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PRIMARY RESEARCH

Ultra-fast observation orbit refinement model established on DOP value for GNSS system

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Abstract

Global navigation satellite system (GNSS) ultra-fast orbit is an important parameter for near-real-time positioning, and its timeliness and accuracy are the key issues to be solved the phenomenon of reduced accuracy in the later stage of ultra-fast orbit observation an orbit refinement model based on orbit parameter accuracy of attenuation factor (DOP) is proposed. First, based on the orbit observation data information criterion is used to construct and optimize the DOP value prediction model; then, the DOP value is used as the independent variable to establish a function model between it and the orbit state parameters then the DOP with high precision prediction The value is substituted into the function model to realize the optimization of the orbit accuracy in the later period of observation. To verify the orbit refinement model, the observation data function and length model were analyzed separately. The results show that the orbit model refinement is optimal based on 1 d of observation data, and there is no clear difference between different function models. The multi-system ultra-fast orbit experiment based on continuous ten days shows that the refined model in the later stage of ultra-fast orbit observation can improve the orbit accuracy by 12.4% ≈ 22.0%. Consequently, this model can perceive the refinement of the ultra-fast observation orbit, which is of great significance to improving the ultra-fast orbit of the analysis center.

I. INTRODUCTION

The ultra-fast track as an important parameter for real-time or near real-time positioning, its accuracy will be then influence the ambiguity fixed and the positioning result. Therefore, analysis The center has strict accuracy for the provided ultra-fast track accuracy Indicator requirements. For example, the international GNSS monitoring and evaluation system (international GNSS monitoring and assessment system, iGMAS) super fast orbit view of various systems and types of satellites.

The accuracy of the measurement and forecast parts has been specified in detail. Can be evaluated It is known that GPS ultra-fast predicts the three dimensional mean square of 6 h and 24 h Root error (three-dimensional root mean square error, 3D RMS) reached 41.7 mm and 80.2 mm, respectively, and the final The precision of the product has a significant difference, and it cannot fully satisfy the high precision The needs of GNSS users. In order to improve the ultra-fast track accuracy, learn The authors selected the forecasting strategy [1, 2], the optimal arc length , the forecast time The separation and the influence of the earth 's rotation parameter error [3, 4], etc. on the super fast The forecast track has been refined. However, these studies are mainly aimed at Is the prediction part of the ultra-fast orbit, for the observation part of the orbit.

The accuracy improvement of the track has not yet been specifically developed. As GNSS flourishes Development, such as Beidou 's "three-step" strategy, Accuracy ultra-fast orbit research is to expand GNSS fast and efficient service Necessary prerequisites. Multi-frequency multi-mode GNSS development, gradually increasing the number of satellites.

And the ever-expanding tracking network, giving the analysis center an ultra-fast track Timeliness brings great chal-

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lenges [5]. Therefore, timeliness is also super One of the factors to be considered in the process of fast track generation. For Effectively improve the efficiency of GNSS orbit determination parameter calculation, different data Processing methods, such as parameter elimination method [6], double-difference ambiguity recovery Method [7], fast fixation of fixed point theory ambiguity and increase of parameters The calculation interval etc. were discussed and verified in detail, as well as different measurements.
Station optimization model was proposed to solve the problem of station distribution and orbit determination.
The relationship between effectiveness. However, these methods still have obvious Defects, such as failure to take into account the correlation between parameters, no guarantee The consistency of products and the lack of accurate function models, etc., are not Can essentially solve the timeliness of the ultra-fast track of the analysis center problem. It can be seen from the orbit determination observation equation that the ultrafast orbit timeliness and accuracy is directly related to the orbit observation data (quality, distribution) Correlation, and analysis of observation data on the accuracy of orbit determination parameters There are two main indicators of contribution, namely the accuracy of observations and the accuracy of parameters.
Attenuation factor DOP [8] Among them, The DOP value is directly related to the orbital space configuration [9]. Based on DOP The optimal spatial configuration of value positioning has been widely and deeply Research, because it optimizes the positioning of the surface to the center of the earth (The DOP value is the smallest), so the relevant theory is not applicable to precision rails Way to determine the model. Distribution of ground tracking stations based on DOP value Some scholars have studied the determination of the earth's rotation parameters [10] and Beidou di Geostationary Orbit Satellite (GEO) The optimal configuration of the star orbit [11] parameters. However, these are based on special The study of conditions is not universal. The experiment found that the ground survey Solution of satellite orbit and related parameters based on the number of stations and spatial position Count plays a vital role. Therefore, for the orbital arc In a certain epoch, its orbital space state parameters (position and velocity) are affected by The influence of observation data can be expressed as the configuration of tracking station and satellite Functional relationship. Experiments show that [12], by establishing satellite orbit parameters The functional relationship between accuracy and its DOP value Indirect improvement of ultra-fast track accuracy under data-restricted conditions, Especially the improvement of Beidou track accuracy is more obvious. Simultaneously, For data redundant areas, establish the minimum DOP as the criterion Tracking station distribution optimization model (to achieve accuracy phase with fewer stations Local orbit determination process), can take into account the accuracy of ultra-fast orbit calculation. And timeliness. Therefore, the full use of the orbit determination DOP value is to increase One of the effective ways for ultra-fast track accuracy and timeliness. This article is mainly aimed at Insufficient measurement data leads to the problem of reduced track accuracy. Function model of fast track accuracy and its state parameter DOP value; Predict the amount of change in DOP value with high accuracy and correct the ultra-fast orbit The problem of reduced accuracy in the later period of observation further improves the forecast orbit Precision.

A. GNSS Ultra-Fast Observation Orbit Refinement Model

1) The principle of orbit refinement based on DOP value: It can be seen from the literature that the orbit state parameter DOP value and There is a certain correlation between the track accuracy. Therefore, in the super fast track In the later period of the track observation, the orbital precision caused by the lack of observation data The degree reduction can be indirectly improved by the orbit DOP value. Specific as Next: Let epoch ti determine the orbit observation equation (to study the orbit state parameters The relationship between the DOP and the parameters other than the track as the Known value, then the parameter to be determined is only the track state parameter) expressed as:

$$\boldsymbol{V}\left(t_i\right)=\boldsymbol{L}\left(t_i\right)-\boldsymbol{A}\left(t_i\right)\boldsymbol{X}\left(t_i\right) \tag{1}$$

In the formula, L (ti) is the observation value; V (ti) is the correction value; X (ti) is the orbit Channel state parameter; A (ti) is the coefficient matrix. In formula (1), height angle If it is greater than $30°$, the equal weight model is adopted, and the high angle model is selected from $10°$ to $30°$ Type, excluding observation data less than $10°$, the coefficient matrix can be The step is expressed as:

$$\boldsymbol{A}\left(t_i\right)=\operatorname{diag}\left(\boldsymbol{a}_1\boldsymbol{a}_2\cdots\boldsymbol{a}_{m-1}\boldsymbol{a}_m\right) \tag{2}$$

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$$a_m = \begin{bmatrix} \frac{\partial \rho_{m,1}^{5_m - r_1}}{\partial x_m^{s_m}} & \frac{\partial \rho_{m,1}^{5_m - r_1}}{\partial y_m^{s_m}} & \frac{\partial \rho_{m,1}^{5_m - r_1}}{\partial z_m^{s_m}} & \frac{\partial \rho_{m,1}^{s_m - r_1}}{\partial \dot{x}_m^{s_m}} & \frac{\partial \rho_{m,1}^{s_m - r_1}}{\partial \dot{y}_m^{s_m}} & \frac{\partial \rho_{m,1}^{s_m - r_1}}{\partial \dot{z}_m^{s_m}} \\ \frac{\partial \rho_{m,2}^{s_m - r_2}}{\partial x_m^{s_n}} & \frac{\partial \rho_{m,2}^{s_m - r_2}}{\partial y_m^{s_n}} & \frac{\partial \rho_{m,2}^{s_m - r_2}}{\partial z_m^{s_n}} & \frac{\partial \rho_{m,2}^{s_m - r_2}}{\partial \dot{x}_m^{s_n}} & \frac{\partial \rho_{m,2}^{s_n - r_2}}{\partial \dot{y}_m^{s_n}} & \frac{\partial \rho_{m,2}^{s_n - r_2}}{\partial \dot{z}_m^{s_m}} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \frac{\partial \rho_{m,n}^{s_m - r_n}}{\partial x_m^{s_m}} & \frac{\partial \rho_{m,n}^{s_m - r_n}}{\partial y_m^{s_n}} & \frac{\partial \rho_{m,n}^{s_m - r_n}}{\partial z_m^{s_n}} & \frac{\partial \rho_{m,n}^{s_n - r_n}}{\partial \dot{x}_m^{s_n}} & \frac{\partial \rho_{m,n}^{s_m - r_n}}{\partial \dot{y}_m^{s_n}} & \frac{\partial \rho_{m,n}^{s_m - r_s}}{\partial \dot{z}_m^{s_m}} \end{bmatrix} \tag{3}$$

$$\left(\frac{\partial \rho_{m,n}^{s_n - r_n}}{\partial x_m^{s_n}}, \frac{\partial \rho_{m,n}^{s_n - r_n}}{\partial y_m^{s_n}}, \frac{\partial \rho_{m,n}^{s_n - r_n}}{\partial z_m^{s_n}}, \frac{\partial \rho_{m,n}^{s_n - r_n}}{\partial \dot{x}_m^{s_n}}, \frac{\partial \rho_{m,n}^{s_n - r_n}}{\partial \dot{y_n}}, \frac{\partial \rho_{m,n}^{s_n - r_n}}{\partial \dot{z}_m^{s_n}}\right) = \left(\frac{x_m^{s_n} - x_n^{r_n}}{\rho_{m,n}^0}, \frac{y_m^{s_n} - y_n^{r_n}}{\rho_{m,n}^0}, \frac{z_n^{s_n} - z_n^{r_n}}{\rho_{m,n}^0}, \frac{\Delta t(x_m^{s_n} - x_n^{r_n})}{\rho_{m,n}^0(t_r)}, \frac{\Delta t(y_m^{s_m} - y_n^{r_n})}{\rho_{m,n}^0(t_r)}, \frac{\Delta t(z_m^{s_m} - z_n^{r_n})}{\rho_{m,n}^0(t_r)}\right)$$

(4)

In the formula, tr is the signal receiving time; $\Delta\, t$ represents the propagation time. By (1) The available parameter co-factor matrix is:

$$Q(ti) = (AT(ti)PA(ti)) - 1 \tag{5}$$

In the formula, P is the weight matrix. The a priori solution accuracy of the k parameter is:

$$\sigma_{\mathrm{k}} = \sigma_0 \sqrt{Q\left(t_i\right)_{kk}} \tag{6}$$

In the formula, $\sigma 0$ is the medium error. From Equation (6) and literature [12] we can see that There is a certain relationship between the accuracy of the numerical solution and its corresponding co-factors Department: Equation (6) without considering $\sigma 0$, the corresponding parameter DOP value.

It can measure the geometric configuration of the station and the satellite. The influence of parameters, which can be expressed as the diagonal of the parameter co-factor matrix The square root of the sum of the elements. Therefore, the k-th orbit state parameter The DOP value can be expressed as:

$$D\left(t_i\right)_k = \sqrt{Q\left(t_i\right)_{kk}} \tag{7}$$

For the construction, the orbit state parameter DOP value is an independent variable Orbit refined function model, need to realize DOP value and orbit parameter The correction numbers correspond one-to-one, and Equation (7) cannot ensure any arbitrary epoch The condition that the DOP values are not equal is established. Therefore, this article defines the overall DOP value, to distinguish the DOP value of each epoch, that is, the k-th ti The total DOP value of the observation parameter of the three parameters is the first ti DOP value Square root of the sum of squares:

$$\left[D\left(t_i\right)_k\right] = \sqrt{\left[D\left(t_{i-1}\right)_k\right]^2 + \left(D\left(t_i\right)_k\right)^2} \tag{8}$$

In the formula, α represents the polynomial coefficient; ξ is the fitting residual; q is the fitting Order. By accurately solving the polynomial coefficients, the orbit can be accurately established The functional relationship between the track accuracy and the overall DOP value. Need It should be noted that the orbit correction amount obtained by Equation (10) is an absolute amount The actual correction amount can be determined through the track change trend [3]. Against super The quick observation of the track reduces the accuracy at the later stage, and the formula (10).

The DOP value is a function expression of the independent variable, so Obtain the DOP value in the later stage of the ultra-fast track, and the track change can be obtained indirectly Positive volume.

$$\mathrm{d}\boldsymbol{X}\left(t_i\right) = \begin{bmatrix} \mathrm{d}X_1 \\ \mathrm{d}X_2 \\ \vdots \\ \mathrm{d}X_6 \end{bmatrix} = \begin{bmatrix} f\left(\left[D\left(t_i\right)_1\right]\right) \\ f\left(\begin{bmatrix} D\left(t_i\right)_2 \\ \vdots \\ f\left(\left[D\left(t_t\right)_6\right]\right. \end{bmatrix}\right) \end{bmatrix} \tag{9}$$

2) Precise prediction method of DOP value: Under the condition of uniform distribution of the stations, the parameters in the orbit determination equation The number corresponding to the DOP value shows a smooth trend [12]. To describe the overall DOP Value change trend, this article is based on a polynomial model to fit the population DOP changes. The epochs in the model are independent variables, the model order needs Real-time determination according to different parameters. Therefore, suppose the overall DOP The change trend is:

$$D'\left(t_j\right)_k = \theta_0 + \theta_1 t_j + \cdots + \theta_b t_{jb} + e\left(t_j\right) \tag{10}$$

θ is the overall DOP curve coefficient; e is the model error; ti table Epoch mark; b is the polynomial order, which is sampled from the observation data The interval, pre-reported arc length and pre-report precision are jointly determined [1]. The formula of The matrix form in (11) is:

$$D_{k'} = G \cdot \theta + dD_{k'} \tag{11}$$

In the formula, G is the coefficient matrix; $\boldsymbol{Dk}'$ Represents the fitted residual; $\theta = [\theta 0 \theta 1 \theta 2 \cdots \theta$ b] T

$$\hat{\theta} = \left(G^{\mathrm{T}} G\right)^{-1} G^{\mathrm{T}} D_k' \tag{12}$$

Let the current epoch tj $= 0$, then the forecast D(t j)k is:

$$D\left(t_j\right)_k = \hat{\theta}_0 \tag{13}$$

Substitute the predicted DOP value in Equation (14) into Equation 10 find Solve the current epoch track correction and correct the track.

In the formula, f (·) represents the orbit state correction function. Based on GNSS Orbit observation equations, the DOP value of each epoch can be accurately determined by Equation (5) Calculation (overall DOP value can be obtained accordingly). Therefore, the available function Represents the relationship between the track state correction number and the overall DOP value. since the state correction function is affected by the modeled data length, sampling interval, Factors such as fitting length and correction accuracy affect together (dynamics Under the same model), the orbit correction algorithm can be constructed to Akaike information criterion, AIC) -based orbit state correction model optimization method. For It is convenient to discuss the orbit refinement model in this paper, taking polynomial function as For example, construct the track state parameter with the overall DOP value as the independent variable Refined model.

$$\begin{bmatrix} f\left(\left[D\left(t_i\right)_1\right]\right) \\ f\left(\left[D\left(t_i\right)_2\right]\right) \\ \vdots \\ f\left(\left[D\left(t_i\right)_6\right]\right) \end{bmatrix} = \left[\begin{matrix} \left[D\left(t_i\right)_1\right] & \left[D\left(t_i\right)_1\right]^2 & \cdots & \left[D\left(t_i\right)_1\right]^3 & 1 \\ \multicolumn{5}{c}{\begin{bmatrix} D\left(t_i\right)_2] & \left[D\left(t_i\right)_2\right]^2 & \cdots & \left[D\left(t_i\right)_z\right] & 1 \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ \left[D\left(t_i\right)_6\right] & \left[D\left(t_i\right)_6\right]^2 & \cdots & \left[D\left(t_i\right)_6\right] & 1 \end{bmatrix} \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \vdots \\ \alpha_4 \\ \alpha_0 \end{bmatrix}} \end{matrix} \right] + \begin{bmatrix} \xi_1 \\ \xi_2 \\ \vdots \\ \xi_6 \end{bmatrix}$$

(14)

II. ULTRA-FAST PRECISION ORBIT DETERMINATION TEST

A. Precision Analysis of Ultra-Fast Orbit Observation

International GNSS Service Organization (International GNSS Service, IGS) formally provided a 12 h interval from December 2000 The GPS ultra-fast satellite orbit service. Since 2004, updated The interval is increased to 6 h, from 48 h arc observation (24 h) and forecast (24 h) Two parts are formed. Currently, GNSS users can obtain 3 h delayed GPS and GLONASS by IGS and its analysis center Combine super fast ephemeris; iGMAS can provide including BeiDou. The multi-system fast ephemeris is used as a reference for precision analysis.

Take the 168th day of year (DOY) in 2017 The fast multi-system track serves as a reference. First, the statistics between the ultrafast orbit observation part and the GFZ orbit Residuals (using Helmert parameters for benchmark conversion), its view The 3D RMS of the orbit corresponding to the late measurement period (last 3 h) is shown in Figure 1. (G represents GPS, R represents GLONASS, and E represents Galileo, C means BeiDou). Then, for super fast track In the forecast part, since the forecast track is obtained by integration, its The error gradually increases with the length of the integration time; mean while ,When calculating the initial state of the predicted orbit, observe the later part of the orbit Have a larger weight. Therefore, in the late analysis of the observation orbit after the impact of the difference on the predicted orbit, this paper takes the ultra-fast orbit observation The last 1 h of data is used for orbit fitting, using the initial data after fitting.

Value forecast 24 h multi-system orbit, and accuracy with GFZ ephemeris In contrast, the first 6 h of orbits are counted (at intervals of 2 h). Repeat the above The experimental procedure is continuous for one month (2017 DOY 168 197 days), the results of ultra-fast observation orbit The average of the accuracy (3D RMS) of the predicted orbit is shown in Table 1, and Table 2.

Not all satellites will show accuracy in the above experiment Significantly reduced phenomenon, only the accuracy is reduced in Figure 1. Related satellites. By the Department of Observation and Forecast of Ultrafast Orbit According to the accuracy statistics, we can get: (1) Ultra-fast orbit observation In the later part (the last 3 h), the accuracy is obviously reduced. In order to analyze the phenomenon of reduced accuracy in the later stage of ultra-fast observation. Based on 409 stations, based on self-edited GNSS data preprocessing Software, statistics the data quality of all stations.

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TABLE 1
3D RMS OF THE OBSERVED ULTRA RAPID ORBIT/CM

	1 ∼ 20 h	21 h	22 h	23 h	24 h
GPS	3.6	3.5	4.6	6.3	7.5
GLONASS	6.1	5.6	6.1	7.5	10.2
BeiDou	12.9	12.1	12.4	15.6	21.8
Galileo	8.2	13.2	13.5	14.4	17.9

TABLE 2
3D RMS OF THE PREDICTED ULTRA RAPID ORBIT/CM

	2 h	4 h	6 h	1 ∼ 12 h	1 ∼ 24 h
GPS	7.8	9.8	10.6	10.8	16.1
GLONASS	12.5	13.4	13.6	14.3	21.9
BeiDou	23.2	39.9	61.1	70.1	139.9
Galileo	16.9	26.6	32.5	32.4	49.9

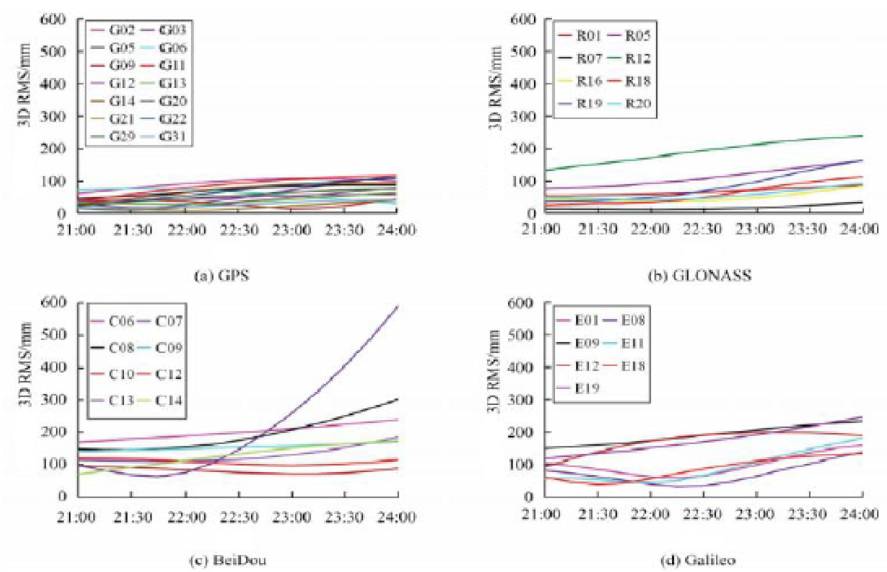

Fig. 1. 3D RMS of the observed ultra-rapid for the last three hours

Table 3 statistics Data quality of the observation data of all stations in the first 21h and the last 3h The average value of There is no significant difference in quality. After using the ultra-fast observation part Orbit forecast (the last 1 h) orbit forecast, which will significantly reduce the forecast Report track accuracy. In summary, in order to improve the ultra-fast track accuracy, there is necessary to revise the later data of the ultra fast orbit observation part Positive, improve the ultra-fast track accuracy.

TABLE 3
COMPARISON OF DATA QUALITY DURING ONE MONTH

	1 ∼ 21 h			3 h		
Data integrity rate	95.80	100.00	97.19	95.20	100.0	96.27
MPI/m	0.03	0.29	0.21	0.05	0.28	0.21
MP2/m	0.04	0.32	0.27	0.09	0.41	0.36
SN1	6.43	50.85	42.17	6.26	50.63	41.77
SN2	4.42	46. 29	34.88	4.31	46.05	34.34
Cycle slip ratio	0.02	4.22	1.49	0.02	4.81	2.48

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Note: MP1 and MP2 represent the multiples of Band 1 and Band 2 on different satellite systems, respectively. The average value of the path effect; SN1 and SN2 represent the average SNR of Band 1 and Band 2, respectively.

B. Orbit Refinement Strategy Based on Orbit Determination DOP value

The main steps are as follows:

(1) Obtain navigation files and list of stations and station coordinates, merge hourly observation files (not in the last 3 h) and preprocessing the observation files, screening orbiting station.

(2) Calculate the DOP value corresponding to each parameter epoch, and Epoch accumulation (to obtain the total DOP value of each parameter).

(3) Super fast Calculation and forecast of high-speed orbits The multi-system orbits should be compared to calculate the orbital residuals.

(4) Built Establish the status parameters of each satellite and the overall DOP value of its corresponding epoch Function model.

(5) Forecast the ultra-fast orbit based on the model in $2.2 The DOP value in the later part (last 3 h) of the observation part.

(6) The forecast The DOP value is substituted into the orbit correction function model, using the function model to Correct the orbit in the later part of the observation part.

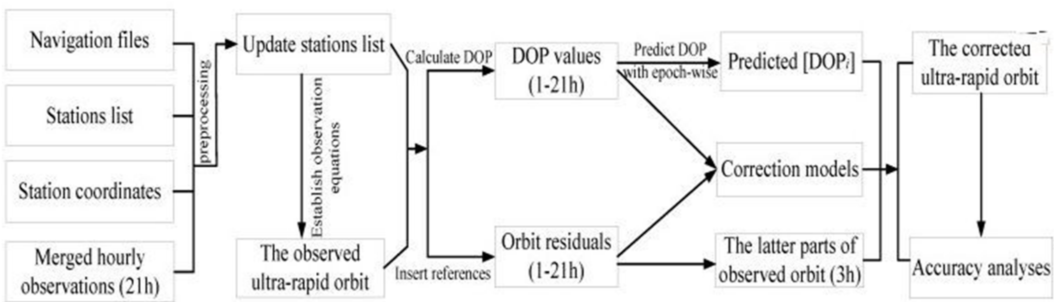

Fig. 2. Flowchart of ultra-rapid orbit correction experiment based on DOP values

C. Analysis of Orbit Correction Model based on DOP Value

To verify ultra-fast observation orbit refinement model based on DOP value The feasibility of the model, this paper fits the DOP value model and the track state Parameter refined function model for analysis. First, analyze the orbital parameters The relationship between the DOP value and the amount of observation data.

the observation data of the tracking station with a sampling interval of 30 s. Figure 3 (a) and Figure 3 (b) shows the distribution diagram of 409 global tracking stations Distribution map of stations used for GFZ orbit determination, shown in different colors Can receive single system (G: GPS), dual system (G+R : GPS + GLONASS), three systems (G+R. +E : GPS + GLONASS + Galileo) and four systems (G + R+ E + C : GPS + GLONASS + Galileo + BeiDou) distributed. Keep any selected 200,150,100,50 and 0 respectively (Do not keep) the hourly observation data of the last 3h at the DOP value calculation and corresponding orbit determination accuracy statistics. Due to orbit The amount of verification data is large. In Figure 4 only the representative G09 and Within a day corresponding to the C13 satellite (Day 153 of 2016 DOY) DOP value and track accuracy change trend (calculated with 409 stations The outgoing track is for reference; due to the 200 stations and 150 stations The results of the station program are very close. The accuracy of the orbit of 200 stations is omitted).

Through different orbits The program can be seen:

(1) With the decrease of the number of stations in the later part of the observation part (The number of hourly observation files in the last 3 h gradually decreases), DOP The value is obviously increasing; meanwhile, the track accuracy and DOP value The trend of change remains consistent.

(2) Observations at the later stage of the orbit will affect The accuracy of the orbit determination for the entire observation arc is mainly due to the number of observations According to the reduction, the initial spatial state parameters of the orbit are affected.

(3) The whole track state parameter DOP value shows a smooth curve within the orbital arc. Then, in order to accurately describe the change trend of the orbit DOP value, This article is based on arbitrarily selected 409, 200, 150, 100 and 50 Observing data from three stations to calculate the orbital parameters within one day of orbit determination DOP value, and use AIC to determine the optimal polynomial order.

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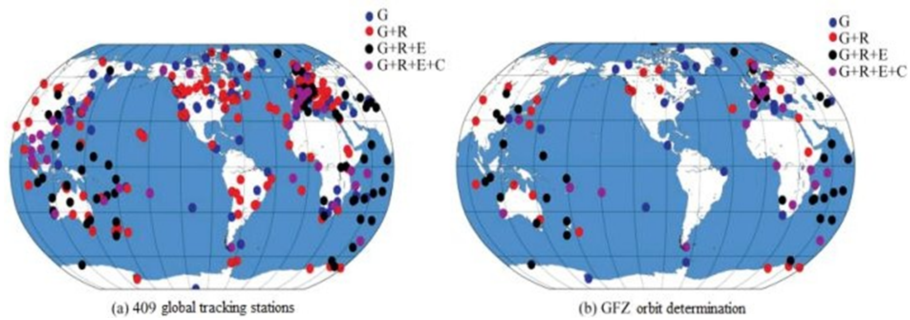

Fig. 3. Distribution of the experiment stations

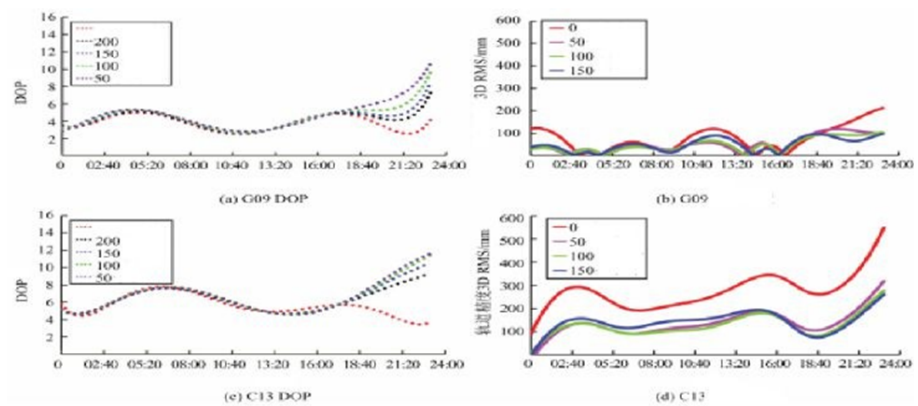

Fig. 4. Variation of DOP values and orbit accuracy in different stations

AIC Defined by:

$$C = n \log \left(\hat{\sigma}^2\right) + 2k \tag{15}$$

Where n is the number of observations; $\hat{\sigma}$ is the mean square error; k is the parameter number. On the right side of the equal sign in Equation (15), the first term represents the model 's Goodness, the second term represents the complexity of the model. Therefore, the preferred mode Type is the model with the smallest AIC value. Take G09 as an example (2016 153th day of the year DOY), the corresponding model information statistics see Table 4.

The interest rate is the smallest, and the fitting model is the best. Based on the refined model of orbit determination DOP value orbit, it should be selected according to different satellites Choose the optimal DOP forecast model order.

TABLE 4
AIC OF POLYNOMIAL MODEL

Order	409	200	150	50
1	51.11	49.70	51.43	57.09
2	36.64	35.52	34.15	48.18
3	27.48	26.41	21.22	28.32
4	18.14	16.50	15.10	18.34
5	21.51	30.40	19.42	28.22
6	28.34	30.18	25.13	38.33

At the same time, in order to discuss the possible Reliability, the experiment from the observation data length and function model two aspects Verify the state correction model. Experiments in $2.1 show that The orbit divergence phenomenon occurred late in the fast orbit observation section, so The experiment mainly predicts the orbital correction number in the last 3 h of the observation part.

The specific experimental protocol is as follows.

Option 1: Based on observation data of 0.5, 1, 2, and 3 d, respectively (Sampling interval 30 s), forecast orbit correction number of 3 h (between orbit Every 5 minutes); statistics for one month (2016 DOY 122 $\sim$ 151 days) forecast accu-

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racy; polynomial order in Equation (10) The results (with reference to the calculated orbits of all stations) are shown in Figure 5.

Option 2: Based on single-day observation data using polynomial, Gray model, neural network model and autoregressive model construction track Model of track correction; the number of orbit corrections for 3 h is also predicted and statistically calculated Orbit correction accuracy for one month in a row. Its corresponding statistical result As shown in Figure 6.

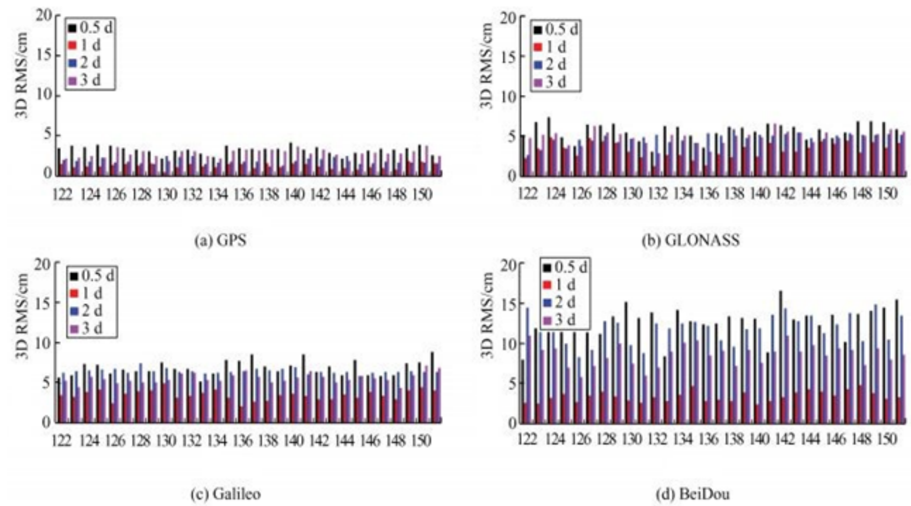

Fig. 5. Results of orbit correction schemes based on different lengths of observed data

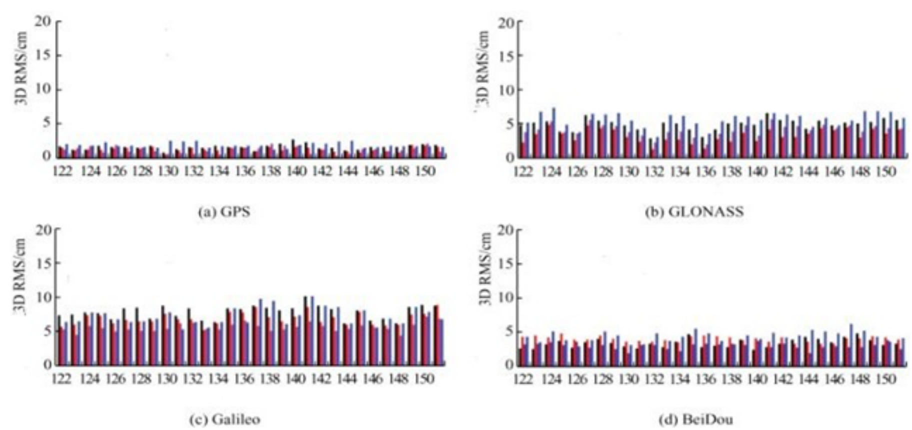

Fig. 6. Reults of different orbit corresctions models

Based on the polynomial function model in Scheme 1, when the observed data and the length is 1 d, the orbit correction effect is the best; and when the data is long and the degree is 0.5 d, the track correction effect is the worst. Through 4 groups of comparisons Experiments can be found:

(1) The ultra-fast orbit correction model proposed in this paper The type is affected by the length of the observation data, which is mainly due to the different numbers According to the length, there is a difference in the fitting degree of the function correction model (There are differences in solving the initial state parameters of the predicted orbit).

(2)The track cannot be completely corrected, because the orbiting camera dynamic model And the parameter estimation model, and modify the model based on the DOP value Only partial corrections are implemented.

(3) In order to take into account the time of super fast Effectiveness and correction accuracy, this paper uses 1 d observation data as the correction Positive model modeling sequence.

Scenario 2 is based on different prediction models, from the revised results (see It can be found in Figure 6) that the neural network model is superior to the other three predictions Model, this is mainly because the other three are linear models. With the time, there is no obvious difference in the correction effect of the four models, so in the construction When the orbit correction model is used, a suitable Func-

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tion model. In the follow-up study, a variance-based on Optimization algorithm for quantity estimation and Akaike information criterion study.

D. Ultra-Fast Observation Orbit Correction Experiment

For specific analysis, the ultra-fast orbit refinement model proposed in this paper experiment selection for consecutive 10 days (2016 DOY No. 141 150 days) comparative analysis of the orbit results. Of which The function model and the DOP value prediction model adopt $2.3 and The polynomial model in $1.2, the model order is all confirmed by AIC Through the super fast observation based on DOP value proposed in this certain extent, it can be improved super fast Speed orbit, the accuracy of the later part of the orbit observation part (last 3h) is improved $12.4\% \sim 22.0\%$; but the observation data cannot be completely There are two main reasons for orbit error correction in case of missing.

(1) Precision orbit determination mechanics model, parameter solution strategy and model Factors such as the fixed rate of consistency are comprehensively affected. The correlation between its accuracy cannot be accurately obtained.

(2) With observation The arc segment gradually increases in the later period of the orbit, and the error of the correction function model gradually Increase, further limit the track correction effect. The above simulation is to add all the downloadable stations of the analysis center to the orbiting party. Process, to ensure that the space configuration of the orbit determination under the condition of the existing station is the most Set.

Figure 7 lists the C13 corresponding to DOY on day 141. The track accuracy of E19, G09 and R11 before and after correction (in GFZ Orbit as a reference, the distribution of calculated orbital stations is shown in Figure 3 (b)) and DOP value (predicted value and calculated value). From the experimental results Out, based on the DOP value ultra-fast track correction method can improve the view.

The accuracy of the orbit under the condition of missing measurement data (Figure 7 (b) statistics Orbital accuracy 3 h after the observation part). Continuous 10 d system tracks The track correction results are shown in Figure 8, and the statistical results are shown in Table 5.

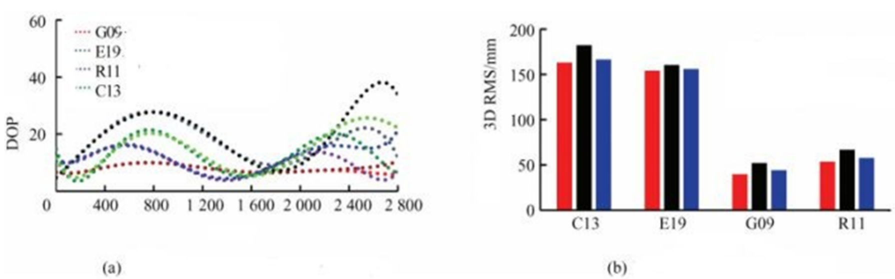

Fig. 7. DOP values and orbit accuracy before and after the orbit correcton for the last three hours

TABLE 5

COMPARISON OF 3D RMS BEFORE AND AFTER ULTRARAPID ORBIT CORRECTION FOR TEN COMSECUTIVE DAYS

			2016 DOY 141 ∼ 150 3D RMS/mm								
Satellitie Type	141	142	143	144	145	146	147	148	149	150	Lift rate %
GPS(B)	42	43	45	48	39	48	36	42	48	42	
GPS(A)	34	31	39	36	34	38	28	37	34	37	19.6
GLONASS(B)	59	56	67	61	66	66	72	61	77	78	
GLONASS(A)	44	50	65	58	58	62	64	55	26	35	22.0
Galilieo(B)	81	88	76	74	88	83	74	83	90	88	
Galileo(A)	73	78	68	63	79	75	63	66	79	76	12.7
BDS.MEO(B)	80	75	88	67	86	68	66	79	88	88	
BDS.MEO(A)	65	66	80	56	72	59	60	74	71	85	12.4
BDS.IGSO(B)	85	78	88	70	88	88	78	79	89	74	
BDS.IGSO(A)	66	64	68	62	72	74	71	71	76	63	15.9

Note: A means after correction; B means before correction; BDS (BeiDou navigation satellite system) stands for Beidou satellite navigation system; Medium Earth Orbit (MEO) is the center circle Spherical orbit satellite; IGSO (inclined geosynchronous orbit) is a tilted geosynchronous orbit satellite.

Through the super fast observation based on DOP value proposed in this paper Modified the model in the later stage of

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the track, to a certain extent, it can be improved super fast Speed orbit, the accuracy of the later part of the orbit observation part (last 3h) is improved $12.4\% \sim 22.0\%$; but the observation data cannot be completely There are two main reasons for orbit error correction in case of missing Points:
(1) Precision orbit determination mechanics model, parameter solution strategy and model Factors such as the fixed rate of ambiguity are combined to affect the The correlation between its accuracy cannot be accurately obtained.
(2) With observation
The arc segment gradually increases in the later period of the orbit, and the error of the correction function model gradually Increase, further limit the track correction effect. The above simulation The test is to add all the downloadable stations of the analysis center to the orbiting party.
To ensure that the space configuration of the orbit determination under the condition of the existing station is in the most Excellent conditions. The geometric configuration between the orbiting tracking station and the satellite cannot be reached Optimal or suboptimal, reduce the correlation between DOP and track accuracy, the effect of ultra-fast track correction based on DOP is limited; In the fast track calculation process, the optimal or suboptimal distribution of stations must be considered.

III. CONCLUSION

Ultra-fast track as required by GNSS users for precise positioning Important products whose accuracy directly affects real-time or near real-time application.

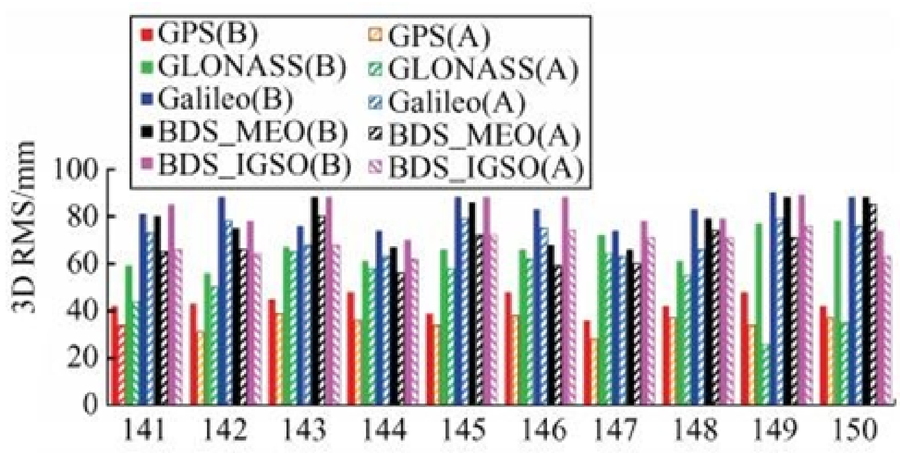

Fig. 8. 3D RMS statistics before and after orbit correction of the last three hours

However, through orbit analysis, it is found that the ultra-fast orbit view In the later part of the survey part (3 h), the orbit accuracy gradually decreases, which will further Affect the ultra-fast forecast orbit accuracy. To correct due to observation The part of the ultra-fast orbit observation caused by the lack of data is divergent From the perspective of the orbital space configuration, this paper studies the concept of difference between the DOP value and the orbit determination accuracy under the condition that the measured data is insufficient relationship. The experimental results show that the ultra-fast observation orbit observation Changes in DOP and track accuracy caused by missing data The potential is the same. Therefore, this paper proposes a track based on DOP value Road refinement model. Through comparative experiments, the DOP value was first verified The feasibility of the forecast model, The optimal order screening method of DOP forecasting model is analyzed.
Orbit results of different function models, and compare 4 different sets of Function model, it is found that the neural network model is better than the linear model, but There is no obvious difference in repair effect; the last 10 consecutive days are analyzed based on The late correction effect of the ultra-fast orbit observation part of the DOP value, The orbit correction method with DOP as an independent variable can improve Phenomenon of reduced accuracy of orbit caused by missing observation data, accuracy Increased by $12.4\% \sim 22.0\%$. Because the track accuracy is affected by the orbital force Learning models, parameter solving strategies, and fixed ambiguity modes Influenced by many factors, and the spatial configuration cannot fully improve the orbital accuracy Line expression, so the effect of track accuracy correction is limited system. Later, based on the research of this article, we will explore the various factors to determine the orbit The effect of refined ultra-fast orbit correction model.

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REFERENCES

[1] K. K. Choi, J. Ray, J. Griffiths, and T.-S. Bae, ``Evaluation of GPS orbit prediction strategies for the IGS Ultra-rapid products,'' *GPS Solutions*, vol. 17, no. 3, pp. 403-412, 2013. doi: https://doi.org/10.1007/s10291-012-0288-2

[2] C. A. Felix, C. Radu, R. A. Ioana, C. A. Florin, M. L. Ciprian, and C. Miron, ``A data analysis platform for high altitude bio monitoring using DEVOPS principles and time series machine learning,'' *Journal of Advances in Technology and Engineering Research*, vol. 5, no. 1, pp. 18-24, 2019. doi: https://doi.org/10.20474/jater-5.1.2

[3] Q. Wang, C. Hu, T. Xu, G. Chang, and A. H. Moraleda, ``Impacts of earth rotation parameters on GNSS ultra-rapid orbit prediction: Derivation and real-time correction,'' *Advances in Space Research*, vol. 60, no. 12, pp. 2855-2870, 2017. doi: https://doi.org/10.1016/j.asr.2017.09.022

[4] M. Szajt and M. Zawada, ``Usage of the analogy of space-time in forecasting changes in employment in knowledge-intensive services sector in Poland,'' *International Journal of Technology and Engineering Studies*, vol. 3, no. 2, pp. 59-64, 2017. doi: https://doi.org/10.20469/ijtes.3.40003-2

[5] C. Hu, Q. Wang, Z. Wang, and X. Peng, ``An optimal stations selected model based on the GDOP value of observation equation,'' *Geomatics and Information Science of Wuhan University*, vol. 42, no. 6, pp. 838-844, 2017.

[6] M. Ge, G. Gendt, G. Dick, F. Zhang, and M. Rothacher, ``A new data processing strategy for huge GNSS global networks,'' *Journal of Geodesy*, vol. 80, no. 4, pp. 199-203, 2006. doi: https://doi.org/10.1007/s00190-006-0044-x

[7] H. Chen, W. Jiang, M. Ge, J. Wickert, and H. Schuh, ``An enhanced strategy for GNSS data processing of massive networks,'' *Journal of Geodesy*, vol. 88, no. 9, pp. 857-867, 2014. doi: https://doi.org/10.1007/s00190-014-0727-7

[8] N. Blanco-Delgado, F. D. Nunes, and G. Seco-Granados, ``On the relation between GDOP and the volume described by the user-to-satellite unit vectors for GNSS positioning,'' *GPS Solutions*, vol. 21, no. 3, pp. 1139-1147, 2017. doi: https://doi.org/10.1007/s10291-016-0592-3

[9] R. Yarlagadda and A.-D. N. Ali, ``GPS GDOP metric,'' in *IEEE Proceedings Radar Sonar and Navigation,* New York, NY, 2000.

[10] Q. Wang, Y. Dang, and T. Xu, ``The method of earth rotation parameter determination using GNSS observations and precision analysis,'' in *China Satellite Navigation Conference (CSNC) Proceedings,* Berlin, Heidelberg, 2013.

[11] L. Zhang, Y. Dang, S. Xue, H. Wang, S. Gu, and C. Wang, ``The optimal distribution strategy of beidou monitoring stations for GEO precise orbit determination,'' in *China Satellite Navigation Conference (CSNC) Proceedings,* Berlin, Heidelberg, 2015.

[12] Q. Wang, C. Hu, and Y. Mao, ``Correction method for the observed global navigation satellite system ultra-rapid orbit based on dilution of precision values,'' *Sensors*, vol. 18, no. 11, pp. 3900-3910, 2018. doi: https://doi.org/10.3390/s18113900

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