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Agenda Item 5: ATM Automation System Implementation Experience by States

5.6. Development of New Technology

RESEARCH ON THE FUSION OF ADS - B AND APPROACH RADAR WITHIN TOWER RANGE

(Presented by China)

SUMMARY

This article introduces the experience of fusion of approach radar and ADS-B within the range of the tower control of Tianfu International Airport, and expounds on the benefits brought by the fusion as well as the existing deficiencies.

1. INTRODUCTION

1.1 Compared with ACC and TMA controllers, tower controllers have specific application characteristics when using integrated tower system or A-SMGCS in the process of implementing radar control：

a) It requires high-precision surveillance data to monitor aircraft deviating from the glide/localizer path, and meanwhile reduce the false alarm rate.

b) It requires surveillance data with a high update rate to avoid significant changes in the aircraft's speed and the aircraft interval caused by a long update interval of the surveillance data, which may lead to misjudgment and inappropriate handling.

1.2 This article conducts a comparative study on the use of approach radar alone and the fusion of approach radar and ADS-B in combination with the experience of Tianfu Airport. The results show that the fusion of ADS-B and approach radar can optimize the accuracy of the track position and the ground speed calculate

2. DISCUSSION

2.1 The advantages of multi-source surveillance data fusion are remarkable. It can cover a wider spatial and temporal range, meanwhile present the target's position, track, and speed more accurately and reliably. Compared with the wide-area multilateration, the ADS-B surveillance data has the advantage of small investment. At the same time, it also has the advantages of fast update frequency and high precision, so can serve as an important supplement to the approach radar.

2.2 The Filtering Conditions and Coverage Scope of ADS-B of Tianfu Airport

When applying ADS-B in the integrated tower system, in order to effectively eliminate the interference of low-quality ADS-B data on track fusion, a filtering mechanism is constructed based on the ADS-B quality factor during the signal access stage. Specifically, the filtering conditions will be set according to the following parameters.

Table 1. ADS-B Filtering Conditions

Quality factor	Set values
Navigation Uncertainty Category for Position (NUCp)	6
Navigation Accuracy Category for Position (NACp)	8
Navigation Integrity Category (NIC)	7
Surveillance Integrity Limit (SIL)	3
Position Integrity Category (PIC)	4

Meanwhile, in order to avoid the situation where the integrated surface track fluctuates due to the insufficient accuracy of ADS-B an ADS-B exclusion zone is set during application. Horizontally, this exclusion zone extends 100 m along the final from the runway threshold. Vertically, it covers a spatial range up to a height of 150 m from airport.

2.3 The Accuracy of ADS-B on the Final at Tianfu Airport

ADS-B depend on GNSS for positioning, so it has the drawbacks of poor stability and susceptibility to interference when using. To evaluate the positioning accuracy of ADS-B within the airspace of Tianfu tower, the following steps were taken:

Data collection: ADS-B message data were collected during the final and landing phase of flights over three consecutive days within a specific time period.

Evaluation index: The NACp (Navigation Accuracy Category Position) in the ADS-B quality factor system was used to measure the accuracy of position information.

Sample details: There were 1,414 valid samples.

Table 2. The Distribution of NACp data

NACp	Quantity of samples	Rate
9-10	4	0.28%
9	1311	92.7%
8-9	41	2.9%
8	51	3.6%
7	6	0.42%
-1	1	0.07%

Explanation: In the above table, 9-10 means that the NACp of the flights varies between the two numbers 9 and 10; 8-9 means that the NACp of the flights varies between the two numbers 8 and 9; -1 indicates that the NACp has not been downloaded.

Evaluation result: The messages with NACp values in the range of 8 and 9 dominate the overall sample. The proportion of samples with NACp greater than 8 during the navigation process of aircraft on the final at Tianfu Airport reaches 92.98%. For cases where the NACp is greater than 8, the estimated position uncertainty (EPU) of the aircraft is less than 30 m.

2.4 Comparison of the Accuracy Between ADS-B and Approach Radar on the Final at Tianfu Airport

In order to conduct a comparative study on the accuracy of ADS-B and approach radar，taking the runway threshold as the reference origin point, the equidistant projection is used to plot the positions of ADS-B messages and those of two approach radars for inbound flights within 24 hours.

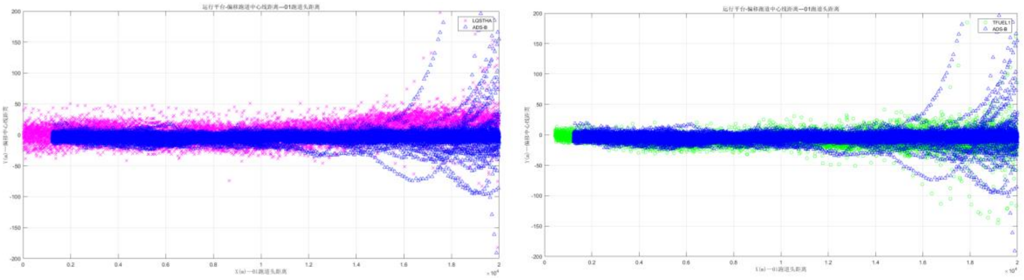

Figure 1. Positions of ADS-B Messages and Approach Radars

a) ADS-B: Above pictures blue plots represents ADS-B message reporting position. In the 24 - hour statistics, the drift of the blue plots on the final is within 30 m, featuring high accuracy and strong stability. In the meantime when the aircraft turning from base to the final, it can accurately and continuously provide a sequence of plots information to precisely depict the turning dynamics.

b) Approach radars: The plots marked in pink and green are plots from two approach radars, which are more scattered in spatial distribution compared with ADS-B plots. When the aircraft is turning to the final, due to its long update interval, it is difficult to accurately depict the turning dynamics as precisely as ADS-B does, which may pose challenges to the accurate calculation of the flight vector in the integrated tower system.

Evaluation result: Compared with the approach radars, ADS-B can report the position of flights timely and accurately on the final. Meanwhile, with its high update rate, so it can precisely reflect the turning dynamics of flights.

2.5 Optimizing the Accuracy of Integrated Track

There are significant differences between approach radar and ADS-B in terms of the detection methods, system measurement errors, data update cycles, etc. Coupled with the limitations of the integrated tower system’s fusion algorithm, these differences may lead to the deterioration of the target tracking accuracy after fusion. So the following comparative study is carried out to evaluate whether the fusion of ADS-B and radar within the airspace of Tianfu Tower can improve the accuracy of the integrated track.

Research setting: Select the period of the long final when aircrafts are aligned with the glide path and localizer, use the same set of integrated tower system, and delimit the research airspace as an area extending 15 km outward along the runway centerline from the runway threshold to final.

Experimental grouping: One group is the fusion of two approach radars, and the other group is the fusion of approach radars and ADS-B.

Measurement content: Analyze the tracks of landed flights and determine the maximum deviation of the fused track relative to the extension of the runway centerline at the final.

Experimental results：

a) The fusion of two approach radars: The total number of samples is 115, with a mean value of deviation 35.21 , a standard deviation of 5.40, a minimum value of 15.98, a median of 33.85, and a maximum value of 57.78.

b) The fusion of approach radars and ADS-B: The total number of samples is 115, with a mean value of deviation 11.31, a standard deviation of 4.17, a minimum value of 5.01, a median of 10.94, and a maximum value of 27.93.

Evaluation result: fusion depend on the approach radars and ADS-B, the mean value and standard deviation of the maximum deviation between the track and the extension of the runway centerline are significantly reduced, the track maximum deviation is significantly decreased, the fluctuation range is smaller, the stability is stronger, and the accuracy and reliability of the monitoring of airspace targets are improved.

2.6 Optimize the Takeoff and Landing Phases

During the critical takeoff and landing phases of an aircraft is often in the area where the signals of the approach radar disappear or are extrapolated, due to various complex factors. The approach radar at Tianfu Airport has the following problems in application:

Signal interference and interruption: When an aircraft takes off or lands, affected by the interference of complex factors such as the obstruction of ground buildings, it is often in the range where the signal disappears or needs to be extrapolated. The blue track points drawn from the radar message in the following picture experience signal interruption due to the influence of the time-varying electromagnetic environment, resulting in the lack of acquisition of the aircraft's position information.

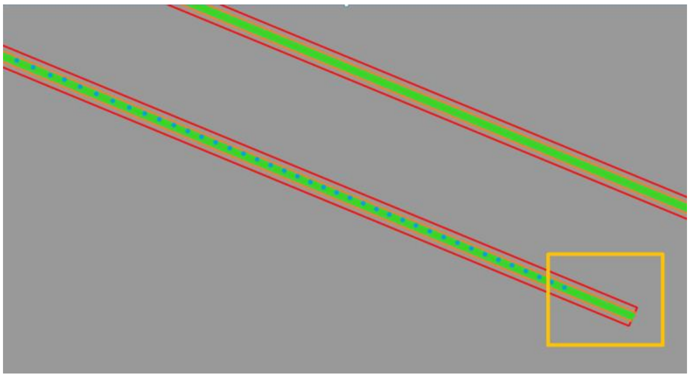

Figure 2. Signal Interruption of Radar Message

The abnormal distribution of plots: Due to the change of the electromagnetic environment, the angle measurement performance of the radar is interfered, causing the plots of the approach radar to be non-uniformly distributed and deviate from the extended runway centerline. The plots of the approach radar marked in blue in the following figure show obvious characteristics of non-uniform distribution.

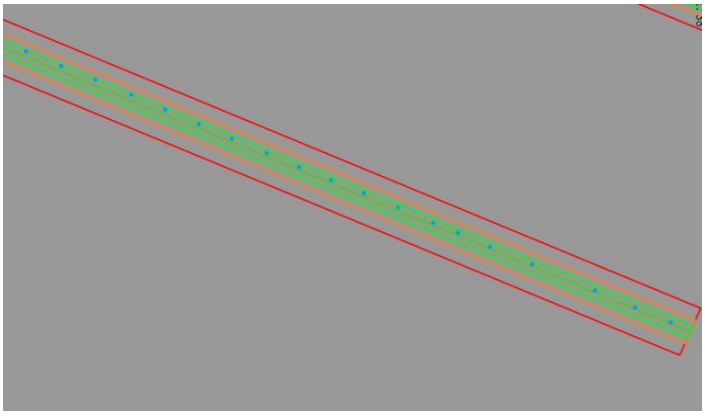

Figure 3. Non-uniformly Distributed of Radar Message

ADS-B message report real-time position, altitude, speed, and heading data obtained from on-board devices such as GNSS , then broadcast through 1090MHz broadcasting. The ADS-B messages on the same final at same time, the plots (in blue) are continuous and stable.

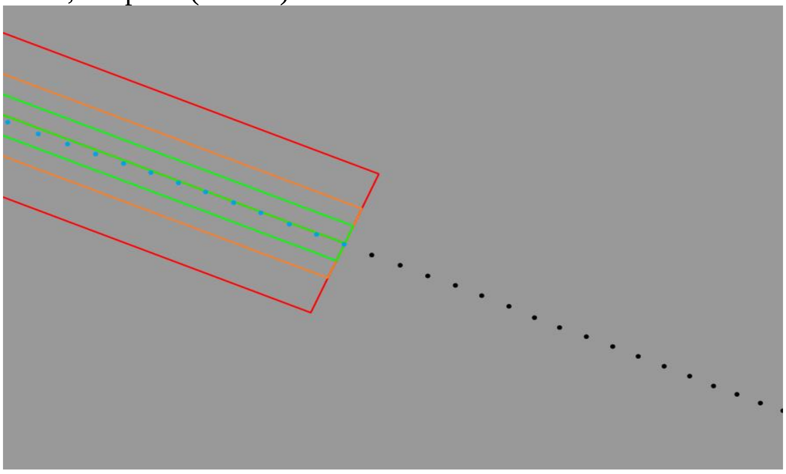

Figure 4. Continuous and Stable of ADS-B Message

ADS-B can effectively make up for the insufficient coverage of approach radar signals during the takeoff and landing phases in the integrated tower system. In the areas where the approach radar signals are unreliable, it can present the real-time and effective situation information of the aircraft. Moreover, the update rate of ADS-B is less than 1 second, which can smooth the flight path during the takeoff and landing phases tracks, provide controllers with near real-time updates of aircraft dynamics, and assist them in making scientific and reasonable decisions.

2.7 Optimize the ground speed

Since the movement trajectory of the aircraft is nonlinear, the integrated tower system has made various improvements to the Kalman filter to optimize the calculation of the ground speed. At the same time, noise interference will seriously affect the accuracy of the data and reduce the quality of the original filtered data. These factors lead to the situation where the ground speed filtering of the integrated tower system cannot perform accurate filtering.

The aircraft obtains position information through the GNSS receiver, processes the position information to obtain the ground speed and direction information, and then broadcasts it through the ADS-B. The ground speed data provided by ADS-B can serve as an important reference for the speed filtering of the integrated tower system, which helps to reduce the fluctuations of ground speed caused by algorithmic defects, external interference, and other factors.

At the final phase, the multilateration are extended outward along the final direction, so that the extended area overlaps with ADS-B which has a second-level update surveillance data. Taking Tianfu Airport as an example, the multilateration extend 1.6 km from runway threshold along the final direction at the eastern runway, and 2.2 km along the final direction at the western runway. By relying on second-level update surveillance data, a stable and smooth comprehensive track is formed, enabling the system to promptly and accurately monitor the speed changes of aircraft, and thus providing a reliable go-around warning service.

2.8 Problems Existing in the Application of ADS-B

The fusion of ADS - B and radar can optimize the integrated track and has cost advantages. However, there are problems in its application, especially the safety issue of ADS-B. ADS-B data depends on the satellite navigation system, and GNSS interference can cause ADS-B to malfunction. According to the statistics of the Civil Aviation Safety Information System of China, in 2024, due to parking lot/vehicle-mounted GPS jammers, UAV radio countermeasure equipment, etc., there were 3,628 unsafe incidents caused by GNSS interference in the transportation airlines of the whole industry, an increase of 2,893 year - on - year. This highlights the seriousness of the problem and endangers the reliable application of ADS-B in the monitoring field. In view of the current interference situation faced by ADS-B, in the actual operation of Tianfu Airport, in order to prevent ADS-B from suffering from position drift, speed jump and other situations due to interference, a filtering measure based on the quality factor is adopted. Data with a quality factor lower than a specific standard will not be included in the fusion calculation.

Outlook

2.9 This information document briefly outlines the advantages of the fusion of ADS-B and approach radar in integrated tower system at Tianfu Airport. However, ADS-B has poor security and is vulnerable to interference. Therefore, it is necessary to deploy wide-area multilateration. It has strong anti-interference ability and good security, which helps to supplement the approach radar in the integrated tower system and ensures flight safety and airspace order.

3. ACTION BY THE MEETING

3.1 The meeting is invited to:

a) note the information contained in this paper; and

b) discuss any relevant matter as appropriate

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