Journal of Fundamental and Applied Sciences

ISSN 1112-9867

Available online at http://www.jfas.info

Research Article

Special Issue

FORECAST ACCURACY OF DETERMINING PSEUDO RANGE IN SATELLITE NAVIGATION SYSTEM THROUGH ANALYSIS OF DATA FROM IONOSPHERE MONITORING

K. A. Katkov[1*], V. P. Pashintsev[1], E. K. Katkov[1], N. N. Gakhova[2], R. P. Gakhov[2], A. I. Titov[2]

[1]North-Caucasus Federal University, 1, Pushkin Street, Stavropol 355009, Russia,

[2]Belgorod State University, 85, Pobedy St., Belgorod, 308015, Russia

Published online: 15 February 2017

ABSTRACT

Annotation: The paper deals with the detection of wave arrival time errors in satellite navigation system by measurements conducted by stationary information system ionosphere monitoring. Develop a method of detecting the field increased ionization and the detection of the conditions for possible reduction of positioning accuracy in the presence of local ionospheric irregularities.

The author examines in detail all mathematical aspects of the nature of the error; visual diagrams and graphs, as well as exhaustive mathematical calculations accompany the study. The article also discusses the process and results of computer modeling, an error that arises based on the data provided by the author, and allows one to verify the author's proposed method of detecting and predicting the occurrence of an error in determining the location. In the conclusion satity, the author speaks about the method of applying the developed method in the context of a specialized information system capable of preserving the positioning accuracy on the navigation radio signal.

Keywords: radio navigation systems, pseudo range, monitoring, data analysis.

INTRODUCTION:

It is known [1-10] that the most significant contribution to the error in the determination of pseudo range in satellite radio navigation systems (SRNS),

Author Correspondence, e-mail: gahov@bsu.edu.ru

doi: http://dx.doi.org/10.4314/jfas.v9i1s.744

Occurring in the propagation distribution the navigation radiosignal (NRS) the arises from ionosphere. Particularly high uncertainty arises in the creation of artificial ionospheric formations (AIF). In [2-8] has shown that under the influence of a powerful short-wave radiation in the ionosphere it is heated, which in turn gives rise to such AIF in the local area. These areas of increased ionization (AII) are characterized by the presence of inhomogeneities of electron concentration (EC), which are aligned along geomagnetic lines. The transverse dimension of irregularities can vary in a very wide range of from 0.1 m to several hundred km. As a result, occurrence of AIF increase the diffraction properties of the ionosphere. This leads to the appearance of fading signals. In the case of simple transfer fading signals are general, and when transmitting broadband signals can be deeper - frequency-selective nature. This is due to the constriction transionospheric coherence bandwidth of the communication channel. Consequently, the noise immunity of the SRNS using wideband signals at AIF will significantly decline.

The local nature of the AIF will lead to the fact that part of the NRS will pass through the disturbed ionosphere, and some through normal. In this case, increasing unequal pseudorange measurements. The extent of this depends on the NRSs unequal parameters and the disturbed ionosphere and AII sizes, positioning of navigational satellites (NS) and the users of navigational system.

It is known [2] that repeated increasing measurement errors pseudorange , even in one radio line will result in positioning errors, not satisfying the requirements of accuracy in the SRNS. In this case the user has no information about the status of transionospheric link and navigation consumer equipment (NCE) does not excludes constellation NS, which the signal enters the AIF, as a signal of incorrect status of NS, in the navigation message is missing.

In this connection it is necessary to have reliable information about the state of the ionosphere and its effects on the characteristics of radio signals passing through it. This can help the results obtained in [9]. According to that, the creation of an information system (IS) of monitoring ionosphere could help to determine the presence and approximate coordinates of the AII. Next there is a problem of practical use of this information. The purpose of this article is to develop methods to prediction the error in determining the pseudorange in case of AIF, and making recommendations to consumers for accurate positioning in terms of occurrence of artificial ionospheric disturbances.

Formulation of the problem. Assume that, in the ionosphere occurs a local region of increased ionization, passing through which NRS is distorted up to the occurrence of frequency selective fading (FSF). It is required to determine the presence of the field with increased ionization in the ionosphere, to give a forecast error in determining the pseudorange radio links in those that will be used by the consumer for session to searching location. This demands processing large amounts of data, as it required make recommendation for session to searching location for huge amount of customers.

METHODS

It is known [1-10] that the positioning error depends mainly on the error determination of pseudorange of each of the RNS operating constellation and geometry factor GDOP. If at least one NS falls in the range of AIF and subjected to FSF, positioning error repeatedly increases [2]. With an increasing number of radio navigation signals error in determining the spatio-temporal coordinates of the consumer increasing beyond the allowable values. The accuracy of location determination is directly proportional to the accuracy of determining pseudoranges to all NS of selected constellation. In turn, the error in determining the pseudorange to the NS ($\pm_D$) is directly proportional to the error tracking a radio signal arrival time ($\pm_{{}^2}$) and is given by

$$\pm_D = c \cdot \pm_{{}^2} . \tag{1}$$

The value for time tracking error ($\pm_{{}^2}$) will determine the standard deviation (SD) signal phase fluctuations ($\pm_{\cdot\cdot S}$), arising during the passage of the NRS by from AII [9]. In this case we can assume that in the conditions of strong ionospheric scintillation of signal arrival time tracking error will be of a provisional sum of error signal fluctuations ($\pm_{{}^2 S}$) and error in determining the time of arrival of the signal peak.

$$\pm_{{}^2} = \pm_{{}^2 S} + \pm_{{}^2 H} . \tag{2}$$

In figure 1a shows the additive mixture of Gaussian noise $n_1(t)$ and the signal amplitude of the voltage at the output of the matched filter for the cases of arrival of the signals with a rectangular envelope and the same duration T_S and different energy $E_{r1} > E_{r2}$. If there is noise when $\pm_n \neq 0$ time of attaining the maximum matched filter output voltage $\left(t = {}^2 + T_S \pm \Delta^2\right)$ it is casual and different from the true value at the error $\pm_{{}^2} > 0$ which is inversely proportional to the amplitude of the specified voltage peak. In this case, $U_{rinput1} > U_{routput2}$ (*a1* - an arbitrary constant), measurement error of the delay time is related as: $\pm_{{}^2 1} < \pm_{{}^2 2}$. This pattern is observed in the case when the temporary signal fluctuations due to strong phase scintillations is not exists $\left(\pm_{{}^2 S} \approx 0\right)$.In case of appearance of AIF and accompanying strong phase and amplitude scintillation signal will be subjected to a navigation frequency selective fading. As a result there will be a "smearing" of the matched filter response (Figure 1b), which is accompanied by a decrease in its amplitude $U_{rinput} l_a < U_{routput}$ and “acuity” (an increase in the base width $T_s °_a > T_s$). In this case $l_ч$- the reduction factor the maximum amplitude of the signal $°_a$ - magnification signal duration at the output of the matched filter due to the input signal FSF.

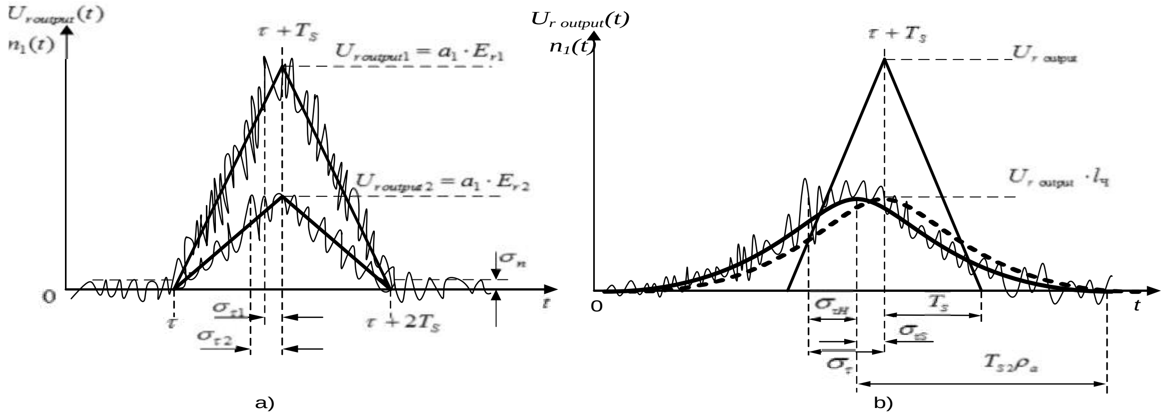

Fig.1. Effect of changes in the matched filter output parameters on the measurement error increase delay time it a) the effect of the amplitude of the output signal of the peak; b) the effect of "spreading" and the displacement of the matched filter response when the signal FSF.

In addition, because of the strong phase fluctuations will occur a temporary fluctuation of the signal $\left(\pm_{²S} \neq 0\right)$, which, according to [11], defined by the expression:

$$\pm_{²S} = \frac{\pm_{¨S}}{2\text{®} f_0}, . \tag{3}$$

where f_0 - frequency of navigational radio signal.

The value of the standard deviation of the signal phase fluctuations () according to [9,12] defined by the expression:

$$\pm_{¨S} = \frac{80,8\text{®}}{cf_0} \pm^{oblique}_{\Delta N} . \tag{4}$$

Where c - speed of propagation; 80.8 - factor with the dimension [m^3/s^2];

$\pm^{oblique}_{\Delta N}$ – the standard deviation of the integral electron concentration (EC) in the ionosphere oblique radio.

Value of $\pm^{oblique}_{\Delta N}$ according to [9; 13] defined by the expression:

$$\pm^{oblique}_{\Delta N} = \pm_{\Delta N_T} \sqrt{L_0 h_э \sec\Theta} \, \frac{\Gamma(p/2-1/2)}{\sqrt{\text{®}}\,\Gamma(p/2-1)} . \tag{5}$$

Where $\pm_{\Delta N_T}$ – the standard deviation of the fluctuations of the electron density in the ionospheric irregularities; L_0 – the maximum size of ionospheric irregularities; $h_Э$ – equivalent to the thickness of the ionosphere (500 km); Θ - zenith angle of navigation satellites; p - phase spectral index. Using the expression (5) to determine the value of $\pm_{\Delta N_T}^{oblique}$ is rather difficult, as not known in advance of the index *p*, the values of L_0 and $h_Э$ values is taken approximately. At the same time there are technical means to carry out a number of measurements that eliminate this uncertainty. Thus, the instrument “NovAtel GPS-6”, set in the North Caucasus Federal University, measures the value directly on the propagation way of navigational radio signal. These measurements allow, according to (4) and (3) to receive the time value signal fluctuations ($\pm_{{}^{2}S}$). To estimate the maximum signal arrival time errors in determining the strengths and ionospheric disturbances arising in this frequency selective fading of the received navigation signal use the expression obtained in [14].

$$\pm_{{}^{2}H}^{2} = \frac{\left(1+4\Delta F_0^2/\circledR\Delta F_k^2\right)^{3/2}}{2\circledR\Delta F_0^2 h^2}. \qquad (6)$$

Where ΔF_0 - the width of the spectrum of NRS, h^2 the ratio of the energy of the received NRS to noise power spectral density, ΔF_k - lane communication channel coherence transionospheric defined as

$$\Delta F_k = \frac{f_0}{\pm_{\ddot{\ }S}\sqrt{2\left(1+d_1^2/2\right)}},. \qquad (7)$$

Where:

$$d_1^2 = \frac{\left(3z^2-3zh_Э+h_Э^2\right)c^2\sec^2\Theta}{192\circledR^2 f_0^2 L_0^4},. \qquad (8)$$

where z - the distance from the upper boundary of the ionosphere to the reception point for vertical propagation (600 km). With regard to (4), (6), (7), the expression (2) becomes [6].

$$\pm_{{}^{2}} = \frac{\pm_{\ddot{\ }S}}{2\circledR f_0} + \frac{1}{\sqrt{2\circledR h^2}\Delta F_0}\left(1+\frac{8\Delta F_0^2\pm_{\ddot{\ }S}^2\left(1+d_1^2/2\right)}{\circledR f_0^2}\right)^{3/4}. \qquad (9)$$

Analysis of the expression (9) shows that the tracking error of the signal arrival time at the maximum selection circuit ($\pm_{{}^{2}}$) it depends on the standard deviation of the phase fluctuations of the received navigation signal ($\pm_{\ddot{\ }S}$). In turn, $\pm_{\ddot{\ }S}$ value can be obtained by measuring the standard deviation of the integral electron density concentration in the inclined in radio link ($\pm_{\Delta N}^{накл}$). In view of (4), the equation (9) takes the form:

$$\pm_{2} = \frac{40,4}{cf_0^2}\pm_{\Delta N}^{oblique} + \frac{1}{\sqrt{2® h^2}\,\Delta F_0}\left(1+\frac{8\Delta F_0^2 ® \left(80,8\pm_{\Delta N}^{oblique}\right)^2\left(1+d_1^2/2\right.}{c^2 f_0^4}\right. \qquad (10)$$

.

Equation (10) establishes a relationship between the error of measurement of time of arrival of the navigational radio signal ($\pm_{2}$) and the measured value of the standard deviation of the integral of the electron density in radio link ($\pm_{\Delta N}^{oblique}$) in the propagation path navigation signal. In the expression (10) contains an element d_1^2, which in the same way as in $\pm_{\Delta N}^{oblique}$, a priori unknown value includes the maximum size of ionospheric inhomogeneities (L_0). This introduces uncertainty in the use of the expression (10) to estimate error the time of arrival of navigational radio signal ($\pm_{2}$).

To assess the impact of this uncertainty on the accuracy of the X was carried out computer simulations in which has been calculated dependence of the standard deviation of the signal arrival time error ($\pm_{2}$) on the value of the standard deviation of the fluctuations of the electron density in the ionosphere inhomogeneities ($\pm_{\Delta N}$) at different value of L_0. The maximum size of irregularities equal to $L_0 = 100$ м and $L_0 = 1000$ м were selected. Next it was calculated the dependence of the mean square deviation determining pseudoranges ($\pm_D$) from the $\pm_{\Delta N_T}$ to the same values of L_0. Calculations showed that the difference in the standard deviation determining pseudoranges for various values of L_0 and the value of $\pm_{\Delta N_T} \le 10^{13}$ el/m^3 10 m. Thus, the expression (10) may well be used in the future to determine whether AII positioning and forecasting errors. It should be noted that the value of L_0 is taken into account when measuring the standard deviation of the integral. It should be noted that the value of X is taken into account when measuring the standard deviation in the integrated electronic concentration in radio link $\pm_{\Delta N}^{oblique}$, according to (5). In further studies, the maximum size of ionospheric irregularities can be taken as $L_0 = 1000$ m.

Prediction positioning quality

The research shows that having equipment capable of measuring the value of $\pm_{\Delta N}^{накл}$, we can detect the presence and location field increased ionization occurring in the ionosphere. The presence of such equipment allows you to create an information system capable of performing the functions of the ionosphere monitoring and prediction accuracy positioning by consumer's satellite radio navigation system in the conditions of the disturbed ionosphere. At the same time users of satellite navigation systems must be constantly linked to this information system [9].

Assume NS (Figure 2) moves in its orbit. The information system receives signals from the navigation of NS. When at time t1 the measured value exceeds the threshold value [18], it can be concluded that the navigation signal enters the increased ionization region. Thus information system, according to the method described in [9,15,16], determines the width transionospheric communication channel coherence bandwidth (ΔF_k) and the presence or absence of frequency-selective fading radio navigation. By reducing the value of X is less than the threshold value (at time t2), it can be concluded that the navigation signal come out of the increased ionization. The dimensions of this area are limited to points and points of intersection route navigation signal and the region of increased ionization. The dimensions of this area are limited to points Q_1 and Q_2, the intersection points of the route navigation signal and field increased ionization. The coordinates of these points in the topocentric coordinate system (*N U E*) where *N* axis is directed to the north in the local horizontal plane, the *U*-axis - the zenith axis *E* - to the east by the expressions [2,19]:

$$\begin{cases} N_{Q_j} = d_{\text{АП}_j} \cdot \cos \yen_j \cdot \cos \sim_j \\ U_{Q_j} = d_{\text{АП}_j} \cdot \sin \yen_j \\ E_{Q_j} = d_{\text{АП}_j} \cdot \cos \yen_j \cdot \sin \sim_j \end{cases} , \quad j = 1,\ 2 . \tag{11}$$

Where $\sim_j$, $\yen_j$ azimuth and elevation point Q_j, equal azimuth and elevation NS signal which falls in the area of increased ionization; $d_{\text{ОПИ}_j}$ - slant range point Q_j defined [2] as:

$$d_{\text{АП}_j} = \sqrt{R_Z^2 \cdot \sin^2 \yen_j + h_e \cdot \left(2R_Z + h_e\right)} - R_3 \cdot \sin \yen_j , \quad (j = 1,\ \ 2), . \tag{12}$$

where R_z - the radius of the Earth at the point of measurement.

It should be noted that the center of the topocentric coordinate system (TSC) is a base station (BS) information monitoring system of the ionosphere.

With the coordinates of points in the Q_j coordinate system topocentric it is easy to translate them into geocentric coordinates ($x_{Q_j}, y_{Q_j}, z_{Q_j}$) [2, 7].

To predict the location accuracy in case of ionospheric disturbances is necessary to determine whether the navigation signal constellation in the device gets in the area of increased ionization. That is, (Figure 2), whether the navigation signal passes from navigation satellites

№2 through this area or not. If passed, what will be predicted with accuracy pseudorange. Consumer satellite navigation systems, taking navigation signal from four navigation satellites continuously refines its position. As a point of initial approach taken position coordinates of the previous session $[X_0, Y_0, Z_0]$. Selecting a constellation of navigation satellites is carried out according to the almanac of satellite navigation systems.

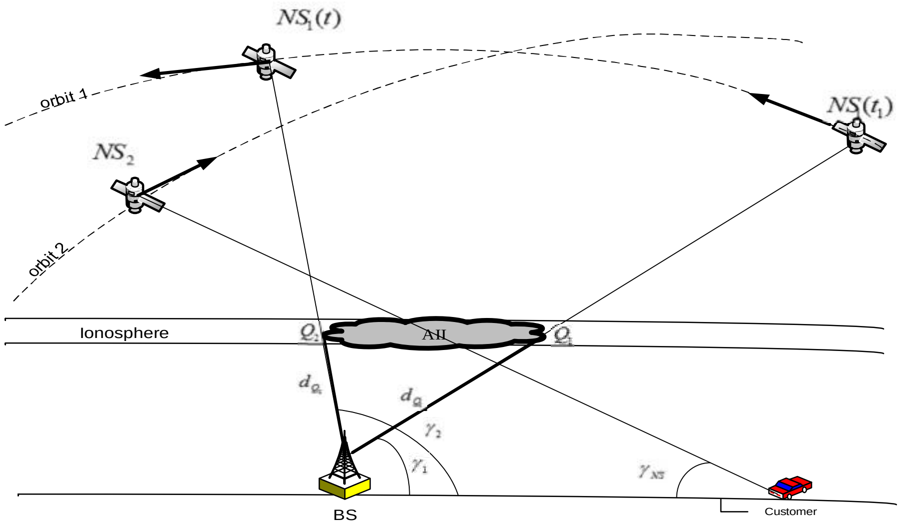

Fig.2. Determination of the coordinates of the field increased ionization

In other words, before the user knows positioning session approximate azimuth and elevation angles of the navigation satellites whose signals it will take for processing. At the same time, having the coordinates of points of increased ionization in the geocentric coordinate system, [$x_{Q_j}, y_{Q_j}, z_{Q_j}$], one can find the coordinates of these points (Q_j) in the local coordinate system of topocentric ($N_Q^{\Pi} U_Q^{\Pi} E_Q^{\Pi}$) centered at the consumer [2,10,19-22]. Azimuth ($\sim_Q$) and elevation angle ($\sim_Q$) are using the expression [19].

$$\left.\begin{aligned} \sim_Q &= \arcsin\frac{E_Q^{\Pi}}{\sqrt{\left(N_Q^{\Pi}\right)^2+\left(E_Q^{\Pi}\right)^2}}, \quad sign(\cos\sim_Q) = sign(N_Q^{\Pi}) \\ ¥_Q &= \arcsin\frac{U_Q^{\Pi}}{\sqrt{\left(N_Q^{\Pi}\right)^2+\left(E_Q^{\Pi}\right)^2+\left(U_Q^{\Pi}\right)^2}} \end{aligned}\right\}. \qquad (13)$$

Now, knowing the angular coordinates of the point Q_j in the local coordinate system and the topocentric and angular coordinates of the selected navigational satellites can determine if this signal from the navigation apparatus passes through the space region of increased ionization.

Now, knowing the angular coordinates of the points in the X coordinate local topocentric system (x) and (y), and angular coordinates of the selected NS (z), can determine whether the signal from the navigation satellites that passes through the region of increased ionization.

$$\begin{cases} N_{Q_j} = d_{AII_j} \cdot \cos \text{¥}_j \cdot \cos \sim_j \\ U_{Q_j} = d_{AII_j} \cdot \sin \text{¥}_j \\ E_{Q_j} = d_{AII_j} \cdot \cos \text{¥}_j \cdot \sin \sim_j \end{cases} , \quad j = 1,\ 2 \cdot \tag{14}$$

Now, knowing the angular coordinates of the points in the Q_j coordinate local topocentric system $(\sim_1, \text{¥}_1)$ and $(\sim_2, \text{¥}_2)$, and angular coordinates of the selected NS $(\sim_{HKA}, \text{¥}_{HKA})$, can determine whether the signal from the navigation satellites that passes through the region of increased ionization. It is advisable in this respect, the use of modular parallel signal processing techniques [20-23]. First, whether the navigation space azimuth coincides apparatus must determine which signal processing is taken in the region with detected azimuth increased ionization. There are several cases of coincidence of the azimuth (Figure 3). If you are one of the systems of inequalities:

$$\begin{cases} \sim_{NS} > \sim_{Q_1} \\ \sim_{NS} \geq \sim_{Q_2} \\ \sim_{Q2} > \sim_{Q_1} + \text{®} \end{cases} .\text{– (figure 3a)} \tag{15}$$

$$\begin{cases} \sim_{HKA} \leq \sim_{Q_1} \\ \sim_{HKA} < \sim_{Q_2} \\ \sim_{Q2} > \sim_{Q_1} + \text{®} \end{cases} .\text{– (figure 3b)} \tag{16}$$

$$\begin{cases} \sim_{Q_1} \leq \sim_{HKA} \leq \sim_{Q2} \\ \sim_{Q_2} > \sim_{Q_1} \\ \sim_{Q2} \leq \sim_{Q_1} + \text{®} \end{cases} .\text{ – (figure 3c)} \tag{17}$$

it is obvious that the NS which the signal is taken into a consumer handling, is in the same part of the visible sky hemisphere as increased ionization region. In this case, you must verify that the angle of position of the navigation satellite (h) and elevation increases ionization region. To do this, verify one of the following systems of inequalities:

$$\begin{cases} \text{¥}_{Q_1} \leq \text{¥}_{NS} \leq \text{¥}_{Q_2} \\ \text{¥}_{Q_1} \leq \text{¥}_{Q_2} \end{cases} \quad \text{or} \quad \begin{cases} \text{¥}_{Q_2} \leq \text{¥}_{NS} \leq \text{¥}_{Q_1} \\ \text{¥}_{Q_2} \leq \text{¥}_{Q_1} \end{cases} . \tag{18}$$

If the system of inequalities (14) - (17) are not satisfied, it can be concluded that the navigation signal does not pass through the area of ionization increased, the detected information monitoring system of the ionosphere, and the user can operate normally.

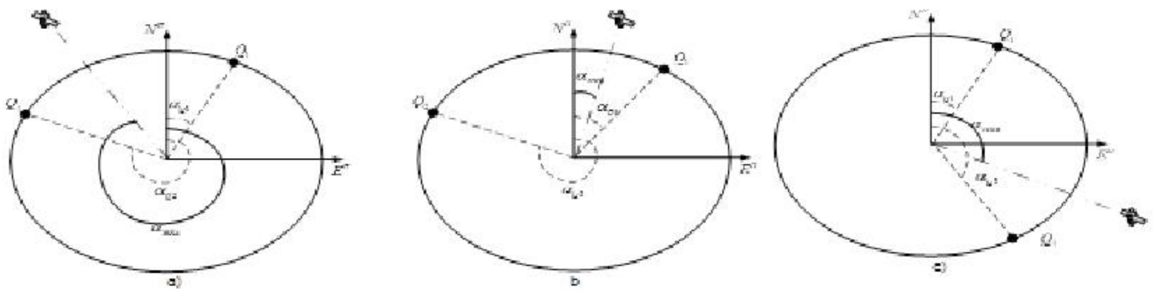

Fig.3. Match azimuth NS with azimuth field increased ionization

Otherwise, the signal passes through the region of increased ionization and positioning accuracy is necessary when using this prediction navigation signal for further processing. Information ionosphere monitoring system must determine a possible error in determining pseudoranges and issue recommendations to the consumer or to continue working in normal mode, or to change the working constellation of navigation satellites. This requires measuring the information system to recalculate the value of $\pm_{\Delta N}^{накл}$ for a radio link "navigation satellite - the consumer.". Let the navigational satellite , which signal is used by an information system for determining the presence and coordinate the field increased ionization (Figure 2, the NS №1), as a "navigation space increased ionization unit area indicator". In the expression (5) is used zenith angle Θ of this particular NS. To convert $\pm_{\Delta N}^{накл}$, measured for the "NCA-indicator", in $\left(\pm_{\Delta N}^{oblique}\right)^C$ desktop NS (Figure 2, NS №2) must take into account the elevation angle of NS (¥_{HKA}). The value of $\left(\pm_{\Delta N}^{oblique}\right)^C$ is given by:

$$\left(\pm_{\Delta N}^{oblique}\right)^C = \pm_{\Delta N}^{oblique}\sqrt{\frac{\cos\Theta}{\sin \text{¥}_{RS}}}\,. \qquad (19)$$

Using (18) and (10) an expression for the pseudorange measurement error in radio link through the increased ionization region takes the form:

$$\pm_D = c\left[\frac{40,4}{cf_0^2}\pm_{\Delta N}^{oblique}\sqrt{\frac{\cos\Theta}{\sin \text{¥}_{RS}}} + \frac{1}{\sqrt{2\text{®} h^2}\,\Delta F_0}\left(1+\frac{8\Delta F_0^2\text{®}\left(80,8\pm_{\Delta N}^{oblique}\right)^2\cos\Theta\left(1+\frac{d_1^2}{2}\right)}{c^2 f_0^4\sin \text{¥}_{RS}}\right.\right. \qquad (20)$$

Where: $d_1^2 = \dfrac{\left(3z^2 - 3zh_e + h_e^2\right)c^2\,\mathrm{cosec}^2\,\text{¥}_{RS}}{192\text{®}^2 f_0^2 L_0^4}$

Equation (19) allows the calculation error in determining pseudoranges if the navigation signal passes through a zone of increased ionization in the ionosphere.

RESULTS AND DISCUSSION

The basis of the above was carried out computer modeling, a result of which the values of the error in determining the pseudorange ($\pm_D$) for the different elevations of working places of navigational satellites (¥$_{NS}$). As «NS-display area increased ionization" device with a zenith angle of $\Theta = 60^0$ was adopted. Other parameters are adopted as follows: the maximum size of ionospheric irregularities $L_0 = 1000$ m; value $z = 600$ km; $h_э = 500$ km; ratio of the received navigation signal energy to noise power spectral density $h^2 = 46$ dBG; $\Delta F_0 = 10$ MG;. Prediction error in determining the pseudo held various elevations of navigation satellites (near horizon NS) and (zenith NS). The results are shown in Figure 4.

Figure 4a is a graph of $\pm_{\Delta N}^{oblique}\left(\pm_{\Delta N_T}\right)$ - the dependence of the measured values from the $\pm_{\Delta N}^{oblique}$ standard deviation of fluctuations of the electron density in the ionosphere inhomogeneities ($\pm_{\Delta N_T}$). From the analysis of the graph shows that when the measurement equal to $\pm_{\Delta N}^{oblique} \approx 10^{17}...10^{18}$ el/m^2, with the assumptions correspond to the values of the electron density fluctuations in ionospheric irregularities equal to $\pm_{\Delta N_T} \approx 10^{13}...10^{14}$ el/m^3. This corresponds to a strong ionospheric disturbance. The measurements were performed on the signals «NS-indicator AII». This corresponds to a strong ionospheric disturbance. the signals «NS-indicator AII» $\pm_{\Delta N}^{oblique}$ measurements were carried out. Figure 4b shows the dependence of the predicted pseudo-measurement error in a radio link "consumer - the working NS» of the measured value $\pm_{\Delta N}^{oblique}$. Charts are presented for different values of the angle of the working places of navigational satellites.

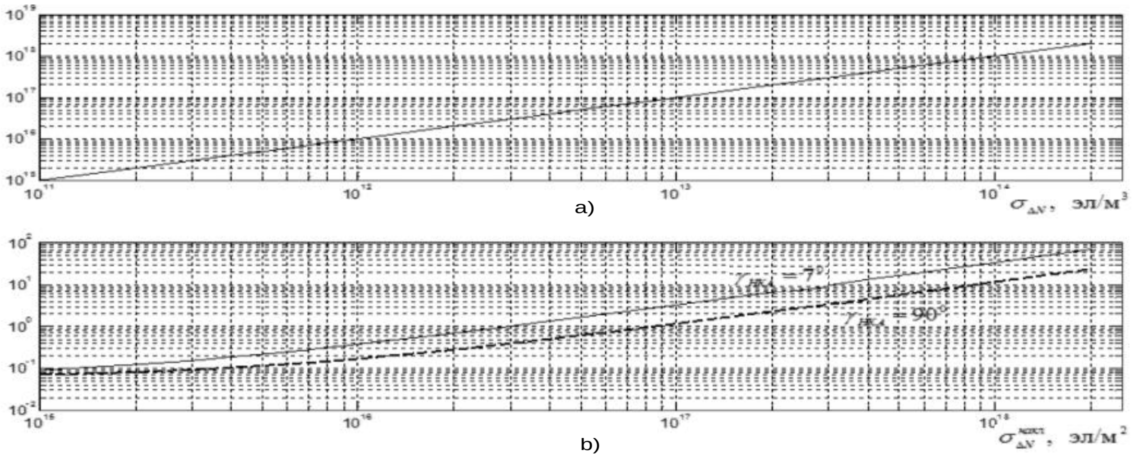

Fig.4. Results of computer modeling

Analysis of these graphs shows that the error in determining the pseudo up near horizon NS will be much higher than before the zenith NS. When an ionospheric strong ionospheric disturbance $\pm_{\Delta N_T} > 10^{13}$ el/m^3, which corresponds $\pm_{\Delta N}^{oblique} > 10^{17}$ el/m^2 measurements, the measurement error for pseudorange near horizon NS increases up to tens of meters, and may reach values of 70 - 80 m. This error does not correspond to the requirements of measurement accuracy requirements for satellite navigation systems. In this case, the information system should signal the user equipment to reduce the accuracy of positioning.

CONCLUSION

The presented method of forecasting accuracy will determine the definition of pseudo-positioning probable error of the consumer in the event of artificial ionospheric disturbances. This requires the creation of an information system for monitoring the ionosphere and the connection to the consumer system. The information system should receive signals from all currently visible NS and conduct quality analysis of radio "NS - Base station". In the presence of artificial ionospheric formations information system determines the coordinates of the field increased ionization and analyzes information from consumers regarding their choice for the working session positioning NS. Information system must determine whether the passage of navigation signal from a selected user desktop NS through the detected area of the increased ionization. If the track navigation signal falls into this area of information system should calculate the predicted value of the pseudo-error determination. If this error does not exceed the permissible values, the user equipment continues to operate normally. Otherwise, you need to give this instrument a fault signal that the navigation of the spacecraft, which will cause the change of the working constellation.

Creating such a system does not require complex equipment of each user of the measuring equipment. At the same time, it will help to keep the required positioning accuracy in the case of strong local nature of ionospheric disturbances.

SUMMARY

The result of this scientific work is a new method that allows to reduce the effect of increased ionization on the occurrence of navigation errors and the positioning of satellite radio navigation systems. In addition, during the work was carried out computer modeling, an error that arises based on the data provided by the author, and allows one to verify the author's proposed method of detecting and predicting the occurrence of an error in determining the location.

REFERENCES

1. Shebshaevich, V.S., Dmitriev, P.P., Ivantsevich, N.V. etc., 1993. Network satellite navigation systems. AM Radio and communication, 408 p.

2. Pashintsev, V.P., Katkov, K.A., Gakhov, R.P., Malofey, O.P., Shevchenko, V.A., 2012. Satellite navigation with ionospheric disturbances. Stavropol: NCSTU, 259 p.

3. Langley, R.B. 2000. Dilution of precision. GPS World, Advanstar Communications, Eugene, OR 97401.

4. Camargo, P., O., Monico, J., F., G., Ferreira, L., D., D., 2000. Application of ionospheric correction in the equatorial region for L1 GPS users. Earth Planets Spase, 52: 1083 - 1089.

5. Lobanov, B.S., 2009. Study the possibility of creating in the ionosphere, space-occupying lesions, effectively interacting with electromagnetic radiation over a wide frequency range. Theory and radio communication equipment, (3): 16 - 24.

6. Hofmann-Wellenhof, B., Lichtenegger, H., Collins, J., 1994. Global Positioning System. Theory and Practice. Springer-Verlag Wien New York, pp. 356.

7. Bogush, R., L., Guiliano, F., W., Knepp, D., L., 1981. Influence of frequency-selective propagation effects on the automatic tracking signal receivers in broadband communication systems. Proc-1981, 69(7): 21 - 32.

8. Jiexian Wang, H., Lu, Baku Caiping, 2002. Dependency of GPS positioning precision on station location. GPS Solutions: 6-7.

9. Katkov, K.A., Pashintsev, V.P., Katkov, E.K., 2016. Information ionosphere monitoring system. Bulletin of Samara Scientific Center of the Russian Academy of Sciences, 18 (2): 907 - 912.

10. Kharisov, V.N., Perov, A.I., Boldin, V.A. 1998. The global satellite navigation system GLONASS. - M .: IPRZHR. - 680 p.

11. Tepljakov, I.M., 1984. Ionospheric distortion of digital signals with broadband modulation. Radio engineering, 8: 8 - 13.

12. Katkov, K.A., Pashintsev, V.P., Katkov, E.K., 2016. Influence perturbed ionospheric parameters for error tracking phase navigation signal. Modern science and innovation, №2 (14):52 - 64.

13. Knight, M.F, Cervera, M., Finn, A., 1999. A Comparison of Predicted and Measured GPS Performance in an Ionospheric Scintillation Environment", Proceedings of ION GPS-99, The Twelfth International Technical Meeting of the Satellite Division of the Institute of Navigation: 1437-1450.

14. Pashintsev, V.P., Solchatov, M.A., Spirin, A.M., Katkov, K.A., 2007. Evaluation pogreshneosti pseudo-range measurements for satellite navigation systems under perturbations in the ionosphere layer F. Physics of wave processes and radio systems, 10 (6): 8 - 13.

15. Katkov, K.A, Gakhova, N.N., 2012. The algorithm for determining the presence of areas of increased ionization in the ionosphere. High Tech., 13(7): 8-15.

16. Katkov, K.A., 2011. Improved navigation equipment for users of satellite radio navigation systems for use in artificial ionospheric disturbances. Information systems and technologies, № 1 (63): 5-14.

17. Katkov, K.A., Kalmykov, I.A., 2013. Application of Parallel Technologies in Navigation Management under the Conditions of Artificial Ionospheric Disturbances. World Applied Sciences Journal, 26 (1): 108-113.

18. Pashintsev, V.P., Chipiga, A.F., Tsymbal, V.A., Peskov, M.V., 2016. The complex definition of the field with small-scale ionospheric irregularities according gps-monitoring. Bulletin of Samara Scientific Center of the Russian Academy of Sciences, 18 (2): 941 - 945.

19. Mamon, P.A., Polovnikov, V.I., Slezkinsky, S.K.,1980. Ballistic software spaceflight. Training. allowance. Leningrad: VICKI them. AF Mozhaisk, 1980, 622 p.

20. Kalmykov, I.A., Katkov, K.A., Timoshenko, L.I., Dunin, A.V., Gish, T.A., 2015. Application of modular technologies in the large-scale analysis of signals. Journal of Theoretical and Applied Information Technology, 80(3): 391-400.

21. Olga A. Ivashuk, Natalia V. Shcherbinina, Sergej A. Lazarev, Orest D. Ivashchuk, 2015. Increasing Efficiency Territory Technospheric Safety Management Based on Improving of Earth's Surface Satellite Images. International Journal of Soft Computing, 10(6): 420-426.

22. Olga A. Ivashuk, Igor S. Konstantinov, Natalia V. Shcherbinina, Denis A. Kvanin, Roman P. Gakhov, 2015. Automated Management of Biotechnosphere of Local Urban Areas. International Business Management, 9(7): 1598-1603.

23. Sidorenko, I.A., Evtushenko, M.A., 2015. Evaluation of satellite communications for GEO, MEO and LEO orbit. Belgorod State University Scientific Bulletin, Economics Information technologies, № 19 (216), Issue 36/1:160-169.

How to cite this article:
Katkov K A, Pashintsev V P, Katkov E K, Gakhova N N, Gakhov R P, Titov A I. Forecast accuracy of determining pseudo range in satellite navigation system through analysis of data from ionosphere monitoring. J. Fundam. Appl. Sci., 2017, *9(1S), 899-913*.