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An Overview of the Effect of GNSS Operation at High Elevation Airport

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Abstract

It analyzes difficulties faced by flight operation in high elevation airport. It puts forward solutions for flight operation on plateau. It analyzes the effect of GNSS in several new navigation technology used in flight operation in high elevation airport, such as RNP AR, and ADS-B, and RVSM, and EFVS/SVS, and EGPWS technology. QAR data is used to analyze the cross track error and height error of a flight on plateau airway.

*Keywords:*GNSS;High Elevation Airport; RNP AR;ADS-B;RVSM;EFVS;EGPWS

1. Introduction

With the deepening of economic construction and reformation, China is faced with economic transition and strategic transition. In the background of "West Development", new transportation system should be established in the western region of China to support the national strategic plan of "great leap forward" development in the western region. In the western region, especially Qinghai-Tibet Plateau, there are a lot of difficulties in the construction of land transport network, but it is quicker, cheaper, safer, and more convenient to establish air transport network, so civil aviation has irreplaceable strategic significance in the western region, especially in plateau region.

In Qinghai-Tibet Plateau of the western region of China, since the elevation is high and the operational conditions are poor etc., requirements for aircraft are high, which restricted the development of civil

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aviation in a long period. During recent years, with the appearance and application of new aviation technologies in the world, operation capability of aircraft in high elevation airport has been greatly improved, and the operational safety of aircraft is obviously strengthened.

According to new navigation technologies appeared in recent years, you can find that the application of most of new navigation technologies is based on satellite navigation technologies of high accuracy. The satellite navigation showed unique position and effect in many applications, such as PBN and RVSM operation, and ADS-B monitoring, and EFVS/SVS "seeing" the obstacles, and EGPWS avoiding the CFIT, etc. The text is going to analyze and introduce the effect of GNSS in high elevation airport.

Nomenclature

ABAS	Airborne Augmentation System
ADS-B	Automatic Dependent Surveillance-Broadcast
A/P	Autopilot
APV	Approach Procedure with Vertical Guidance
CDFA	Continuous Descent Final Approach
CFIT	Controlled Flight into Terrain
EFVS	Enhanced Flight Vision System
EGPWS	Enhanced Ground Proximity Warning System
ES	Extended Squitter
HUD	Head-up Display
GBAS	Ground-based Augmentation System
GNSS	Global Navigation Satellite System
PBN	Performance Based Navigation
QAR	Quick Access Recorder
RAIM	Receiver Autonomous Integrity Monitoring
RNP AR	Required Navigation Performance Authorized Required
RVSM	Reduced Vertical Separation Minima
SBAS	Satellite-based Augmentation System
SVS	Synthesis Visual System
UAT	Universal Access Transceiver
VIP	Vertical Interception Point
WGS-84	World Geodetic System 1984

2. Difficulties in Operation Faced by High Elevation Airport

Compared with airports of low elevation, high elevation airport have many typical characteristics, which directly influence the flight operation in high elevation airport.

These major characteristics and their influences are as follows:

- Terrain environment is complicated

High elevation airports are generally located in plateau and river valleys, the complicated environment of mountains and valleys will influence the arrangement of ground-based navigation station and signal coverage, and it is easy for ground-based navigation signal to generate multi-path effect, bending and distorting the signal, reducing the ground-based navigation accuracy, which might not be able to meet the requirements on navigation performance of flight operation.

- Meteorological environment is complicated

The complicated meteorological environment is mainly represented in turbulence in parts of regions, which is easy to generate wind shear. Temperature in sunlight area is greatly different from that in shaded area and the atmospheric pressure changes quickly; it is easy to appear gusty wind or sand blowing, and lower of bottom of cloud in airport on high elevation etc. These complicated meteorological environmental factors will influence visibility, runway visual range, downwind or upwind overrun etc. Even if local air pressure is set for the barometric altimeter, great barometric altitude error is easy to occur, influencing height maintaining and missed approach decision.

- Difficult to design flight procedure

The complicated geological environment would result in difficulties in obstacles assessment and waypoints arrangement, as well as difficult to design terminal flight procedures. Such as in Linzhi Airport, even the ground-based navigation flight procedure is designed, it is still difficult in flight calibration and operation. For example, in Panzhihua Airport, it is even difficult to design RNP AR (RNP 0.3) approach procedures. If it is needed to design the missed approach procedure in case of one engine out, it is even more difficult.

- Difficult to form correct situation awareness

The terminal and approach procedures for most of high elevation airport, especially on high plateau are designed along valleys. When flying in clouds, the pilots can not see the surrounding high mountains and obstacles, so it is difficult to form correct situation awareness. Since the elevation of airport is high, it is possible that the bottom of cloud is close to decision height or minimum descent height, and the margin of missed approach decision is small.

- Difficult to operation monitoring

ATC surveillance radar is not constructed in most of airports on high plateau in China; the controller can only realize surveillance to the aircraft through procedural control. Even if the surveillance radar is constructed, it is difficult to monitor the operation status of aircraft accurately and in real time in parts of regions because of the high mountains.

- Aerodynamic performance reduces

One of the typical characteristics of operation in airports of high altitude is that the drop in aerodynamic performance of aircraft will cause reduction of power of engines, relative small climb gradient, long runway required, and serious payload reduction etc.

3. GNSS Navigation Performance

According to definition in Attachment 10[1] of the ICAO, GNSS system includes three parts, i.e. GPS constellation, GLONASS constellation, and augmentation system. The augmentation system includes ABAS, SBAS, and GBAS. In the future, with the successful construction of the “Compass” of China and the Galileo global navigation satellite system of Europe, GNSS might include GPS, GLONASS, Galileo, and Compass constellations and relative augmentation systems, and the navigation capacity of GNSS will further improved.

According to different flight stages and operation conditions of civil aircraft, the ICAO gives detailed definitions and requirements on GNSS special signal performances (including accuracy, integrity, alerting time, continuity, and availability etc.) in Attachment 10. For navigation for civil aircraft, the integrity of navigation is the most important.

Attachment 10 gives detailed parameters [1] of alerting limits of integrity of GNSS system. Requirements for the integrity of GNSS are high if non-precision approach, APV and precision approach are required to be implemented in the terminal area of the airport. Especially for CAT I precision approach, its requirement for vertical integrity is higher than for other status, the minimum vertical alerting limit is 15m. So the vertical integrity of GNSS system has always been one of the emphasis and difficulties for civil aviation.

An effective method to improve the vertical accuracy and integrity of GNSS navigation is to use SBAS or GBAS system. If the GBAS system, airborne GNSS navigation receiver or MMR in terminal area of high elevation airport can receive augmentation signals from GBAS, the horizontal and vertical navigation performances can be greatly improved, even if the RNP AR is operating, the operational safety level can be further improved.

4. Operation Plan for High Elevation Airport

Since there are many differences between operation in high elevation airport, especially on high plateau, and in airports of low altitude, it is difficult to operate by using traditional navigation technologies, so relative new navigation technologies can be used to improve the flight availability, safety, and operational efficiency of high elevation airport. Operational efficiency can be improved from different aspects for different new navigational technologies. All of these new navigation technologies are based on GNSS navigation.

4.1. RNP AR operation

The core of RNP AP operation is based on GNSS navigation, and the only GNSS navigation source can be selected at present is GPS. In the PBN Manual [2] issued by ICAO, there are detailed definition for navigation specification and operational requirements for RNP AR.

RNP AR operation has many characteristics, the typical characteristics include:

- GNSS is the only navigation source, once GNSS navigation function is lost, missed approach must be carried out immediately;
- There is no need for any ground-based navigation facilities, which will reduce the construction cost for navigation base design for airports;
- Reduced approach procedures horizontal protection area, which can be reduced to 0.3 nautical miles at most (95% probability) to the left and to the right at present;
- By using Radius to Fix segment, flight path can be designed flexibly to avoid obstacles;
- The decision height can be down to 75m, which is lower than the minimum descent height of non-precision approach;
- CDFA can be realized from the VIP;
- Having high temperature and low temperature limit, mainly restricting low temperature operation;
- Having special additional requirements for airborne system, such as requiring double sets of A/P, double sets of FMS, and EGPWS etc.;

- RAIM prediction etc. must be carried out before dispatch.

Because of the characteristics of RNP AR operation mentioned above, many problems such as difficulties in operation of high elevation airports, even the impossibility for operation of traditional navigation and flight procedures. At the same time, the operational safety and efficiency are improved, and the landing minimums are lowered.

4.2. ADS-B monitors by ATC

The core of ADS-B to realize three-dimensional position monitor for aircraft by using the horizontal position information provided by GNSS, and the barometric altitude information provided by coded barometric altimeter. ADS-B is divided into UAT mode and 1090ES mode. The Civil Aviation Administration of China suggests to use UAT mode for universal aviation, and to use 1090ES mode for transportation aviation.

Air traffic flow is increasing continuously with the economic development, separation of aircraft needs to be reduced for plateau airways in the western region, such as Chengdu – Lhasa airway, to improve operational flow. But there is no ground-base ATC surveillance radar for plateau airway and airports in the western region of China, so the separation between aircraft is large in the surveillance mode of procedure control, which is difficult for the flow to be improved further. At the same time, there are also many problems to construct surveillance radar on mountains on plateau.

After experiments and tests for a period of time, the Civil Aviation Administration of China plans to implement ADS-B trial operation on Chengdu – Lhasa airway in the southwest region since 00:00 (Beijing Time) on May 18 of 2011. There are also some problems to implement ADS-B (1090ES mode) surveillance operation in the airway. First of all, the access aircraft must be equipped with ADS-B airborne equipments. At present, aircraft installed with S-mode transponder all have ADS-B operation capability. Second, it is difficult to provide power for constructing ADS-B ground station on high mountains. Third, it is difficult for information networking for ADS-B ground stations.

As long as the problems above are solved, ADS-B can cover the full range of Chengdu – Lhasa airway. The realization of operation based on ADS-B surveillance can greatly improve the operational ability of the airway. Construction of ADS-B ground stations in terminal areas in relative airports, taxiing surveillance on the airport ground can be realize, the operation safety and efficiency can be improved, and operation costs can be reduced.

4.3. RVSM improves airway flow

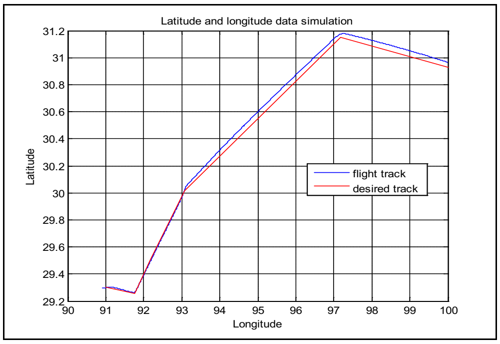

Fig.1. Chongqing – Lhasa horizontal offset flight track

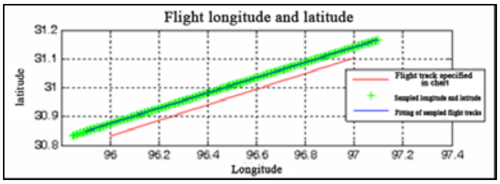

Fig. 2 Fitting track for offset flight

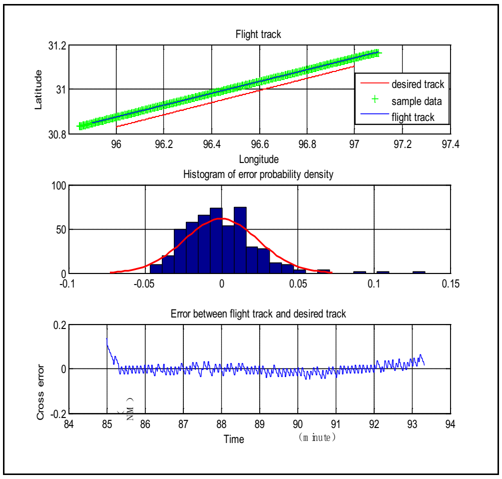

Fig. 3 Distribution of lateral flight track for offset flight

RVSM operation has been implemented in some airways in the western regions. Establishment of parallel airway operation can greatly improve airway flow. In RVSM operation, horizontal track maintaining is still dependent on GNSS navigation.

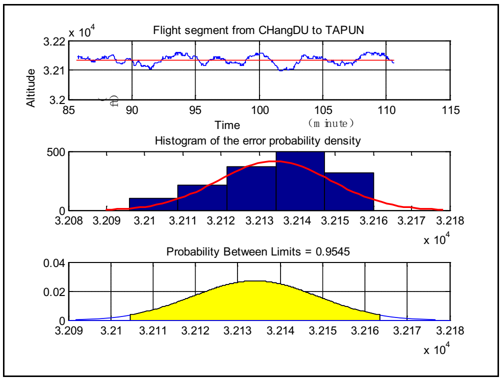

Fig. 4 Distribution of altitude error

For the flight of “Chongqing – Lhasa” airway by A319 aircraft of an airline, relative analysis is carried out by using the QAR data recorded by an aircraft of this flight. As shown in Fig. 1, Fig.2 and Fig. 3, according to analysis, by comparing the desired track with the actual horizontal offset flight track, the average separation between the two tracks is 2.067NM, and the fitting of horizontal track is very good. The horizontal cross track error in actual offset track is very small, the standard error of its lateral track is only 0.024 NM (44.4M), and the lateral position error complies with normal distribution.

According to *Operation Requirements in Reduced Vertical Separation Minimal*[3], RVSM operation based on GNSS navigation is implemented, when instructed by ATC, flight can be offset 1NM or 2NM to the right. Actually in RVSM operation, in order to avoid a midair collision in case the aircraft has to descend (loss of power), or in order to avoid flying to the wrong flight level, it is necessary to use offset flight.

QAR data analysis shows that between Changdu to TAPUN flight section, the minimum safe altitude is 7470m (24508 feet), the average flight altitude used in flight is 32135 feet (9800M) (average value). As shown in Fig. 4, according to calculation, in RVSM operation of the flight section, the variance of altitude error is 14.7 feet, the twice variance is 29.4 feet, and the altitude maintaining is very accurate.

4.4. EFVS/SVS improves situational awareness

For EFVS, airborne infrared sensor or microwave radar is used to detect terrain and landscape for aircraft in real time, and indicate on relative cockpit displays (such as HUD), to strengthen direct understanding of obstacles or ground features ahead, even for flight in clouds or at night, the pilots can “see” obstacles ahead. In the final approach stage of the aircraft, the aircraft has aimed at the runway, sight can be seen on the image sensor is mainly limited to the runway, light, and adjacent areas, and the content of images is easier to identify and understand.

Since the infrared or microwave used by EFVS is easily affected by thermal radiation source or storm etc., so it is possible to occur ambiguous images or false targets. At present, integration of EFVS images and SVS is under research in the world, to achieve the effect of “can be seen” in a clear and reliable way.

The SVS image is three-dimensional terrain data base of high resolution, which is to be provided and scheduled by SVS. In order to achieve matching and integration of EFVS images and SVS images, GNSS navigation and inertial system attitude measurement etc. of high accuracy must be used. If EFVS/SVS is used to integrate real time image information to provide information of terrain and obstacles ahead for flight crew, then even in clouds or at night, flight in mountains and valleys on plateau, the flight crew can establish good situational awareness to improve decision ability.

4.5. EGPWS realizes ground proximity warning

EGPWS is a system providing terrain situation sensing and ground proximity prediction warning [4]. Terrain models and man-made obstacle database stored by airborne memory are used to continuously calculate the position relationship between status vector of the aircraft and the virtual three-dimension terrain database, to predict the approaching dangers and to avoid the CFIT from happening.

Locations input into EGPWS computer mainly come from GNSS location and barometric altimeter of the airborne navigation system, as well as other relative navigation parameters and aircraft parameters. Because of the highly accurate navigational performance of GNSS, the GNSS navigational parameters are important in the navigational parameters input by the EGPWS.

Since failure of double set of FMS occurred before during trial flight of RNP AR program in an high elevation airport in the western region of China, the Civil Aviation Administration of China requires that in all RNP AR operation additional requirements, airborne system must be installed with EGPWS as the final defense line for RNP AR operation, ensuring there is terrain sensing and alerting system for reference when double set FMS is failed.

5. Requirements of GNSS Navigation to Navigation Database

Operation of RNP AR of high elevation airport must rely on navigation database, and the requirements on the accuracy and integrity of airborne navigation database. Because there is highly reliable airborne navigation database of high accuracy, only be using satellite navigation of high accuracy can ensure the flight safety of RNP value (such as RNP0.3) in flight. Only by using navigation database of high accuracy can effectively monitor the accurate location of the aircraft, reduce flight separation, increase flight flow in ADS-B monitor and RVSM operation, can avoid key obstacles when using EFVS/SVS for flight status sensing in low visibility, and the alerting information of EGPWS system is real and reliable.

Since the coordinate system referenced by GPS navigation in GNSS is WGS-84[1], and GPS is the only navigation constellation available for GNSS at present, so in RNP AR operation in high elevation airport, all waypoints and obstacle coordinates in the navigation database must be based on WGS-84 coordinate system, and its resolution must be controlled within the safe operational range.

6. Conclusion

Operation of high elevation airport has always been difficult for civil aviation operation all over the world. China has a large area, there are many high elevation airports and high plateaus in the western region, and with the economic development, more and more high elevation airports will be constructed. Therefore, emphasis and research on relative problems of flight operation in high elevation airport have important strategic significances to the flight operational safety and development of western region economy in plateau regions in the west of China.

Since GNSS navigation (the available system at present is GPS) has irreplaceable advantages compared with other navigation systems, so the effect and potential of GNSS in PBN technology and other new navigation technologies should be fully exerted. Meanwhile, we should also acknowledge that, GPS navigation is still radio navigation, whose special signals, especially the civil navigation code, are extremely weak and easy to be interrupted. Once the signal in space is interrupted, the positional accuracy of navigation will be reduced, or even the navigation function will be lost. Therefore, it is extremely necessary to carry out the RAIM prediction to GPS before dispatch, the RAIM monitoring during the flight, and the QAR data analysis after the flight. Once GPS navigation integrity or GPS navigation function is lost, the backup navigation system must be initiated immediately to ensure safe flight operation.

Acknowledgements

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