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USE OF GPS NETWORK DATA FOR HF DOPPLER MEASUREMENTS INTERPRETATION

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Abstract. HF Doppler technique has the high sensitivity to small frequency variations and the high time resolution, but interpretation of results is difficult. In this work we make an attempt to use GPS data for Doppler measurements interpretation. Modeling of Doppler frequency shift variations with use of TEC allows to separate ionosphere disturbances of medium scale. The join use of dual frequency phase GPS measurements and Doppler measurements will allow to estimate spatial localization of disturbances.

1 INTRODUCTION

An HF Doppler technique based on frequency shift measurements is widely used for ionosphere research. Advantages of the HF Doppler technique are the high sensitivity to small frequency variations and the high time resolution. It allows to research various disturbances in the ionosphere. This technique is used at radiophysics department of Kazan University (Russia) since 2001 for ionosphere sounding. The measuring equipment is a system of closely spaced receivers. Characteristics of the measuring equipment, technique of experiment and data processing are described in our early work[1].

Experimental data were analyzed using window Fourier transform. The interval of spectral analysis has been chosen according to the stationarity interval of oblique sounding signal[2]. Typical values of this interval are the order of 40 seconds. The mean values for Doppler frequency shift (DFS) of radio signal were calculated as

$$\Delta f_D = \frac{\Sigma_i |A(f_i)|^2 f_i}{\Sigma_i |A(f_i)|^2} \tag{1}$$

where $A(f_i)$ - amplitude, f_i-frequency of harmonics. Thus, we have the continuous DFS series. The subsequent wavelet processing of the series allows to analyze the ionosphere disturbances of different scale.

However the interpretation of Doppler technique results is difficult because of cumulative nature of data both in space and in time. Therefore the analysis demands use of results obtained by other methods. In this work we make an attempt to use GPS data for Doppler measurements interpretation.

2 MODELING OF DOPPLER FREQUENCY SHIFT WITH USE OF TOTEL ELECTRON CONTENT

DFS is proportional to change of the ionosphere electron content.

$$\Delta f_D = -\frac{1}{2}\frac{e^2}{\pi m_e c}\frac{1}{f}\frac{d}{dt}N_s \tag{2}$$

$$N_S = \int_S N_e dS$$

where, f- operating frequency, N_e-electron density, S-ionosphere signal path. Change of N_s correlates with change of Total Electron Content (TEC) measured using GPS signal. Therefore DFS has been modeled with help of TEC. The model of linear regression has been applied.

$$\Delta f_D^{model} = a_1 I + a_2\frac{\partial I}{\partial t} + a_3\frac{\partial I}{\partial \theta} + a_4\frac{\partial I}{\partial \varphi} \tag{3}$$

where *a1,a2,a3,a4* - regression coefficients, I - TEC, $\frac{\partial I}{\partial t}$ - time derivation, $\frac{\partial I}{\partial \theta}$ I - longitude derivation,$\frac{\partial I}{\partial \varphi}$ - latitude derivation. The regression coefficients have been calculated by the least squares technique. Figure 1 shows experimental data and results of modeling.

For this example we used Doppler measurement received on 2.03.2006, frequency 4.996 MHz, radio path Moscow (Moscow $(55^o45'N, 37^o18'E)$ Kazan $(55^o49'N, 49^o08'E)$.

We used Global Ionosphere Maps (ftp://cddisa.gsfc.nasa.gov/pub/gps/products/ionex) for DFS modeling. This allowed to take into account the global-daily variations of TEC. The residual component variations are caused by ionosphere disturbances of medium and small scales. Their propagation to the ionosphere is an important factor in the system of the global atmospheric circulation. HF Doppler technique allows to study of these disturbances.

3 LOCALIZATION OF IONOSPHERE DISTURBANCES WITH USE OF DOPPLER MEASUREMENTS AND GPS DATA

The spectral analysis of DFS variations for HF signals has been presented in our early work[3]. In this work we intend to analyze spatial localization of medium-scale ionosphere

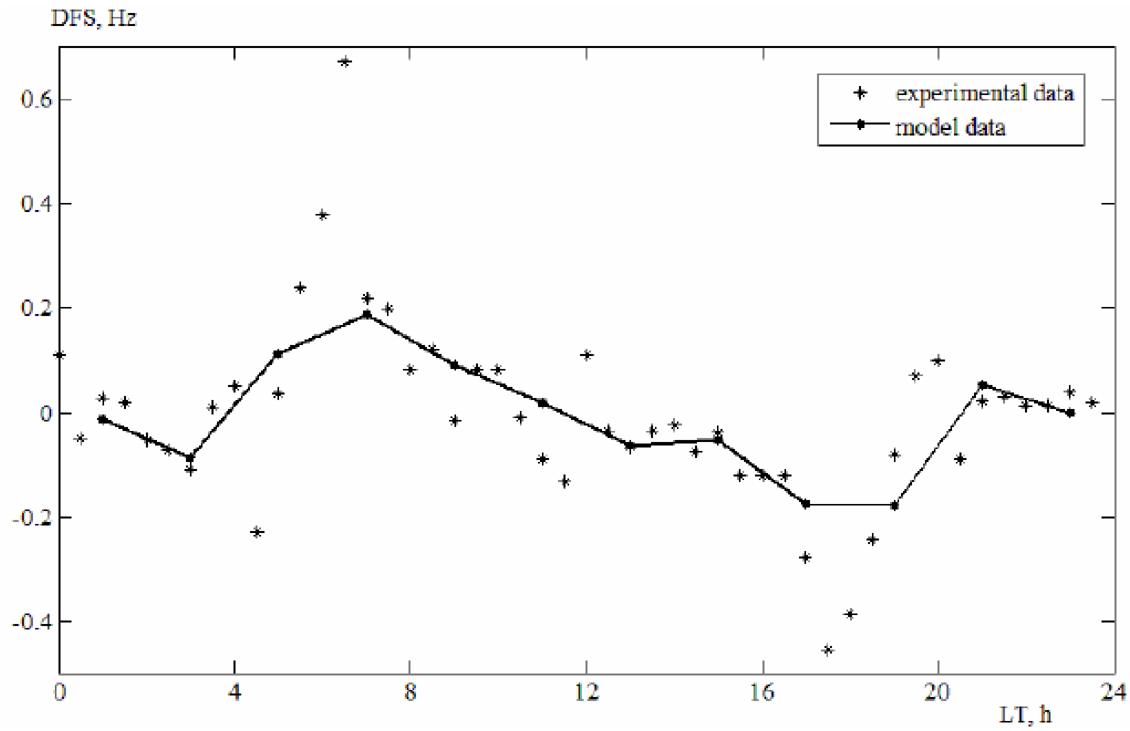

Figure 1: Experimental data and results of DFS modeling (LT local time).

disturbances and their effect on DFS.

The dual frequency phase GPS measurements can be used for localization of ionosphere disturbances. GPS data corresponding to Doppler measurements are selected. Regular changes of pseudorange because of satellite movement are corrected. The cross-spectral analysis of DFS and pseudorange series is performed. Pseudorange variations coincident with DFS variations i.e. the having the same periods are selected. Correlation coefficients for different tracks are compared. It allows to deduce a spatial localization of ionosphere disturbances. The motion direction of ionosphere disturbances can be estimated on the basis of calculations for the different time points. Joint use of Doppler measurements and GPS data allows to improve a technique for localization of ionosphere disturbances based on the GPS data.

4 CONCLUSIONS

- In this work will be presented the results of DFS modeling with use TEC, their comparison with experimental data Doppler measurements and analyze obtained ionosphere disturbances of medium scale.

- The join use of dual frequency phase GPS measurements and Doppler measurements will allow to estimate spatial localization of disturbances.

REFERENCES

[1] I.R. Petrova, V.V. Bochkarev, V.Yu. Teplov, O.N. Sherstyukov. The daily variations of Doppler frequency shift of ionospheric signal on middle-latitude radio lines, Adv. Space Res.,40 (6), 825-834, (2007).

[2] V.V. Bochkarev, I.R. Petrova and V.Yu. Teplov. Experimental study of the nonstationarity of an oblique ionospheric sounding signal on a mid-latitude HF radiopath. Radiophysics and Quantum Electronics, 47, N8, 619-629, (2004).

[3] I.R. Petrova, V.V. Bochkarev and R.R. Latipov. Application of HF Doppler measurements for the investigation of internal atmospheric waves in the ionosphere, Adv. Space Res., 44, 685-692,(2009)