BDS/AeroMACS Integrated Positioning Algorithm for Airport Surface Surveillance

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BIOGRAPHY (IES)

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ABSTRACT

With the increasing traffic volume of the airport, ensuring the safe and effective operation of the airport has become one of the major challenges in the field of civil aviation. The real-time positioning in the airport is worthwhile devoting much effort. The paper proposes a method of Beidou Navigation Satellite System (BDS) and Aeronautical Mobile Airport Communications System (AeroMACS) integrated positioning for airport surface surveillance, based on the experimental scene at Hehua Airport. Compared with the original GNSS positioning method, the integrated positioning algorithm can effectively solve the problem that GNSS is unavailable, because of the occlusion happened at the airport surface. The method gives the Doppler Shift ranging for AeroMACS, Fault detection and identification algorithm based on Kalman Filtering, and protect level algorithm based on filter innovation. Results of simulation shows that this paper breaks the limitation of satellite conditions by means of the cooperative positioning, and improves the availability of Receiver Autonomous Integrity Monitoring.

1.INTRODUCTION

In recent years, the number of airports and surface traffic flow increase rapidly. The security of airport surface is facing challenges. Surface monitoring relies on reliable, continuous positioning and efficient communication technology. However, the traditional airport communication methods are difficult to meet the commercial operation and service needs for large airports with the limited frequency band bandwidth. Moreover, the satellite navigation system is limited under the condition of complex scene, due to the satellite invisibility and other interferences, which may lead to the

https://doi.org/10.33012/2020.17179

failure of satellite positioning system. The requirements of integrity monitoring for the civil aviation system are more and more strict, so it is necessary to develop an integrated positioning method and improve the performance of integrity monitoring.

In 2012, AeroMACS technology was explicitly wrote in the aviation block upgrade plan (ASBU) at the 12th International Aviation Conference [1,2]. AeroMACS uses the 5091-5150 (MHz) internationally frequency band that is recommended by the International Telecommunication Union (ITU) and is allocated to 11 5-MHz frequency channels. AeroMACS support the terminal mobile speed up to 120km / h, which meets the demand of airport ground mobile terminal (vehicle taxiing or on-site vehicle monitoring); and it has certain non-line of sight communication ability to meet the actual demand of terminal [3]. As a new generation of airport aviation mobile communication system, it is a new generation of data link technology under the international civil aviation standard system [4]. AeroMACS can guarantee the transmission and acquisition of various information among airport ground equipments, which meets the increasing traffic volume of large airports.

By the end of 2018, BDS 3 has completed the basic system construction and provided open, authorized services worldwide. At present, China has successfully implemented airport surface surveillance applications based on AeroMACS and BDS at Hehua Airport of Hunan province. The current position and speed information of vehicles are obtained through the BDS high-precision positioning system, and AeroMACS network in the tower monitors the vehicle and vehicle position in the airport surface, so as to realize the real-time monitoring of complex activities and make sure the high-precision positioning. The combination of navigation and communication technology successfully realizes the real-time scene monitoring [5]. However, Hehua Airport has a special geographical environment that the Tian-men mountain located in the south of it, which will cause the invisible of satellites and the unavailable of BDS system. Therefore, the paper proposed the integrated positioning algorithm that AeroMACS is participate in.

Combined positioning has attracted great attention recently. This paper focus on the integrated positioning algorithm of BDS and AeroMACS to solve the problems mentioned above, using the real data collected in the Zhangjiajie Hehua Airport. By using the technology of Doppler Shift, we can transmit the frequency to pseudo range rate of AeroMACS that replaces the pseudo range of invisible satellite. Next, using Kalman filter technology to integrate the observation measurements of satellite and AeroMACS and get the final state value of the current time. Then, the fault detection model is established based on the of Kalman filter algorithm.

This paper is organized as follows. Section 2 illustrates an approach to calculate the pseudo range of AeroMACS by using the communication frequency. The results of data will be applied in the next chapter as one of the observation measurements. Section 3 introduces an improved method to realize the safe and real-time positioning for airport surface under the limited environment. Section 4 verifies the integrity performance of BDS and AeroMACS integrated positioning algorithm, such as the ability of fault detection, fault identification and protect level, based on the real experiment in Hehua Airport. Completing the evaluation of the performance for combined positioning. Section 5 offers a brief summary of the paper’s key points.

2. RANGING MODELING OF AEROMACS

2.1 The theory of Doppler shift ranging

Generally, the methods of communication ranging include pulse ranging, phase ranging and frequency ranging. And representative technologies include Received Signal Strength Indication (RSSI), Time of Arrival (TOA), Time Difference of Arrival (TDOA), etc. RSSI is much easier to realize in technology, but it is seriously affected by the path environment; TOA and TDOA use time difference to measure distance, which requires high time accuracy and is more complex in airport environment. Therefore, this paper chooses to use the Doppler shift ranging of frequency ranging method, which is less affected by the environment [6,7].

Doppler effect is occurred due to the relative motion between the transmitter and the receiver. The frequency difference between the transmit frequency and the receive frequency is Doppler shift. The relationship between Doppler shift and pseudo range rate is shown as follows:

$$\Delta f = f_r - f_t \tag{1}$$

$$\Delta f = -\frac{f_t}{c} \cdot v = -\frac{f_t}{c} \cdot \frac{dr}{dt} = -\frac{f_t}{c} \cdot \dot{r} \tag{2}$$

Δf is the doppler frequency shift， f_t and f_r are the transmitting frequency from the transmitter and the receiving frequency from the receiver, and c means the speed of light, $\dot{r}$ is the pseudo range rate. When the receiver and the transmitter are close to each other, $\Delta f > 0$, otherwise, $\Delta f < 0$.

2.2 Pseudo range rate acquisition of AeroMACS

AeroMACS needs to get the distance information between communication nodes to participate in the combined positioning. Base station is the access point of AeroMACS network, which realizes the access of air interface and various functions. It is divided by sector angle or frequency [8,9]. There are three base stations as transmitters in Zhangjiajie Hehua Airport
The base stations in the surface communicates with the mobile target in the field at a fixed frequency as 5.1 GHz transmission frequency. The pseudo range rate got from the doppler shift between the base station and the target can be further transformed into three dimensional coordinates:

$$\Delta f = -\frac{f_t}{c} \cdot \dot{r} = -\frac{f}{c} \left[\frac{(x-x_i) \cdot v_x + (y-y_i) \cdot v_y + (z-z_i) \cdot v_z}{\sqrt{(x-x_i)^2 + (y-y_i)^2 + (z-z_i)^2}} \right] \tag{3}$$

(x_i, y_i, z_i) is the three-dimensional position of the base stations of the Hehua airport. And we can get the position of the target coordinates (x, y, z) from the above formula. The relationship between Doppler frequency shift and target velocity like (2) can be further transformed into a non-linear relationship with three-dimensional coordinates, so as to obtain redundant pseudo range measurement from AeroMACS to be used in realizing the combined positioning.

3.THE MODEL OF BDS/AEROMACS INTEGRATED POSITIONING ALGORITHM

In China, there are many airports locate in the area of plateau and mountainous, like Zhangjiajie Hehua Airport, whose complex geographical environment leads to the low availability of BDS navigation system, and it is difficult to ensure the real-time positioning. Focusing on the conditions of invisible satellite caused by complex terrain, this paper proposes a BDS / AeroMACS combined positioning method to break the restraint of availability of GNSS. After getting the pseudo range rate in Section 2, we can integrate the pseudo range from satellites with the pseudo range rate from AeroMACS. Considering the non-linear relationship between pseudo range observation measurements and coordinate state quantity, Kalman filter algorithm is used to predict the system state value to complete the positioning solution [10]**.** BDS and AeroMACS system will make full use of their advantages, improve positioning accuracy, and achieve stable and reliable positioning solution under complex airport surface conditions.

3.1 Integrated positioning state model

Since the updating frequency of AeroMACS system is much higher than that of BDS satellite system, the updating frequency of satellite system is selected as the updating frequency of BDS / AeroMACS combined positioning system (i.e. the update every second). At this time, the combined state model based on Kalman filter algorithm is as follows:

$$\theta_k = F_{k,k-1}\theta_{k-1} + \zeta \tag{4}$$

θ_{k-1} is the state value of the previous time k-1, the initial state value is seen as the known value.

The state value at time K is: $\theta_k = \left[x, y, z, v_x, v_y, v_z, \delta t\right]^T$, and ζ is the process noise quantity of the system，which obey the Gaussian white noise distribution with the mean value of zero, $F_{k,k-1}$ is the one-step state transition matrix from (k-1) time to K time:

$$F_{k,k-1} = \begin{bmatrix} 1 & 0 & 0 & t & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & t & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & t & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \tag{5}$$

According to the combined state model, the prediction state value at k time can be obtained. The state variables describe the current working state of the system, and these state values will be directly reflected in the observation measurements of system.

3.2 Integrated positioning observation model

The BDS / AeroMACS combined positioning method collects the pseudo range observation measurements and pseudo range rate measurements of AeroMACS at the same time when the measurements value of BDS system is updated, and fuse the two kinds of observation measurements at the fusion center. According to the Kalman filtering algorithm, the observation model of the integrated positioning method is:

$$Z = G \times \theta + V \tag{6}$$

Where: Z is the system observation measurements of the combined positioning system , $Z = [\rho_1, \rho_2, \cdots \rho_n, \dot{r}_1, \dot{r}_2, \dot{r}_3]^T$, Assuming that the number of pseudo range measurements of satellite is n, ρ is the pseudo range value of satellite, $\dot{r}$ is the pseudo range rate of AeroMACS positioning method, θ is the state quantity of the combined system at the current time, which can be obtained from the section 3.1. G is the combined observation matrix， V is the observation noise matrix with the dimension of $(n+m)\times 1$.

$$G = \begin{bmatrix} G_{BDS} \\ G_{AeroMACS} \end{bmatrix} \tag{7}$$

$$G_{BDS} = \begin{bmatrix} g_{11} & g_{12} & g_{13} & 0 & 0 & 0 & 1 \\ g_{21} & g_{22} & g_{23} & 0 & 0 & 0 & 1 \\ & & & \cdots & & & \\ g_{n1} & g_{n2} & g_{n3} & 0 & 0 & 0 & 1 \end{bmatrix} \tag{8}$$

Where:

$$g_{i1} = \frac{\partial \rho_i}{\partial x}, g_{i2} = \frac{\partial \rho_i}{\partial y}, g_{i3} = \frac{\partial \rho_i}{\partial z} \tag{9}$$

$$G_{AeroMACS} = \begin{bmatrix} g_{11} & g_{12} & g_{13} & g_{14} & g_{15} & g_{16} & 1 \\ g_{21} & g_{22} & g_{23} & g_{24} & g_{25} & g_{26} & 1 \\ & & & \cdots & & & \\ g_{m1} & g_{m2} & g_{m3} & g_{m4} & g_{m5} & g_{m6} & 1 \end{bmatrix} \tag{10}$$

Where:

$$g_{i1} = \frac{\partial \dot{r}_i}{\partial x}, g_{i2} = \frac{\partial \dot{r}_i}{\partial y}, g_{i3} = \frac{\partial \dot{r}_i}{\partial z}, g_{i4} = \frac{\partial \dot{r}_i}{\partial v_x}, g_{i5} = \frac{\partial \dot{r}_i}{\partial v_y}, g_{i6} = \frac{\partial \dot{r}_i}{\partial v_z} \tag{11}$$

The purpose of Kalman filter is exactly to measure and predict the system state values from the system observation values.

3.3 Kalman filter fusion algorithm

As a common time-domain processing method in the engineering field, Kalman filter is also a common positioning solution method in GNSS global positioning system. Compared with the traditional least square method, Kalman filter does not need to obtain all the measured values to estimate the state values, and the time-domain observation processing method can eliminate the strict requirements of the instantaneous visible satellites [11].

The fusion of AeroMACS pseudo range rate observation measurements and satellite pseudo range values are the combined observation measurements of Kalman filter. The target needs to be equipped with Beidou signal receiver and AeroMACS receiver at the same time. According to the state model and observation model described in the section 3.1 and 3.2, the positioning solution is estimated by Kalman filter prediction method. The specific process is as follows:

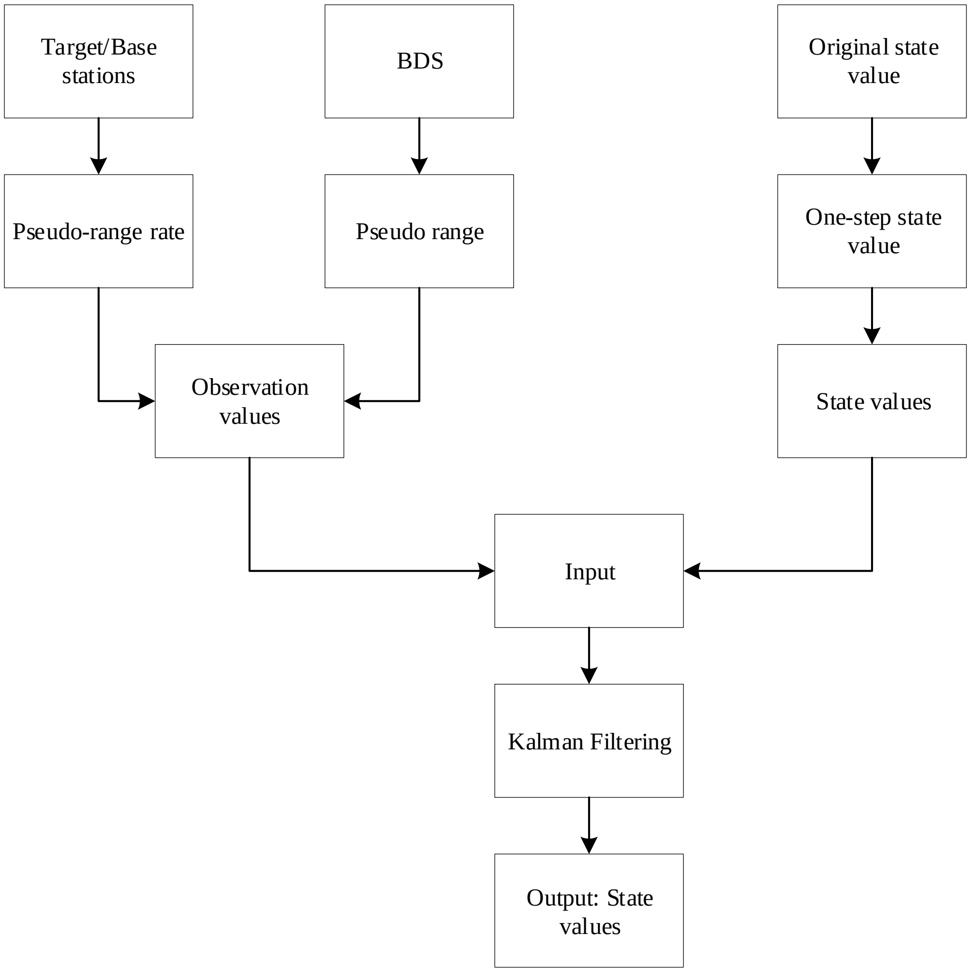

Fig 1. Flow chart of the BDS/AeroMACS integrated positioning

Step 1: Predicting the state value of K time according to the state value of the previous time, and outputting the one-step prediction value θ_k^- of the state quantity:

$$\theta_{k-1} = \left[x_0, y_0, z_0, v_x, v_y, v_z, \delta t\right]^T \tag{12}$$

$$\theta_k^- = F_{k,k-1}\theta_{k-1} + \zeta \tag{13}$$

Step 2: Calculate the one-step transfer covariance matrix of state value:

$$P_{k,k-1}^- = F_{k,k-1}P_{k-1}F_{k,k-1}^T + Q_{k-1} \tag{14}$$

Where, Q_{k-1} is the variance matrix of process noise ζ , $Q_{k-1} = E(\zeta\zeta^T)$. Each state estimate must follow a mean square error matrix to measure the reliability of the state estimation values for Kalman filtering.

Step 3: Calculate the matrix of Kalman gain value:

$$K = P_{k,k-1}^- G^T[GP_{k,k-1}^- G^T + R_k]^{-1} \tag{15}$$

where R_k is the variance matrix of the system observation noise, $R_k = E(VV^T)$.

Step 4: Calculate the state estimate value at the current time:

$$\theta_k = \theta_k^- + K[Z_k - G\theta_k^-] \tag{16}$$

This is the final result of the Kalman filter that is corrected by actual measurements from BDS and AeroMACS system.
Step 5: Calculate the covariance matrix of state estimation value:

$$P_k = (I - KG)P_{k,k-1}^- \tag{17}$$

In the process of Kalman filtering, the state estimation values are verified by the actual measurement value, so the mean square error is smaller and the reliability of the integrated positioning method is increased. Kalman filtering algorithm is especially suitable for the real-time and dynamic characteristics of positioning.

3.4 Results of integrated positioning method

In order to analyze the performance of BDS / AeroMACS, this paper does the experiments in Zhangjiajie Hehua Airport whose altitude is 250m. There is the Tianmen Mountain that located in the 4 km to the south of the Hehua airport with an altitude of 1518m, and the satellites are seriously blocked by environment factors. Moreover, the satellite signal receiver of the air traffic control building may be blocked by the tower in the airport surface, which will affect the reception of the North satellite signal and cause the multipath error of the satellite signal in other directions, and will finally affect the availability of the BDS navigation system.
There are three AeroMACS base stations in the scene of Hehua airport which use the Siemens ruggedcom win AeroMACS system and the figure 2 shows their distribution and specific structure. Two stations are located in the air traffic control building near the tower and the other is set in the self-observation platform.

Fig 2. Distribution of the AeroMACS stations

Our test vehicle is equipped with the antenna of BDS and AeroMACS to receive the real time signal (Figure 3); The taxiway with a length of about 2600 meters is selected as the operation track of simulation experiment with a pad showing the situation of the airport surface, and the target vehicle runs at a constant speed of 5 m / s on the runway. The red line in the figure 4 is the taxiway.

Fig 3. Target vehicle in the Hehua Airport

Fig 4. Target track of the experient vehicle

The original position and speed datas are acquired by the experiment, which means the input of the BDS / AeroMACS integrated positioning system. The thermal noise (σ) of integrated system is set as 17.6 meters. Comparing the positioning results with the true path, the result is shown as figure 5. The blue line is the true track of test vehicle, while the red line is the result of the integrated positioning system.

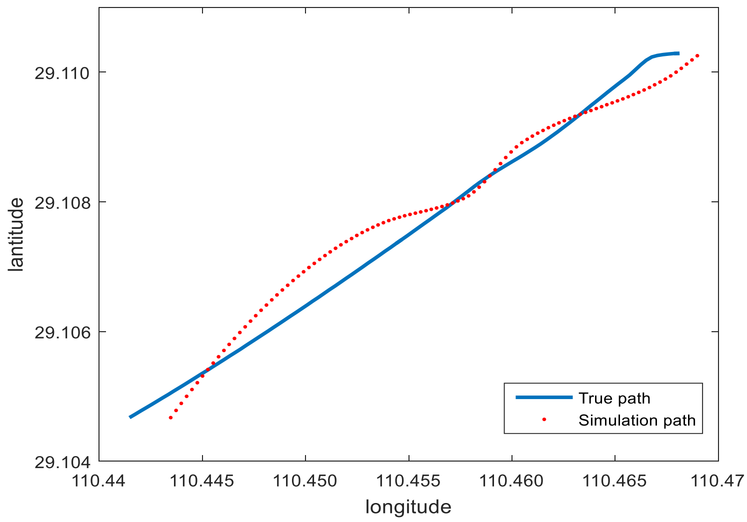

Fig 5. Positioning result of integrated positioning method

The result shows that the integrated positioning algorithm can complete the real time positioning when the GNSS is unavailable. And figure 6 and figure7 respectively show the lateral and radial positioning errors of the algorithm. The maximum value of lateral positioning errors is 18.80 meters and the mean value is -2.37 meters; while the maximum value of radial positioning errors is 13.68 meters and the mean value is -1.32 meters.

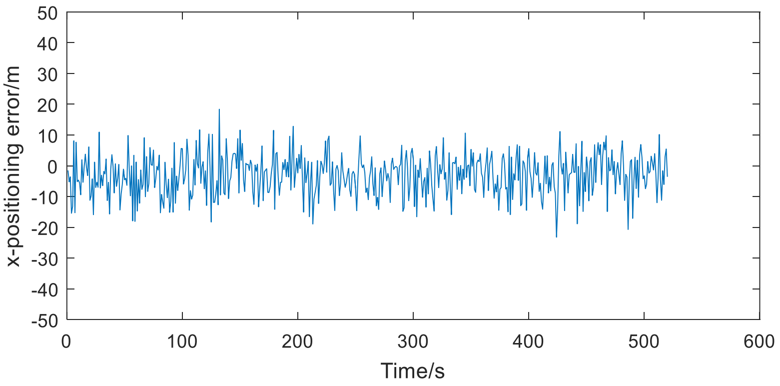

Fig 6. Positioning error in the direction of longitude

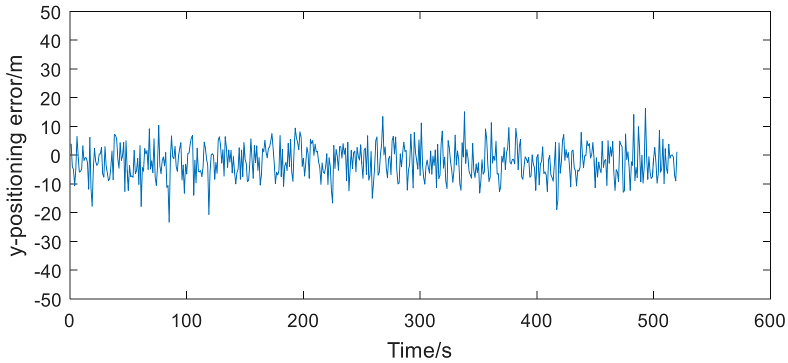

Fig 7. Positioning error in the direction of lanitude

4. INTEGRITY MONITORING ALGORITHM BASED ON KALMAN FILTERING

4.1 Fault detection and identification

(a) fault detection

The traditional fault detection methods of receiver autonomous integrity monitoring include the least square method, the odd even space method and the distance comparison method. Comparing with the traditional integrity methods, this paper uses the RAIM detection method based on Kalman filter innovation of BDS/AeroMACS combined positioning algorithm, because there is no need to monitor the integrity until the measurement finishes. The RAIM method based on Kalman filter innovation is used to eliminate the limitation of the lack of visible satellites by the time-domain updated observation [12]. The fault detection algorithm of BDS/AeroMACS integrated positioning is carried out by using the statistical characteristics of its innovation variance, which obey the Chi square distribution to determine the detection threshold and carry out fault detection.

According to the section 3, the discrete state equation and observation equation integrated with AeroMACS pseudo range rate are as follows:

$$\theta_k = F_{k,k-1}\theta_{k-1} + W_k$$

$$Z_k = G_k \theta_k + V_k \tag{18}$$

The state value of time (K-1) is θ_{k-1}. Using the state equation and the state one-step transition matrix to get the state value $\theta_{k/k-1}$ at k time，Then, using the observation equation, the predicted value of the observation measurements at time k is obtained as following:

$$Z_{k/k-1} = G_k \theta_{k/k-1} \tag{19}$$

The innovation of Kalman filtering is defined as the difference between the value of pseudo range (rate) from BDS/AeroMACS system at k time : Z_k and the predicted value of the observed value $Z_{k/k-1}$ in (19) at k time：

$$\Delta Z_k = Z_k - Z_{k/k-1} \tag{20}$$

The covariance matrix of KF Innovation is as follows:

$$\begin{aligned} S_k &= E[\Delta Z_k \Delta Z_k^T] \\ &= E[G_k \tilde{\theta}_{k/k-1} \tilde{\theta}_{k/k-1}^T G_k^T] + E[V_k V_k^T] \\ &= G_k P_{k/k-1} G_k^T + R_k \end{aligned} \tag{21}$$

where，$\tilde{\theta}_{k/k-1} = \theta_k - \theta_{k/k-1}$ is the variation of state value，and $P_k = E[\tilde{\theta}_{k/k-1} \tilde{\theta}_{k/k-1}^T]$ is the one step prediction error variance matrix.

At this time, create the test statistics t_k :

$$t_k = (\Delta \mathrm{Z}_k)^T (S_k^-)^{-1} \Delta \mathrm{Z}_k \tag{22}$$

According to the statistical distribution theory, if there is no fault satellite in the visible satellite, the observed noise vector V_k is Gaussian white noise. Each component in the innovation $\Delta \mathrm{Z}_k$ is 0, and distribution of the test statistic follows the chi square distribution with n degrees of freedom (n is the number of the visible satellites).

If there is a fault in the visible satellites, the observed noise vector V_k not only contains Gaussian white noise, but also contains fault error vector,
In this case, the mean value of each component in $\Delta \mathrm{Z}_k$ is not zero, and the test statistic obeys the noncentral chi square distribution with n degrees of freedom, and decentralized parameters equal to $\lambda = E(t_k)$. Using the inconsistency of diagonal elements of innovation variance matrix in the case of faulty satellite to determine whether there is a fault satellite, and then realize fault identification.

Therefore, the fault assumption is as follows:
Fault free H0：$E(\Delta Z_k) = 0$, $\mathrm{t} \in \chi^2(n)$
Single fault H1：$E(\Delta Z_k) \neq 0$, $\mathrm{t} \in \chi^2(n, \lambda)$

Supposing that P_{FA} is the maximum false alarm rate given by the combined positioning system，as 4×10^{-6} ， and the threshold T for fault detection can be determined by the follow equation ：

$$P(t < T) = \int_0^T f_{\chi^2(n)}(x) dx = 1 - P_{FA} \tag{23}$$

Where, n is the degree of freedom of chi square test, and the detection threshold T can be obtained from the above formula. The test statistics calculated at k-time are compared with the threshold value to determine whether there is a fault satellite. If the test statistics are more than the threshold

T, the result of fault detection obeys the H1 hypothesis, and the next step is to identify and remove the fault satellite. In this paper, we use the innovation variance to eliminate the faulty satellite.

(b) fault identification

Assuming the square of each element in the innovation vector of Kalman filter as X， $X_j = \Delta Z_{k,j} \times \Delta Z_{k,j} > S_{jj}$. Comparing the X_j with the diagonal corresponding elements S_{ii} of the innovation variance matrix S_k： if $X_j > S_{jj}$， the satellite j will be determined to be a faulty satellite. The corresponding pseudo range value should be isolated. If the satellite is considered to be fault free, we can use its pseudo range to going on the integrity monitoring. The process of integrity monitoring algorithm for BDS/AeroMACS integrated positioning method is as follows:

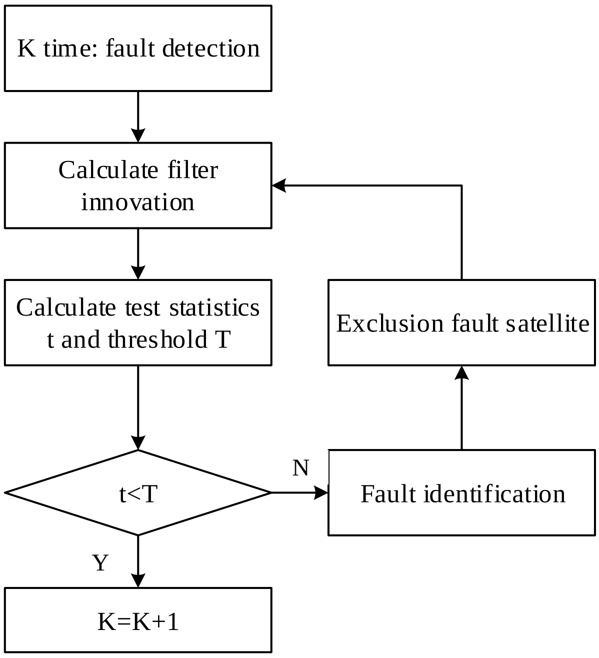

Fig 8. Flow chart of fault detection and identification

4.2 Protection level

In fact, HPL is the maximum value of horizontal positioning error that can be detected by integrity monitoring algorithm under the condition of certain false alarm rate and missing detection rate that are given by BDS/AeroMACS combined positioning algorithm. The ratio of positioning error and test statistics is defined as SLOPE. When the SLOPE value is the largest, the corresponding inspection statistics is the smallest, which means the satellite corresponding to the SLOPE is the most difficult to detect, so the integrity monitoring algorithm must ensure that the satellite with the largest SLOPE value can be successfully detected.

This paper adopts the HPL estimation method based on the Kalman filtering innovation. Its principle is based on the RAIM least square method of HPL derivation [13]. The formula of the horizontal protection level derivation is as follows:

$$HPL = SLOPE_{\max} \times \sigma_0 \times \sqrt{\lambda} \tag{24}$$

By definition：

$$SLOPE_i = \sqrt{\frac{(A_{1i}^2 + A_{2i}^2)}{S_{ii}}} \tag{25}$$

where $A = (H_k^T H_k)^{-1} H_k^T$， $S = I - H_k (H_k^T H_k)^{-1} H_k^T$， $H_k = \begin{bmatrix} G_k \\ I \end{bmatrix}$

G is obtained in Section 3.2. I matrix means the unit matrix.
The above method is used to calculate the protection level to ensure that the integrity monitoring meets the requirements of false alarm rate and missing detection rate for the combined system.

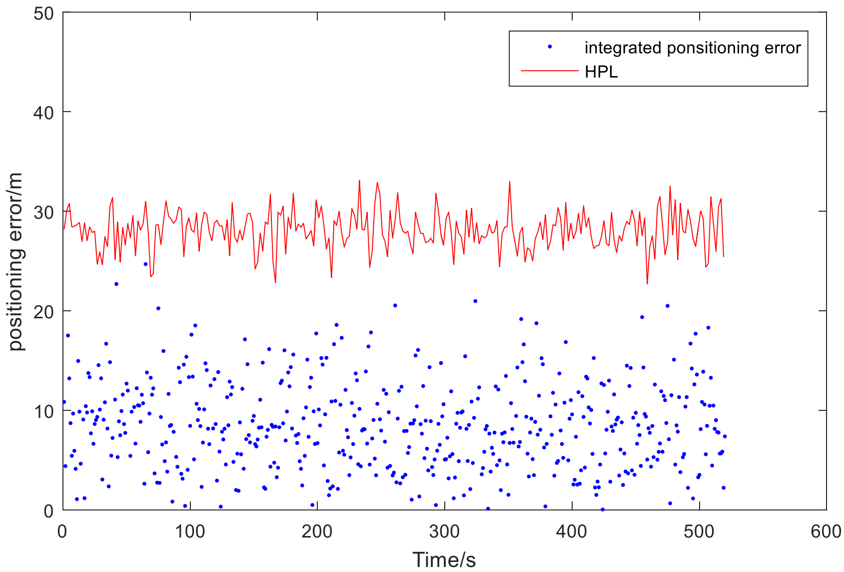

Fig 9. Positioning error envelope of combined algorithm

According to the calculation model of protection level, we can get the envelope of combined algorithm positioning error. The result is shown in the figure 6, and the mean of HPL is 28m. The integrated positioning errors almost distribute in 10m and the protection level can envelope the error.

4.3 Simulations and performance analysis

According to the Kalman filter algorithm, the distribution disgram of the test statistics of BDS / AeroMACS combined positioning is obtained. According to the filter innovation model in Section 4.1, the threshold value of the test statistics is obtained, and the fault is injected in the simulation from 300s to 350s. The results show that the fault is successfully detected under the KF fault detection method based on RAIM.

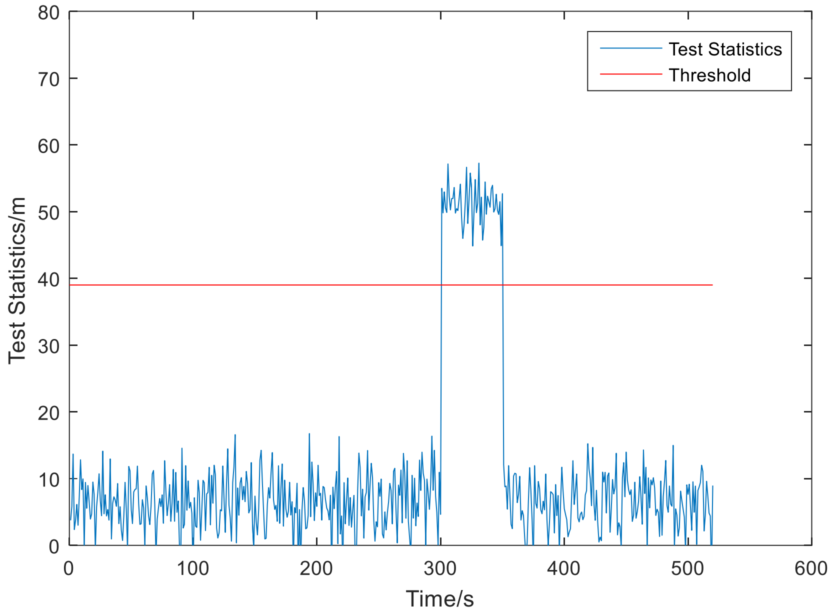

Fig 10. Kalman Filter innovation with fault detection

Based on the above simulation conditions and modeling results, the BDS / AeroMACS algorithm is tested under different satellite observation conditions. In this paper, two typical satellite observation conditions are set to analyze the performance of the algorithm under limited observation conditions [14]. Scenario 1: four satellites (PRN = 01,04,07,11) are visible to the target vehicle. At this time, the observation measurement just meets the basic requirements of positioning, but it is not enough to achieve the RAIM integrity monitoring.

Scenario 2: three satellites (PRN = 04,07,11) are visible to the target vehicle, and the observation measurement cannot meet the requirements of positioning and integrity monitoring. Based on the two simulation scenarios, a single satellite is selected to be injected the step fault, and then verifies the fault detection and fault recognition ability of RAIM algorithm based on Kalman filtering innovation variance.

In scenario 1, a single step fault of 40m was injected into satellite 7 from 300s, continuing for 50s. Only the pseudo range residual of the satellite prn 07 has exceeded the fault recognition threshold. The red line is the fault recognition threshold, while blue line is the residuals of integrated positioning system. The simulation results show that the fault detection method based on Kalman filter innovation of the integrated positioning system can successfully detect the fault, with no missing detection happens.

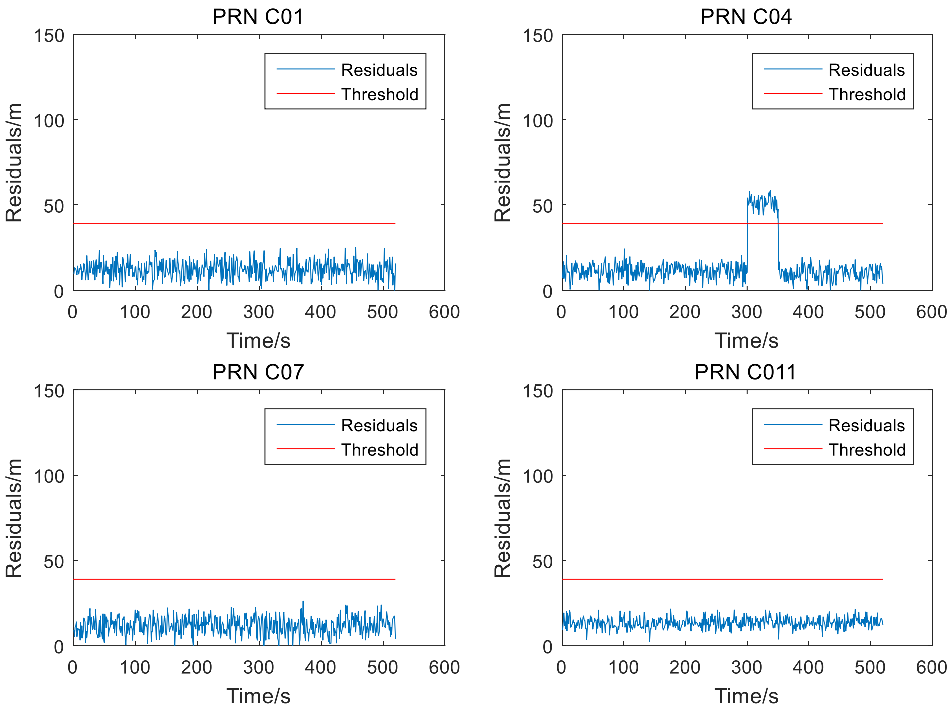

Fig 11. Fault identification of combined system with four visible satellites

The simulation experiment in scenario 2 is also injected 40m single step fault into satellite 4 in a period of 300-350s. The results show that the pseudo range residual of satellite 4 with step fault is successfully detected.

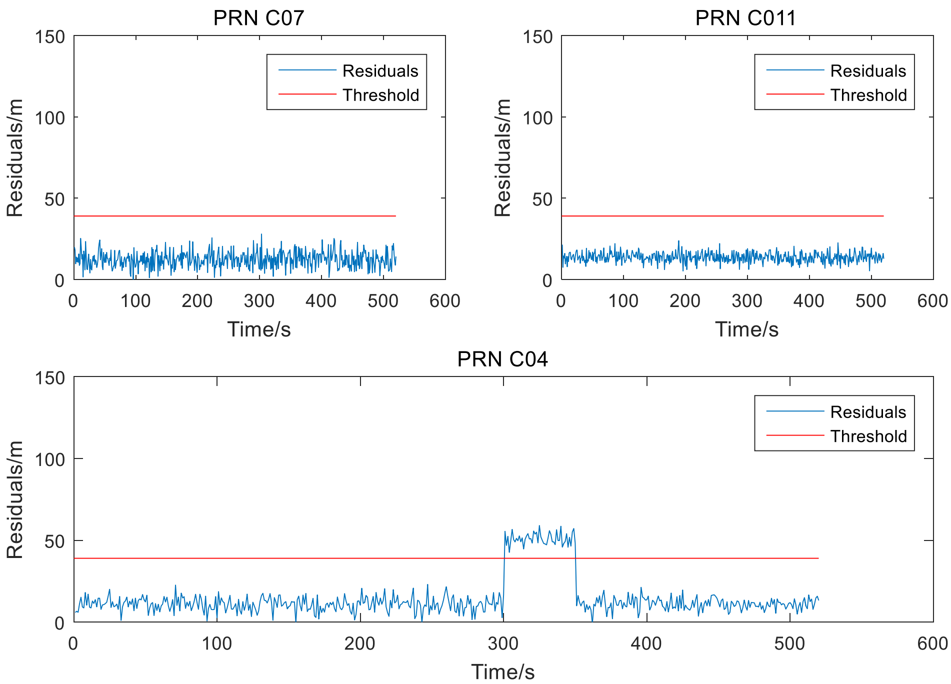

Fig 12. Fault identification of combined system with three visible satellites

The results of integrity monitoring indicate that the BDS/AeroMACS integrated positioning algorithm meets the needs of surface monitoring when GNSS is unavailability. In brief, the continuous and high-availability RAIM based on the proposed solution in this paper makes it possible of ensuring a fault-free measurement set from both GNSS and assistant sensors for trustworthy positioning.

5. SUMMARY

This paper introduces the integrated positioning model based on BDS and AeroMACS by using the Kalman Filtering algorithm for the complex and limited situation of airport surface. Firstly, because of the invisible satellite, the AeroMACS system on the airport ground is used to obtain the virtual pseudo range rate with the help of Doppler Shift ranging principle, which is not limited by environment or other conditions. Secondly, carrying out the BDS/AeroMACS combined positioning method based on Kalman Filtering to get the real-time state value and error that are used in the integrity analysis. Thirdly, through the field experiments and simulation experiments in Hehua Airport, the feasibility of BDS/AeroMACS integrated positioning algorithm based on the KF is verified, and the integrity monitoring method based on KF innovation can achieve fault detection, identification and elimination. The simulation results show that receiver autonomous integrity monitoring method based on KF innovation can improve the RAIM integrity monitoring performance, effectively ensure reliable positioning under the limited conditions.

Our future work plan is to expand the analysis of multiple fault hypothesis, further verify and improve the performance of the combined location algorithm; overcome the limitations of the fixed hypothesis of ranging error and location error; conduct combined location experiments in multiple airports to further verify the integrity monitoring performance.

ACKNOWLEDGMENTS

The authors would like to thank many people in the National Key Laboratory of CNS/ATM for their advice and interest. The work was carried out with financial support from the National Natural Science Foundation of China (Grant Nos. 61871012 and U1833125), the project from Ministry of industry and information technology (Project Name: Airborne RAIM/ARAIM Technology), Open fund project of Intelligent Operation Key Laboratory of Civil Aviation Airport Group（Grant No.KLAGIO20180405）,Young top talent support program of Beihang University, and 2019 Beijing Science and technology new star plan（Grant No. Z191100001119134）.

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