipath associated to this random propagation mechanism. Equatorial scintillations are strongest at solar maximum, near the equinoxes in March-April and September-October. In general, ionization irregularities can be seen on an ionosonde as a spreading of F2 layer.

GPS AND HF MEASUREMENTS

The rationale behind the methodology used in the analysis of GPS errors was based on the following ideas:
i) GPS errors are caused by scintillations due to small-scale irregularities in the ionosphere;
ii) HF radio waves propagating through the ionosphere also exhibits a multipath variations;
iii) GPS and HF signals crossing simultaneously the same portion of the ionosphere are probably highly correlated;
iv) Ionospheric soundings in the afternoon could anticipate intense scintillations in the post-sunset period.

In order to verify statement iii) above, the following experimental setup was implemented. A 100 W HF radio link 1500 km long, operating in the frequency of 23 MHz, was installed between Cuiabá (19.02S ; 57.65W) and Rio de Janeiro (22.88S ; 43.28W). A GPS station was located near the middle point of this path in Presidente Prudente (22.12S ; 51.37W). This configuration is illustrated in Fig. 2.

About 40,000 samples a day of HF signal levels were registered from 01 October to 06 December 2002. Simultaneous observation of GPS errors (latitude, longitude and altitude) were done in the same period. Figures 3 and 4 show examples of these measurements. In figure 3a it is observed a regular variation of the HF signal. The corresponding GPS errors (figure 3b), in spite of a larger deviation from the median value, has essentially the same behaviour. However, in figure 4, both HF signal and GPS errors have an abnormal behaviour from 19:00 to 22:00 hours. The same behaviour was observed along the whole period mentioned above, being an indication that GPS errors and HF multipath fading are probably highly correlated.

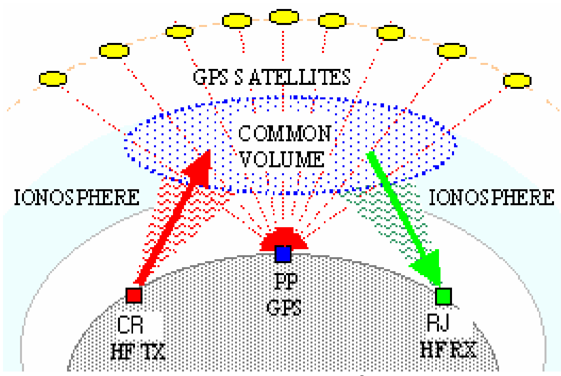
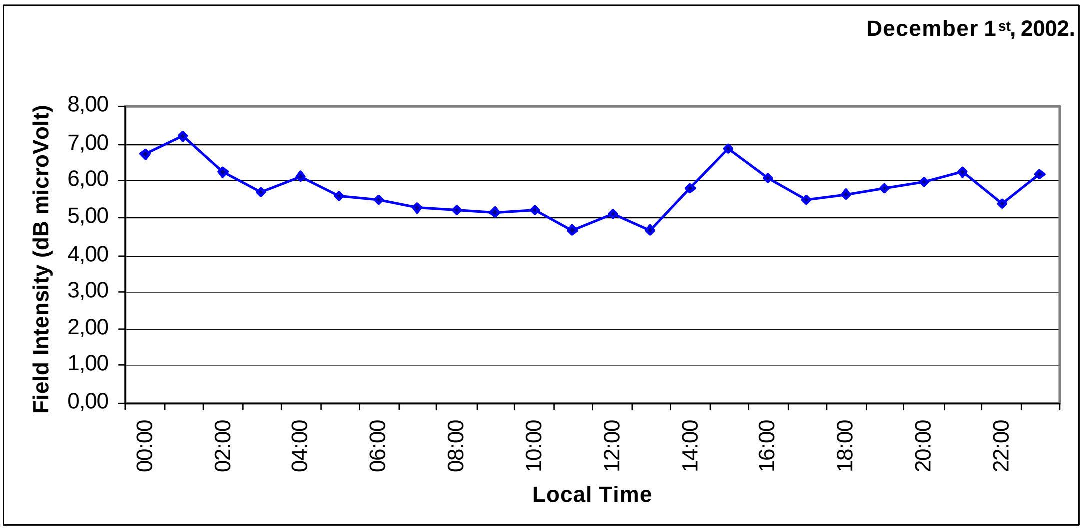
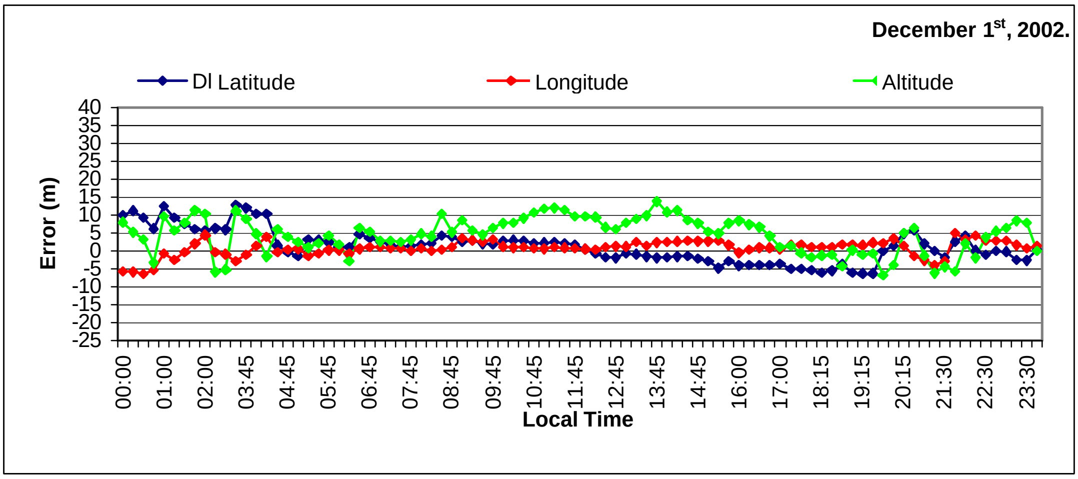


Fig. 2 – Measuring configuration



a) HF measurements

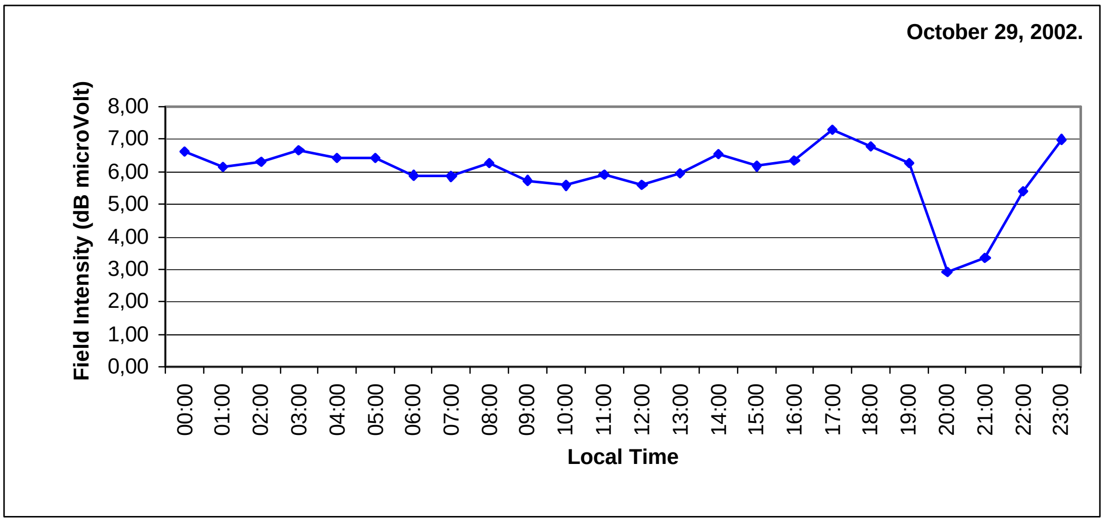


b) GPS errors

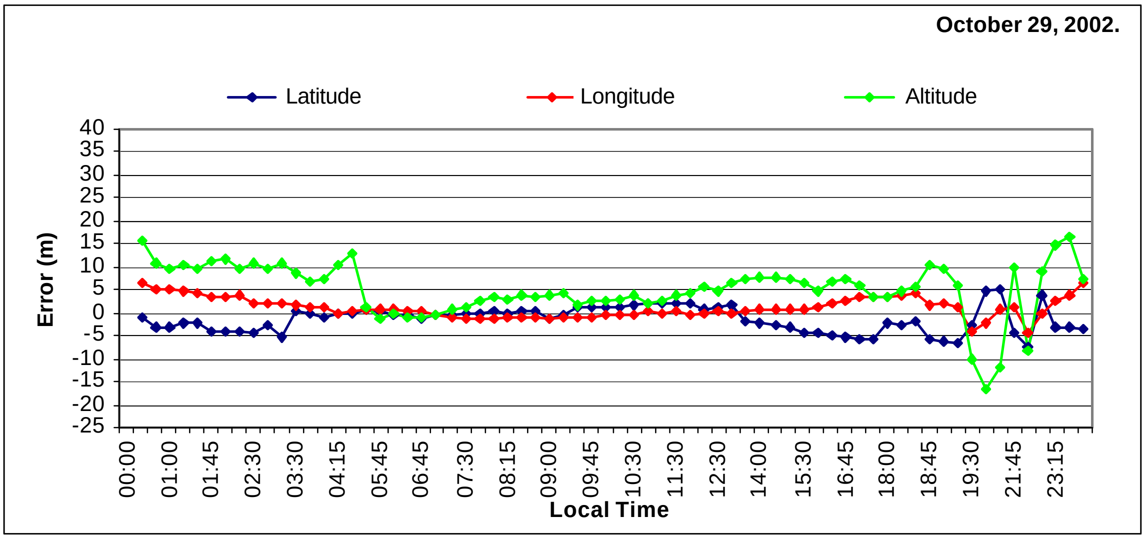
Fig. 3 – Regular behaviour

CONCLUDING REMARKS

The results presented in this paper show the evidence of a correlation between GPS errors and HF radio signal variations. Of course, more experimental data are needed, preferably at frequencies lower than 23 MHz, to better fix the starting of the abnormal behavior of HF signals. On the other hand, considering that equatorial anomaly is the origin of ionospheric scintillations, based on ionosonde measurements, the next step will be a detailed study of this phenomenon.



a) HF measurements



b) GPS errors

Fig. 4 – The effect of ionospheric scintillations

ACKNOWLEDGEMENTS

The authors are deeply indebted to Mr. M. A . Alves da Silva for his dedication in collecting and processing a very large amount of HF radio measurements. Thanks is also due to Prof. Dr. P. O. Camargo who supplied GPS data collected at Presidente Prudente.

REFERENCE

[1] Paul, A., “Prediction of equatorial ionospheric bubbles in the post-sunset hours”, *XXVIIth General Assembly of URSI*, Maastricht, Netherlands, 2002.