Discussion and Research of Aviation Data Link Based on ADS

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ABSTRACT

With the rapid development of the global aviation industry, air traffic flow has increased dramatically. In order to ensure the safe and orderly operation of air traffic, higher requirements are put forward for air traffic control and surveillance technology. This paper introduces ADS system which is widely used at present, briefly analyses its research status, communication channels and networking protocols used at the present stage, gives the typical application scenarios of the system, analyses the data integrity and security problems that restrict the development of ADS-B, and finally forecasts the future development direction of ADS-B, including ATN, FANS and BDS. Positioning and satellite-based ADS-B system.

1. INTRODUCTION

With the rapid development of the global aviation industry, the air traffic flow continues to increase. How to ensure the unimpeded and orderly flight of air traffic puts forward higher requirements for the monitoring technology of air traffic control.

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ADS-B technology is the indispensable technical basis for realizing "free flight", and it has been well applied in surveillance and communication. ADS-B can detect some conflicts, so as to effectively guarantee the safety of the aviation system and the smooth progress of related services. Both the North American-led FANS (Future Air Navigation System) architecture and the European-led ATN (Aeronautical Telecommunication Network) architecture integrate the command and control data link based on CPDLC (Controller to Pilot Data Link Communications) and the situation monitoring data based on ADS (Automatic Dependent surveillance) in the aviation data link. ICAO (International Civil Aviation Organization) has been trying to promote ADS-B (ADS-Broadcast) in recent years. At present, all countries in the world are also carrying out related technical research. This paper will discuss the aviation data link based on ADS technology. [1~4]

2. INTRODUCTION OF ADS-B

2.1 Definition of ADS-B

ADS-B is a function for aircraft to automatically acquire airborne equipment parameters, provide relevant information to other aircraft or ground users, or regularly transmit their state vectors and other information to vehicles operating in airport scenes. It is applied to various airspace and airport surveillance, and has the advantages of wide surveillance range, fast update of information and low maintenance cost of equipment.

The definition of ADS-B by the American Association of Aeronautical Radio Technology (RTCA) is: ADS-B is an aircraft-based surveillance system, which transmits the longitude, latitude, altitude, time, identification information and other vector information of the aircraft to others by broadcasting, and provides them to the surrounding aircraft and ground users for receiving and displaying. This surveillance system improves the utilization of airspace, reduces the limitation of cloud and visual visibility, increases the surveillance capability of airport scene, and improves flight safety.

2.2 Research status of ADS-B

Since 1991, Bromma Airport in Stockholm, Sweden, successfully demonstrated ADS-B function by CDTI, some countries, such as the United States, Europe and Australia, have begun to develop and evaluate ADS-B technology, and have achieved practical results in the application of different models. ADS-B technology has gradually entered the practical application stage. The earliest known is the mandatory use of ADS-B in Hudson Bay, Canada, in November 2010; the mandatory operation of ADS-B in Australia began in December 2013; and the Federal Aviation Administration of the United States requires that ADS-B equipment be installed in
most areas of North America and manned aircraft flying in the Gulf of Mexico after January 2020. In October 2018, 96.7% of CAAC transport aircraft had the function of ADS-OUT in China. ADS-B OUT is the basic function of ADS-B, which is responsible for transmitting signals from the aircraft sender to the ground receiving station or other aircraft through the line of sight.[4]

3. ELEMENTS OF ADS-B SYSTEM

If ADS-B system is regarded as data link system, we can discuss the characteristics of ADS-B system from three elements: message format, networking control protocol and communication channel.

In terms of message format, the airborne navigation system obtains precise navigation data, including the identity code, four-dimensional position, velocity vector, flight intention, etc. by using the ground-air data link, the ADS-B system broadcasts these navigation information to the outside world in real time, spontaneously and intermittently after integrating these data,. On the ground, the surveillance target can be captured by the corresponding receiver without radar participation; in the air, in a certain range of aircraft can sense the traffic situation around the aircraft by intercepting the broadcast messages sent by other aircraft, thus judging and avoiding conflicts.

In terms of communication channel and network protocol, ADS-B can use three kinds of transmission links and corresponding protocols, namely 1090ES, UAT and VDL-4. These three technologies are basically mature and can meet the support of ADS-B in general. [5]

3.1 1090ES

1090ES (1090MHz Extended Squitter) is a technology based on S-mode extended transponder. It provides air-to-ground and air-to-air data links and is suitable for high-speed data transmission. The old S-mode broadcast message format is 56 bits, which is extended to 112 bits in the application of ADS-B system. The additional 56 bits are used to transmit ADS-B related information, including 24 bits code, height and so on. Because the message format is simple and the information carrying capacity is weak, only one specific type of information can be transmitted in one encoding.

At present, ADS-B mainly uses 1090ES data link. ALOHA protocol is used in the control of the data link network. Collisions occur more. With the increase of the number of targets, the interference problem is very serious. Although the performance of ADS-B is not better than the following two ways, it embodies the best compatibility in the application of ADS-B system.
3.2 UAT

UAT (Universal Access Transceiver) is a research project proposed by MITRE/CAASD in the United States. Its goal is to develop transceivers to support ADS-B applications. The equipment is simple and practical, and can operate in any airspace or airport. UAT is specially designed to support ADS-B. It also has the function of broadcasting upstream from the ground station. The access mode is time division multiplexing. Its carrier frequency is 966 MHz, using 2-3 MHz bandwidth, sending and receiving the same frequency, allowing all air-to-air links with the smallest new hardware. All aircraft access this channel randomly and automatically without central ground support. The performance of air-to-air ADS-B using UAT is superior to the other two technologies in high density and low density.

3.3 VDL-4

VDL-4 (VHF/UHF Digital Link-Mode 4) is a standardized VHF data link technology recommended by ICAO and ETSI (European Telecommunications Standards Institute). It is a monitoring and communication system based on STDMA (Self-organizing TDMA) protocol. VDL-4 is based on OSI standard reference model. It can provide point-to-point and broadcasting communication services with ground-to-air and ground-to-ground data links. It can also use an additional channel in high density areas. In addition, STDMA multiplexing can significantly reduce bandwidth requirements and improve message collision. VDL-4 airport ground surveillance performance is better.

4. TYPICAL APPLICATION SCENARIOS OF ADS-B

4.1 Monitoring system

In the airway and terminal part, when the ADS-B ground station receives the ADS-B message from the airplane broadcast, the ATC monitoring system can transmit it to the ATC Center for data integration, and then display it on the monitoring screen. In transoceanic and remote areas, messages from adjacent aircraft can be used for transmission, increasing the monitoring scope of the ATC surveillance center. Especially in areas beyond radar coverage, such as mountains and sea level far from land, ADS-B can provide comprehensive and seamless surveillance from airport to airport.

ADS-B can also be used to monitor the traffic situation on the airport scene. Through ADS-B data messages sent by aircraft and vehicles on the airport scene, tower controllers can clearly understand the use of the airport scene in various areas, to effectively avoid runway intrusion and prevent safety accidents.[6]
4.2 Anti-collision system

At present, pilots’ situational awareness mainly comes from the voice communication information of air traffic controllers. Air traffic controllers can only imagine the relative position of nearby target aircraft in their minds. After equipped with ADS-B system, pilots can clearly "see" the position, heading angle, speed and other information of the adjacent target aircraft, thus effectively avoiding the occurrence of collision accidents.

Aircraft acquires precise position from GPS. ADS-B system broadcasts ADS-B messages periodically and spontaneously. Without answering and inquiring, aircraft equipped with ADS-B equipment can receive and process such messages. At the same time, ADS-B receivers are constantly receiving information from other aircraft to determine whether there are potential conflicts. Aircraft does not need to use traditional ground radar surveillance system, so it can achieve better safety interval, increase pilots’ awareness of flight scenarios, and reduce flight safety accidents.

4.3 Free flight

The "free flight" is a concept to make the use of airspace more effective. Through the adjustment of airspace use procedures and the application of various advanced technologies, pilots can flexibly adjust the air route, speed and altitude, so as to make the flight cost lowest and the flight safety highest. Using ADS-B technology and GPS positioning information, not only can the aircraft get more navigation information, improve flight safety, but also can enhance the communication ability between pilots and air traffic controllers, and improve the efficiency of airspace use.

4.4 Auxiliary Entry

In order to ensure the safety of the aircraft landing, more accurate positioning and navigation are needed when the aircraft enters the airport scene due to the shorter distance between the aircraft. ADS-B technology can increase the efficiency of instrument landing system. Aircraft can take off and land in parallel within a small interval to improve the efficiency of the airport. If there is no instrument landing system in the airport, ADS-B technology can increase the safety of visual approach, increase pilots’ awareness of flight scenarios and visual range, avoid collision conflicts and improve the safety of visual flight. [6]
5. The Problems of ADS-B

5.1 Data Integrity

Equipment using 1090MHz frequency band includes ADS-C (ADS-contract), TCAS, vehicle ADS equipment, DME and other electronic systems. Strong co-frequency interference between electronic systems affects the normal operation of electronic systems and easily leads to missed detection of targets. After collecting and analyzing the track data of Fuzhou and Nanjing in real-time and non-real-time, we find that ADS-B system is prone to serious information collision in dense air space, which leads to packet loss. The rate of packet loss is time-dependent, and the rate of packet loss is low in non-peak traffic time. When the aircrafts in transmission range increases, the rate of packet loss is higher. Some experimental data are shown in Fig. 1. According to the statistics collected in Fuzhou, it is concluded that the ground receives one track data every 0.158 seconds, with a variance of 0.138 square seconds, but the time difference of receiving is more than 17.154 seconds. As shown in Fig. 2, the error is relatively large and the packet loss rate is at least 5.2%. Obviously, ALOHA protocol and frequent situation monitoring information reporting are the important reasons for packet loss. In the follow-up technical research, optimization should be carried out to reduce the packet loss rate of track data in order to ensure the integrity of data.
5.2 Security issues of ADS-B

For civil systems, the data redundancy of ADS-B system has a certain impact on the safety performance of civil aviation system. The information source of the existing ADS-B system is completely from the broadcasting of the airborne equipment of the ADS-B system. The source is single. Once interruption occurs, the system will be no longer functional completely. Redundant backup should be strengthened and corresponding risk control measures should be formulated.[7]

For military applications, especially for the US military, ADS-B is integrated into airborne avionics, which is easily effected by the impact of aggressive electronic warfare. It will have the same potential effect as many other Internet technologies, and may be activated or deactivated remotely or operated without permission. We need to pay more attention to its supervision and security deficiencies.

6. Development of ADS-B

6.1 ATN and FANS

ICAO has approved the concept of future aviation communications, which complements voice communications with digital data links and provides improved air traffic services. An essential component of the concept is ATN, which manages digital data transmission between aircraft and civil air traffic control. On this basis, due to the limited spatial availability or high cost of different data links, commercial aircraft are expected to be equipped with multiple air/ground data links to remedy this shortcoming. For the U.S. military, ADS is mainly used at present. If we want to develop military ATN equipment on the basis of civilian use, we need to consider security issues. Data must be encrypted in the process of data transmission.[8]

FANS is mainly used in marine airspace, including North America. It can enable aircraft to fly over the sea or in remote airspace. Its communication content includes not only location report, but also air traffic control permission, pilot request, etc. That is, the system allows both manned and unmanned operation, which improves the safety performance. CPDLC allows two-way, text-based digital communication between controllers and pilots when the aircraft goes beyond the traditional high-frequency radio voice communication range, thus resolving the language barrier problem. With the support of the system, the aircraft can seamlessly enter and exit domestic airspace and enter the sea. At the same time, it can choose the most ideal route, reduce operating costs and flight time, and accommodate more aircraft to fly safely and effectively in the air.

6.2 ADS-B Development Based on BDS

On the afternoon of December 27, 2018, the China Satellite Navigation System Administration Office announced that Beidou satellite navigation system（BDS）
began to provide global services, formally entering the global age present, the three-dimensional positioning information of aircraft transmitted by ADS-B mainly comes from the GPS (Global Positioning System). Therefore, BDS will first be used as a backup system of GPS in the field of civil aviation in China, and gradually realize the compatible operation with GPS interoperability to enhance and supplement the existing performance of GPS, so as to achieve the goal of higher precision positioning service.

Recently, the Civil Aviation Administration has launched the verification and evaluation of Beidou satellite enhanced system for civil aviation applications, which will provide an effective means for China’s transport and general aviation navigation, and provide a more secure and efficient technical basis for the full implementation of ADS-B operation.[9]

In addition, in September 2014, the first military aircraft equipped with ADS-B equipment successfully completed the altitude flight test mission, and the information of procurement of ADS-B equipment has been made public on the military procurement network, indicating that ADS-B will also play an important role in national airspace support. For the location information of military aircraft, it can also be combined with BDS to ensure security.

6.3 Satellite-based ADS-B System

ADS-B monitoring equipment is usually installed and used only in aircraft and airport, and its coverage is limited. It can only acquire aircraft and airport peripheral airspace target recognition signals. Satellite-based ADS-B system refers to the ADS-B receiver on the satellite, which uses its high-range characteristics to extend the monitoring scope to areas beyond the coverage of traditional ground-based equipment such as oceans, polar regions and remote areas, to achieve global coverage. However, Satellite-based ADS-B system requires high sensitivity and stability due to the influence of long-range, high dynamic and special space environment. At present, small satellite launch is widely used to carry out the technology research on Satellite-based ADS-B system worldwide. On October 12, 2015, the University of National Defense Science and Technology conducted the first Satellite-based ADS-B signal reception experiment. The main star "Lvliang 1" receiving system can receive more than 400,000 ADS-B messages worldwide every day on average. Satellite-based ADS-B system can effectively avoid the loss of aircraft connection, and extract potentially valuable information from massive data analysis, providing information services for aviation safety, route optimization, aviation control and improving aviation efficiency. In the development of aviation data link, the performance improvement of ADS-B system will also become an important direction. [10]
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