GLONASS/GPS SINGLE FREQUENCY RECEIVER TEST VALIDATION USING IGS AND DORIS DATA

Andrei Alechetchkine[2], Shota KAVTARASHVILY[1], Mikhail KAZANTSEV[2], Vladimir KOKORIN[2], Yuri Fateev[2]

[1] NPO PM, Lenin st., 52, Zheleznogorsk, Krasnoyarsk region, 662990, Russia
[2] Krasnoyarsk State Technical University (KSTU), acad. Kirensky st., 26, Krasnoyarsk, 660074, Russia

The numerous researches testify that on the eve of earthquake there are various perturbations of electromagnetic waves propagation in near Earth space. These perturbations are fixed by various equipment, and can serve as indications for the of earthquakes prediction.

In [1] the method consisting in use of a web control - corrects stations (CCS) of a differential subsystem of space navigational systems (SNS) for seismic monitoring of the Earth is offered. The essence of the given method is that above a site of preparing earthquake an area of ionosphere perturbations with increased concentration, on a comparison with the adjoining sites ones of charge carriers. Since each navigational satellite of SNS is moved on a beforehand known orbit and the CCS coordinates are known with a high accuracy, the true values of CCS-satellites ranges also are known with a high accuracy. The measured and known distances difference represents a measurement error, which magnitude substantially depends on ionospheric conditions, so can be used for the earthquake prediction. Knowing a satellite position with anomalous values of measurements it is possible to find an ionosphere area of the increased electronic content (concentration) and so to locate a preparing earthquake.

Shortage of the offered method is the necessity to use for the ionosphere parameters definition the expensive two-frequency navigation receivers.

For the definition of ionosphere parameters can be used the orbitographic satellite system DORIS. This system activity is based on a onboard measurements of a doppler shift frequency of signals received from ground beacons network. The measurements are fulfilled on two frequencies 2036.25 and 401.25 MHz, that allows taking into account an ionospheric condition [2]. The international DORIS service (IDS) publishes data on an ionospheric and troposheric conditions, and meteorological data for the locations of transmitters of a system DORIS [3]. Obtained ionosphere data also can be used for the earthquakes prediction in the ground stations locations of the DORIS system.

Shortages of use of the DORIS system for the earthquake prediction are: impossibility of the operative definition of ionosphere parameters in the beacon location, high cost of an equipment, complexity of its installation, necessity of a permission deriving for the bacon installation from France Goverment and permission for frequencies using in the country of the arrangement. The enumerated shortages limit DORIS system use possibilities for the seismic activity monitoring in various areas of the Earth.

The submitted report is devoted to a solution of an ionosphere condition evaluation problem with the aid navigational GLONASS/GPS one-frequency phase receiver.

Most perspective method is one that takes in account an ionosphere influence with the aid of GLONASS/GPS one-frequency receivers, based on accounting of signs opposition of phase and group delays of signal propagation. The given approach allows to determine an ionosphere signal delay with the aid of one-frequency receivers measured differences between code and phase pseudo-ranges [6]. A pseudo-range measurement difference of a code and phase delay is equal double a signal ionosphere delay and can be used for its definition

$$I_i(k)=\frac{r_i(k)-\varphi_i(k)+N_i(k)\lambda_i}{2}, \quad (1)$$

where: $I_i(k)$ - a signal ionospheric delay at k step ($k=1,2,\ldots$); $r_i(k)$ - measured code pseudo-range; $\varphi_i(k)$ - measured carrier frequency phase pseudo-range; $N_i(k)$ - initial ambiguity of phase measurements; λ_i - satellite signal wavelength; i - satellite number, $i=\overline{1,n(k)}$; $n(k)$ - total observed satellite number.

Methods, described in abstracts [5, 6, 7] have series of lacks for it practical realization, the researches carried out in KSTU were devoted to its elimination. The principal problem at a phase-group approach realization a is a phase measurements $N_i(k)$ initial ambiguity determination. At that the code pseudo-range measurements casual error exceeds carrier frequency phase pseudo-range measurements error of the satellite signal on an order.

In order to eliminate a given shortage the method permitting to determine ionosphere signal delay on a difference of increments of code and phase measurements is offered. The code pseudo-range is determined by expression [6]:

$$r_i(k)=\rho_i(k)+I_i(k)+T_i(k)+\Delta\tau(k)\cdot c+\delta_i(k)+\xi_i(k), \tag{2}$$

where: $\rho_i(k)$ - range up to satellite; $T_i(k)$ - satellite signal troposphere delay; $\Delta\tau(k)$ - clock divergence between satellite and receiver; c - velocity of light; $\delta_i(k)$ - systematic error; $\xi_i(k)$ - casual error. The carrier frequency phase pseudo-range is determined by the expression [6]:

$$\varphi_i(k)=\rho_i(k)-N_i(k)\lambda_i-I_i(k)+T_i(k)+\Delta\tau(k)\cdot c+\delta_i(k)+\zeta_i(k), \tag{3}$$

where: $N_i(k)$ - initial ambiguity of the carrier frequency phase measurements; λ_i - signal wavelength; $\zeta_i(k)$ - casual error.

The error magnitude caused by ionosphere influence will depend on an satellite signal path length in ionosphere. For satellites with low elevation angles the signal path length will be more, than for satellites with high elevations. Therefore the ionosphere error will be inversely proportional to a satellite elevation. It is distinguished a vertical delay (satellite elevation angle $\gamma=90^0$) and sloped (inclined) delay (satellite elevation angle $\gamma<90^0$). Their correlation is defined by the following expression [6, 7]

$$I_i(k)=Ob(\gamma_i(k))I_v(k), \tag{4}$$

where: $Ob(\gamma_i(k))$ - mapping function [7]; $I_v(k)$ - vertical delay of an ionosphere signal; $\gamma_i(k)$ - satellite elevation angle. The mapping function intended for recalculation of a vertical delay in a sloping delay is defined by the following expression [7]:

$$Ob(\gamma_i(k))=\frac{1}{\sqrt{1-\left(\frac{R_\oplus}{R_\oplus+h}\cos\gamma_i(k)\right)^2}}, \tag{5}$$

where: $R_\oplus$ - mean Earth radius; h - ionosphere stratum height.

Proceeding from the equations (2) and (3), residual of increments code and carrier frequency phase pseudo-ranges in time $\Delta t = k-1$ (Δt - a measurements interval) is equal to the double increment of an ionosphere signal delay for the same phase of time

$$(r_i(k)-r_i(k-1))-(\varphi_i(k)-\varphi_i(k-1))=2\cdot(I_i(k)-I_i(k-1)).$$

For the theoretical researches check was developed algorithm and GPS/GLONSASS phase receiver software for the satellite signal ionosphere delay definition. This receiver is created in KSTU and works with an L1-band frequencies GPS/GLONASS signal. During experimental researches the registration of measured radio navigational parameters and navigational message GPS/GLONASS satellites was produced. This data and developed method were used for the determination of the satellite signals ionospheric delay. At 2001 several measuring companies under various geomagnetic conditions (perturbed and quiet ionosphere) were made. In tab.1 is given Ap-index for the geomagnetic activity description.

Tab.1. Experimental researches results

Experiment date	Duration, h	Ap-index, nT	RMS of single frequency method σ_1, m	RMS of Klobuchar model σ_2, m	$\frac{\sigma_2}{\sigma_1}$
April, 25	26	6	0.45930220	2.16281361	4.7089119
April, 26		6			
April, 28	29	40	0.86405742	2.02093429	2.3388889
April, 29		13			
May, 16	46	7	0.3878384	1.23400857	3.1817600
May, 17		6			
May, 18		8			
October, 8	24	16	1.08973087	2.24708779	2.0620576
October, 9		18			
Averaged value on all Experiments			0.69675343	1.76357926	2.7712769

For check of developed method accuracy we use the information about an ionosphere condition, obtained from a Crustal Dynamics Data Information System (CDDIS) center. These data are obtained from the International GPS Service for Geodinamics (IGS). The correspondence of the information about an ionosphere condition for Krasnoyarsk is defined by a two-frequency navigational TurboRugue SNR-8000 GPS receiver, included in structure of a IGS stations that is operated in KSTU. For an experimental data accuracy estimation, the DORIS system beacon information also located in KSTU was using. During the experiment the researched GPS/GLONASS receiver was placed in immediate proximity from TR SNR-8000, and DORIS beacon, that has allowed to accept DORIS and IGS measurements as reference ones.

On the Fig.1-2 shown the vertical ionosphere signals delay estimation, obtained according with of developed method, Klobuchar model, and data-processing centres IGS: CODE (Center for Orbit Determination in Europe), Bern, Switzerland; JPL (Jet Propulsion Laboratory), Pasadena USA.

On the graphs on an axes of abscissas the number of hours, passed from a beginning of the first day of experiment is presented. The day beginning is determined at local Winter time ZT = GLONASS system time + 4 hours.

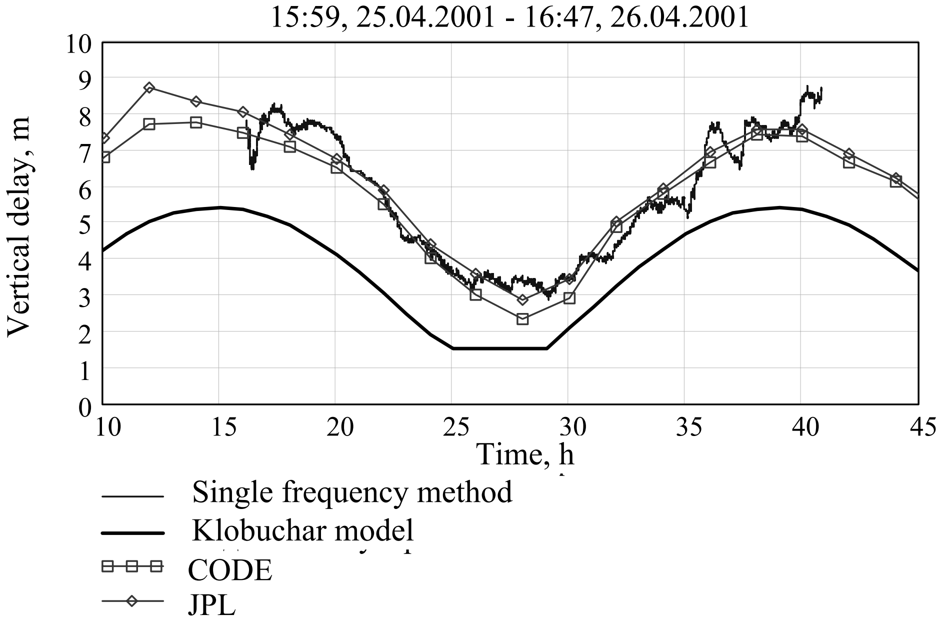

Fig.1. Experimental results, April 25-26, 2001

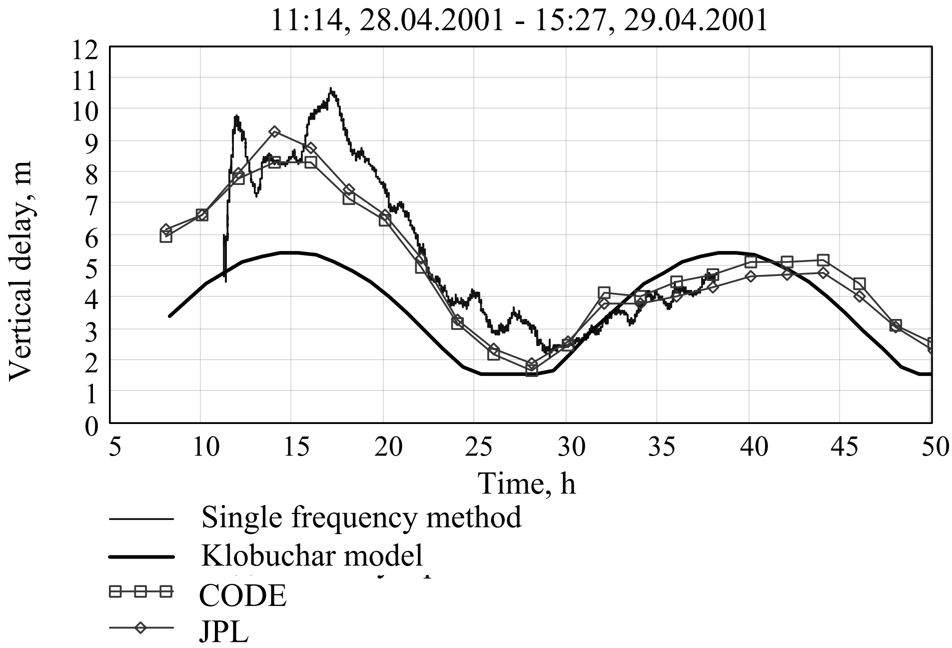

Fig.2. Experimental results, April 28-29, 2001

The comparison of experimental results with DORIS and IGS data shown a developed method accuracy and stability to a wide range of ionospheric condition modifications. This method has allowed increasing ionospheric delay determination accuracy, on a comparison with the Klobuchar model and can be used for monitoring seismic activity of dangerous zones.

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