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ADS-B Distributed Processing System Based on Parallel Computing on Universal Platform

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Abstract: Automatic Dependent Surveillance-Broadcast (ADS-B) technology is a kind of aircraft operation surveillance technology that has emerged in recent years. It has been widely regarded as the core technology of next-generation aviation surveillance in the international community. Many countries have already adopted ADS-B technology. For a relatively mature system, my country is also actively promoting the application of ADS-B technology. The research purpose of this paper is the ADS-B distributed processing system based on parallel computing on the general platform. In the experiment, the processing flow of the system is analyzed and the basic mathematical functions are used. Experiments and analysis are carried out on the carrier frequency test and carrier power test of the ADS-B system, as well as the ADS-B track filtering and processing system based on the parallel algorithm.

1. Introduction

In recent years, with the rapid improvement of the civil air transport industry, the air traffic flow has continued to grow. In order to meet the needs of air traffic management, the construction of a new generation of civil aviation navigation system has become the improvement trend of all countries in the world [1]. ADS-B technology is a communication technology between aircraft and aircraft or between aircraft and ground. It is an integral element of the U.S. next-generation air transportation system and one of the surveillance technologies recommended by ICAO for improvement.

With the rapid improvement of China's civil aviation industry, flight traffic has shown a sustained high growth trend, and the operational pressure of air traffic management is also increasing.Mott J H has conducted research on the basis of unmanned multi-role vehicle systems, which are popular for their low cost, high performance and simplicity of operation relative to manned aircraft. While the FAA currently regulates drone altitudes, pilot qualifications and locations. To assess the frequency and severity of manned and unmanned aircraft separation incidents, and to assess emerging sensor technologies that can be used to facilitate such assessments, aviation services in the administrative area of the Orlando-Melbourne International Airport are monitored. One sensor system deployed at Orlando's Melbourne International Airport reports drone position, altitude and flight duration, while another system uses ADS-B signals to report human flight position, altitude and time stamp [2]. Kosiachuk V V studied the Automatic Reliability Recording System (ADS-B) as an important means of ensuring the safety and efficiency of air traffic. In the future, the role of ADS-B will increase. At the same time, the network security of ADS-B is clearly not enough. A low security issue of ADS-B is analyzed. The main reasons for the inefficiency of ADS-B are the openness of the system and the modern achievements of computer technology and the improvement of software-defined radio. A classification of possible attacks on ADS-B systems is given. The conclusion is that other airborne radio technology systems have similar weaknesses that need to be adequately addressed to improve safety levels. The main reasons for the insufficient security of aeronautical communication, navigation and surveillance systems are: long improvement and certification cycles, frequency overload and the choice of open systems [3].The application of ADS-B technology can realize all-round surveillance coverage of aircraft in the airspace.

This paper studies the types and characteristics of automatic dependent surveillance technology, the composition and working principle of ADS-B system, the airborne equipment of ADS-B system and the Kalman filter algorithm. In the experiment, the system processing flow is analyzed, using basic mathematical functions. Experiments and analysis are carried out on the carrier frequency test and carrier power test of the ADS-B system, as well as the ADS-B track filtering and processing system based on the parallel algorithm.

2. Research on ADS-B Distributed Processing System Based on Parallel Computing on Universal Platform

2.1. Types and Characteristics of ADS Technology

Automatic Dependent Surveillance (ADS) is a technology in which the aircraft automatically provides its own position information to the outside world after relying on the airborne equipment to achieve positioning, so that the outside parties can realize uninterrupted monitoring of it. ADS technology can be divided into two types: ADS-A/C and ADS-B according to their different operating mechanisms.

The emergence of Automatic Dependent Surveillance-Broadcast (ADS-B) technology has further promoted and applied the Automatic Dependent Surveillance (ADS) technology. The biggest difference between ADS-B and ADS-A/C is that ADS-B uses broadcast communication instead of ADS-A/C contract communication [5]. The airborne equipment of ADS-B does not need to establish a communication link with the ground user, but directly broadcasts and transmits the aircraft flight number, latitude and longitude, speed and other information obtained by the airborne equipment. It can be other aircraft in the surrounding airspace or other users with ADS-B data reception and processing capabilities. After the ADS-B transceiver equipment is installed on the aircraft, ADS-B realizes mutual monitoring between aircraft and aircraft, changing the previous system mode of passively accepting ground monitoring, turning passive into active, and realizing the aircraft's active monitoring of surrounding airspace conditions. Perception, aircraft relying on the ADS-B system can actively avoid flight conflicts, which greatly improves the utilization of airspace [6-7].

2.2. Composition and Working Principle of ADS-B System

Automatic Dependent Surveillance-Broadcast (ADS-B) is one of the future safe and reliable air traffic control ground vision technologies established by ICAO [8-9]. ADS-B provides a more efficient and safer way to monitor air traffic based on satellite earth system and ground/air data communication links, which can greatly improve the working situation knowledge of pilots and captains, and expand the surveillance area for air flight transportation. Safety levels, wind energy and efficiency. ADS-B uses the information generated by airborne equipment such as navigation as the data source, uses the air-to-air/air-to-air data link as the communication method, and transmits flight information data in the form of broadcast or unicast. And know the communication between the ground station and the aircraft. Real-time communication and aerial photography visualization capabilities; at the same time, airlines can observe local air traffic conditions by receiving information broadcast by other airlines [10-11].

The ADS-B ground station receives the aircraft's position and altitude information for signal processing and finally displays it in the air management system to provide the controller with basic information; the moving aircraft can also receive the ADS-B traffic information, which is displayed on the ADS-B after simple signal processing. On the CDTI of the cab, the CDTI is the main man-machine interface in the ADS-B system. Its function is to provide the pilot with position reports, weather conditions, traffic conditions, topography and traffic information services through the display interface, so that the pilots can Have a clearer air traffic management information [12-13]. Install ADS-B transmitting and receiving equipment on the vehicles in the airport, the tower ground control station can monitor the vehicles on the apron in real time, and the vehicles in the airport can also monitor the surrounding aircraft and vehicles, Prevent runway and taxiway conflicts from occurring.

2.3. Airborne Equipment of ADS-B System

Whether it is the ADS-B airborne equipment of the UAT data link or the airborne equipment of the 1090ES data link format, the system composition is roughly the same, mainly composed of the ADS-B system airborne data link transmitting antenna, airborne transmitter, It consists of data source input, GNSS signal receiving antenna, airborne receiver, airborne display unit and aircraft power supply [14].

The system obtains the positioning data of the aircraft through the GNSS receiving antenna. After the data is processed by the transmitter, the data is broadcast to the ground equipment and other aircraft in the airspace through the transmitting antenna located on the fuselage together with the call sign, altitude, speed and other information to achieve ADS-B. OUT function; at the same time, the airborne receiving antenna receives the signals of the same data link broadcast by other aircraft or ground stations, and after being processed by the airborne receiver, the airborne display unit provides the altitude, speed, call sign, position and other information of the aircraft in the surrounding airspace., to realize the ADS-BIN function [15].

2.4. Kalman Filter Algorithm

Filtering and prediction are the top priorities of the track processing process [16]. The filtering and estimation methods are used to estimate the current and future kinematics of the target, such as the target's position, velocity, and acceleration. Filter flow diagram. The theory of Kalman filtering has existed since the middle of the last century. This theory uses an autoregressive method to find the best estimate of the existing data, which transcends the constraints of common Wiener filtering ideas and methods. This theory can obtain the linear and unbiased minimum variance estimation of the system condition and the recursive method of the estimated error size covariance matrix when the autocovariance of the observed amount, the cross-covariance of the observed amount and the trait are unknown. The Kalman filter algorithm is widely used in contemporary optimization thought, and the process block diagram of Kalman filter is proposed. In essence, the Kalman filter algorithm is a progressive algorithm [17]. It includes two processes: the estimation process and the change innovation process. The estimation process can obtain the estimated value of the state and the estimated value of the state covariance, and the change of the innovation process can obtain the size of the filter gain value, and give changes to both the estimated state and the state covariance. Set the filtering state of the time state variable value and the estimated value of the time optimal state. It can be seen from the above that the Kalman filter algorithm can no longer store the previous information. Referring to the linear progressive method, the estimated value of the initial state and the Based on its covariance matrix, it is possible to obtain an estimate of the situation at the next time, revising the size of the estimate and reducing the computational and storage capacity [18]. Because of this, the Kalman filter has an estimate-revision composition, implemented as a linearly progressive algorithm for an optimal estimate. The algorithm has the characteristics of small computing capacity, fast computing rate, high convergence rate, and is convenient for practical analysis. The Kalman filter is optimal in an ideal state and can accurately calculate the results. It is also a well-recognized and classic algorithm, so it is more widely used in the analysis process of the trajectory of the aircraft [19-20].

3. Investigation and Research of ADS-B Distributed Processing System Based on Parallel Computing on Universal Platform

3.1. Processing Flow

The ADS-B data collection and analysis subsystem is the main external interface device of the data processing system, which is mainly responsible for receiving and processing ADS-B data.

The main work of the ADS-B data collection and analysis subsystem is concentrated in the single ground station ADS-B data processing. The processing flow is to analyze different types of data according to the configuration of the data format of each ADS-B ground station data source.

3.2. Basic Mathematical Functions

The main purpose of parallel computing is to reduce the computing time of the system and improve the ability to solve complex tasks. The longitude and latitude position information sources of the airborne ADS-B system are GPS and IRS systems, and the original data format precision uses IEEE-754 industry standard 32-bit single-precision floating-point numbers. The encoding result is normalized by the interval normalization method, and the overflow problem that may be caused is corrected. The processing formula is as follows:

$$yz_e(i) = \frac{yz_i - yz_{min}}{yz_{max} - yz_{min}} \tag{1}$$

In the formula, $\overline{1.M}$ represents a decimal number, the integer part is 1, and the fractional part is M. Since M is constant in 23-bit binary in the number system representation, the expression is as follows:

$$\overline{1.M} = 1 + \frac{M}{10^{23}} \tag{2}$$

The representation method of floating point number consists of three parts: sign bit S, decoding E and mantissa M. Floating point numbers are represented as follows:

$$x = (-1)^S \left(\overline{1.M}\right)^{E-127} \tag{3}$$

4. Analysis and Research of ADS-B Distributed Processing System Based on Parallel Computing on Universal Platform

4.1. Carrier Frequency Test

Quantitatively analyze the mean value characteristics of the residuals, set the error limit for the carrier frequency signal with a required accuracy of ±1ppm error, and make a carrier frequency test result table, as shown in Table 1 and Figure 1:

Table 1. Carrier frequency test result table

Frequency point (MHz)	Test Almissible Value Range (MHz)		Test truth value (MHz)
	Least value	Crest value	
1005	1004.6525	1005.1025	1004.9812
1040	1039.8455	1040.0451	1039.8701
1095	1094.4514	1095.4120	1095.3142
1098	1097.6541	1098.3641	1098.1245
1203	1202.8440	1203.0142	1202.9364

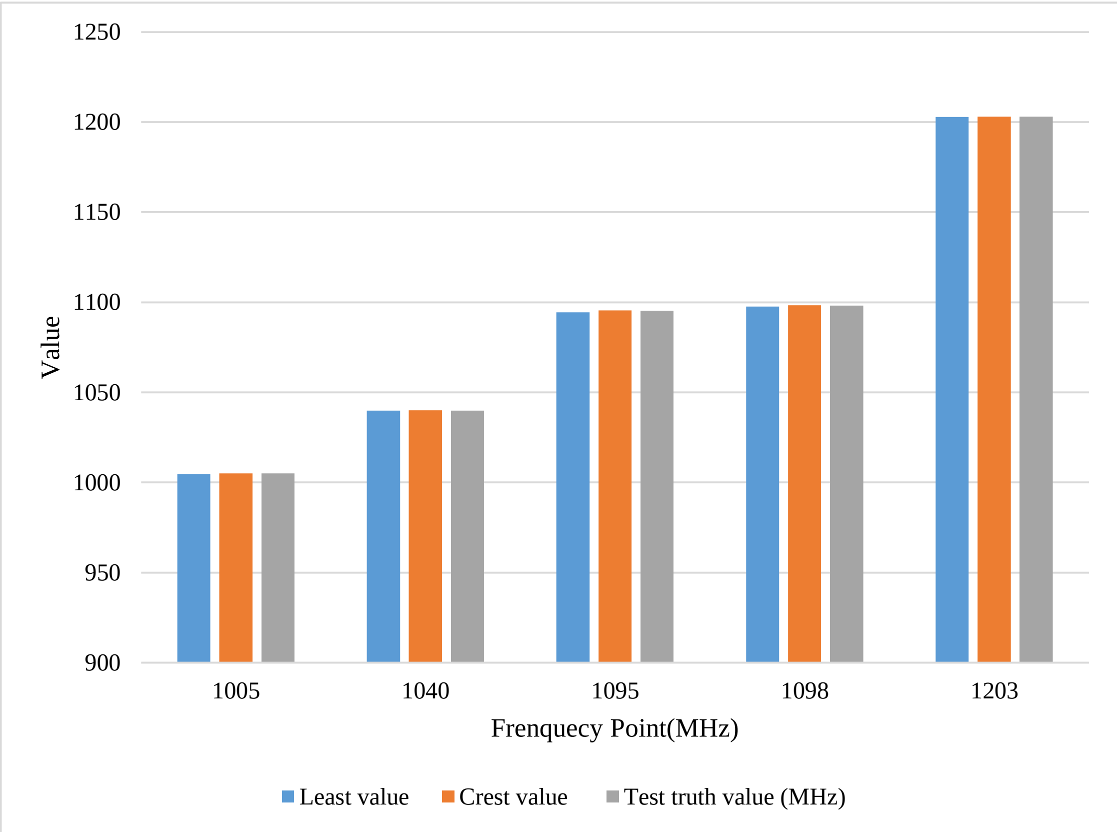

Figure 1. Comparison diagram of the test data

The data shows that, in order to further optimize the performance of the carrier frequency accuracy, the test true value of each frequency point fully meets the test allowable range required by the index, and the test conclusions are all passed the test.

4.2. Carrier Power Test

Quantitatively analyze the mean value characteristics of the residuals, calculate the error limit for the carrier signal power with a required accuracy of ±0.1dBm error, and make the carrier power test result table as shown in Table 2 and Figure 2:

Table 2. Data table

Frequency point (MHz)	Least value	Crest value	Test truth value (MHz)
2.60	2.30	2.80	2.551
1.96	2.15	1.50	2.124
-4.87	-4.90	-4.50	-4.854
-5.33	-5.40	-5.20	-5.412
-39.4	-40.4	-39.0	-39.014

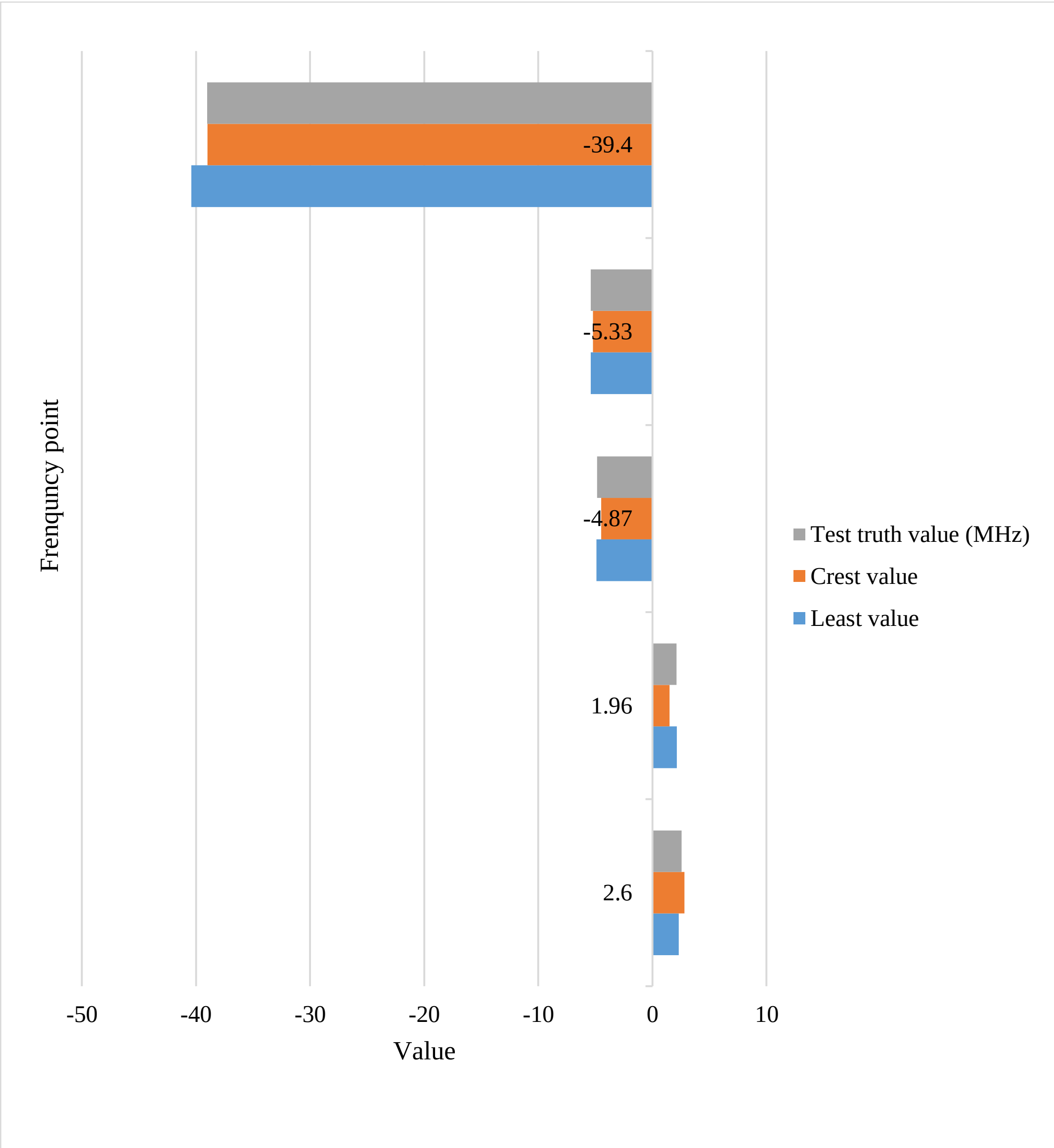

Figure 2. Carrier frequency test results

The data shows that the test true value of each power point all meets the test allowable range required by the index, and the test conclusion is all passed the test. The measurement results at the power lower limit of -50.00dBm are relatively discrete, but the average characteristic is better. This is due to the limit value of the RF chip selected by the implementation scheme, and the jitter is large at the edge of the lower power limit. In addition to this power point, the residual characteristics at other power points are relatively stable, so the control compensation should choose the method of point-by-point calibration, and correct the minimum precision control words one by one.

4.3. ADS-B Track Filtering and Processing Based on Parallel Algorithm

Experiment and result analysis the simulation results are given for the functional processing based on the Kalman filter algorithm. A circular motion on the XY plane is simulated, and the radius of the circle is equal to 80m; based on the Kalman filter algorithm, the filter analysis is given: the simulation is carried out in the XY plane of the Cartesian coordinate system, and the measurement noises in the X and Y directions are set respectively is a Gaussian distribution with mean zero and variance 3. The ADS-B track filtering and processing data are shown in Table 3 and Figure 3:

Table 3. Filter the error standard deviation data table

Filter the error standard deviation curve	X coordinate	Y coordinate
40	30	42
60	43	61
80	108	98
100	56	63
120	532	561
140	98	106

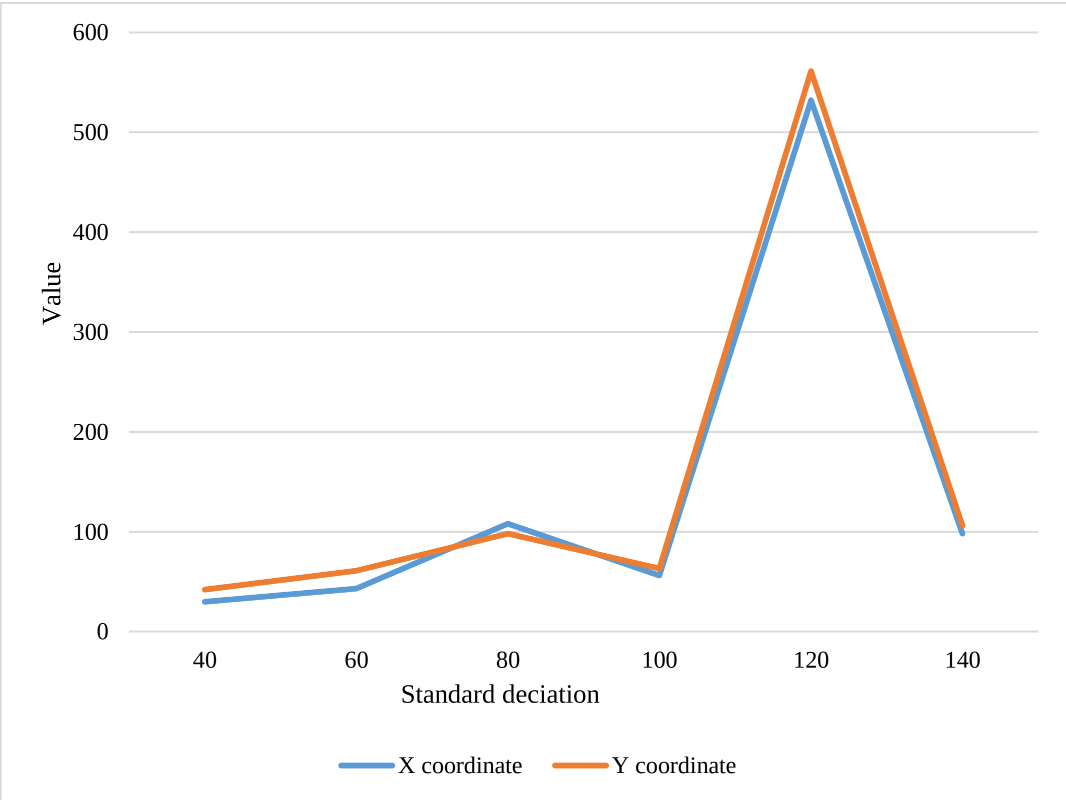

Figure 3. Simulation contrast

In general, in the flight state, the Kalman filter algorithm can provide accurate estimates for non-maneuvering or maneuvering aircraft targets, which can map the maneuvering transformation of the aircraft more realistically, and can provide timely The target's condition estimate.

5. Conclusion

ADS-B ground equipment can provide a full range of air traffic conditions to the flight by broadcasting ADS-B information. Since the maintenance cost of the ADS-B surveillance system is much lower than that of the air traffic control surveillance radar system, and the ADS-B system can achieve maintenance-free maintenance, it can be used in difficult environments such as mountains, oceans, and inland, and can transmit more flights, information, location information, etc. Because the position report and altitude report sent by the ADS-B airborne equipment are real-time information, the ground station can obtain timely flight information and support airborne ACAS applications or air traffic control applications. ADS-B can broadcast ADS-B and flight information services, and comprehensively process flight plan information, providing technical support that is not available for the implementation of free flight.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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