GPS anisotropy measurement on high latitude

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ABSTRACT

Fluctuations in the parameters of the radio signal passing through the ionosphere called scintillation in the case of GPS measurements come down to measuring the amplitude and phase of the signal of the carrier wave signal at the GPS frequency 1575 MHz. These measurements allow for the study of irregularities in ionospheric electron concentration, but these measurements are largely depend on movement of the satellite-receiver raypath (scan) and the evolution of if ionospheric irregularities.

For measurements at high geomagnetic latitudes this is a big problem. Scan speed is a small fraction of the expected ionospheric drift that could reach several hundred meters per second. The result is that it is hard to transfer frequencies to scales of observed structures. At the same time low signal to noise ratio only in rare cases permit for determination of the drift velocity by finding of the Fresnel frequency.

The alternative method is to measure scintillation on a set of at least three antennas which allow for estimation of the drift velocity and the shape of irregularities responsible for the formation of scintillation. Though due to weak signal to noise ratios of GPS measurements as well as the nature of studied irregularities the estimation is not always possible.

Below we present the result of the analysis of data from 3 independent GPS receivers installed on the Polish Polar Station on Spitsbergen. The receivers are arranged in the corners of a right triangle with oriented sides geographically oriented north-south, east-west. Separation between the antennas is approximately 100m. Amplitude and phase of the GPS signal is sampled at 50Hz. Permanent observations started in September 2007.

On the basis of these data S4 (amplitude scintillation index) and phase variance indexes have been determined to quantify intensity and phase scintillation respectively. The level of indices and signal spectra form a criterium for a low signal to noise ratio. For amplitude scintillation power spectrum remains generally flat across the frequency range which shows an insufficient sensitivity of the measurement method. Only during very large disturbances one can observe power law behavior consistent with ionospheric scintillation theory. At the same time there is a significant correlation between the intensity of scintillation and geomagnetic activity index Kp and location of cusp, which in the periods of high activity should move towards low geomagnetic latitudes and be better seen by the receivers.

In case of phase scintillation the signal appears to be less contaminated with noise. The in the frequency range 0.1-1.0Hz power spectra show power-law character. Useful frequency range broadens with increasing sigma phi, confirming the assumption on high noise influence on the signal.

In order to investigate the usefulness of multi-antenna measurement the level of spectral coherence of signals from different antennas has been used. It allows to choose the frequency range useful for further analysis. To determine the drift velocity and derive anisotropy of irregularities we used correlation method described in [1]. The data has been initially filtered leaving only the band between 0.3 and 1.2 Hz. This largely eliminates the influence of noise on estimation.

Statistical analysis of estimated drift velocities is in a good agreement with the expected drift pattern for large latitudes. It should be noted, however, that the amount data suitable for the analysis does not exceed 15% of the total number of measurements for phase and 8% for amplitude. A small percentage of data useful for the analysis is caused on the one hand by weak intensity of scintillation that causes the need for strong data filtering. On the other hand, it may be the effect of fast structure evolution between successive measurements on antennas and non-compliance of observed waveforms. Weak correlation for higher frequencies seems to suggest that the settled distance between the antennas (100m) can be too large.

It seems that a possible solution to the GPS method shortcomings could be application of lower frequencies where diffraction effects should be much larger and increase of antennas number which could allow to verify the hypothesis about the evolution of irregularities. We are considering the application the LOFAR observations for this purpose. It has both a large number of antennas, as well as scintillation in the UHF / VHF should be several times stronger. Location of the station will give opportunity for studying mid latitude ionospheric scintillation.

Key words: Irregularities, Anisotropy, Ionosphere, GPS, Scintillation, LOFAR

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