Real-time downloading and analysis of QAR data using Air-to-Ground wireless communication

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***Abstract*—Due to the limitation of communication technology, the downloading and analysis of Quick Access Recorder (QAR) data in the past are carried out after flight. This is the first time that QAR data's real-time download and analysis experiment is carried out in China by using Air-to-Ground wireless broadband communication technology. Firstly, a dedicated communication frequency was obtained. Then, a complete Air-to-Ground wireless broadband communication network has been constructed. Based on this, 34 actual tests were carried out on the flight from Beijing to Chengdu, and got about 280,000 QAR real-time data. The integrity, consistency and delay of QAR data transmission via Air-to-Ground communication network are tested. The test results show that the integrity of downloaded QAR data is 99.99%, the consistency rate of data content comparison is 100% and the average round trip delay of QAR data transmission is 71.45 millisecond. It's fully meet the needs of real-time analysis. Secondly, the method of QAR data decoding is introduced. A real-time QAR data decoding software is developed to decoding while downloading. Finally, based on the real-time decoded QAR engineering data, the corresponding application software is developed. This work can not only solve the lag caused by QAR data post-flight analysis, but also can monitor the operation status of aircraft in real time, supervise flight safety, discover potential safety hazards in time, and realize efficient management and emergency disposal.**

Keywords—Quick Access Recorder; QAR; Real-time; Air-to-Ground; ATG.

I. Introduction

Flight safety is the eternal theme of the aviation industry. The Flight Operations Quality Assurance (FOQA), as an important tool and means of safety management, can monitor the operation behavior of aircrew and aircraft performance and operation dynamics of the aircraft by acquiring and analyzing flight parameter data recorded in flight [1]. Once problems are found, the reasons can be found by analyzing the recorded flight parameters data, and improvement measures can be taken to eliminate potential safety hazards and ensure aviation safety.

The flight quality monitoring project has been implemented since 1997 by Civil Aviation Administration of China (CAAC) [2]. Flight Data Recorder (FDR) and Quick Access Recorder (QAR) have been installed on all registered transport aircraft operating in China since 1998. QAR can collect more than 1000 kinds of data at the same time, so it can provide sufficient data basis for all-round aircraft condition monitoring and fault diagnosis [3]. The CAAC required that aircraft in China must begin to be equipped with Wireless Quick Access Recorder (WQAR) after September 1, 2015 and completed by June 30, 2017. WQAR is a kind of wireless fast access recorder with the function of transmitting flight data to data server through mobile communication technology like GPRS or 3G/4G. The flight data will transfer to the data server on ground after the aircraft landed and the engine was shut down, which made the data acquisition more convenient.

For a long time, the downloading and analysis of QAR data have been carried out after flight due to the lack of economical and effective means of real-time communication between aircraft and ground. With the maturity of Air-to-Ground (ATG) wireless broadband communication system, it is feasible to download and analyze real-time QAR data using ATG communication technology, and it will help maximize the value of QAR data.

The ATG communication technology is a bidirectional communication method between aircraft and ground by using mature LTE mobile communication technology and special ground base station and airborne communication equipment. Compared with LTE mobile communication technology that used on the ground, it solved the problems of high penetration loss of radio wave through aircraft cabin, large Doppler frequency shift during high-speed flight and frequent cell switching [4]. It mainly consists of airborne network and ground network.

The ATG airborne network mainly includes airborne antenna, Wireless Access Point (AP), airborne server, Customer Premise Equipment (CPE), etc. The ATG Ground network includes ATG ground base station, supporting ground transmission net, Evolved Packet Core (EPC), ground data center and business platform. The specific implementation is to deploy ATG ground base stations along air routes which connect to the EPC through ground transmission net, install CPE on aircraft, and communicate with ATG ground base stations by 4G or 5G wireless communication technology. The EPC realizes data conversion and routing, and Internet access through gateway devices. The network structure of the ATG communication System as shown in Fig. 1.

Compared with communication between airplane and satellites, the ATG communication can apply for a larger spectrum width, so the communication bandwidth of a single

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aircraft can be much larger than that of satellites, which allows more passengers to connect to the Internet and meet the needs of large flow data communications. The ATG communication technology has the advantages of lower cost equipment , lower network delay, lower traffic charges, faster technology iteration and upgrading [5], it can smoothly upgrade to 5G communication technology, but the disadvantage is that the aircraft should not deviate from signal coverage of base stations. Due to these advantages, the ATG communication technology has been widely used in the United States and other European countries.

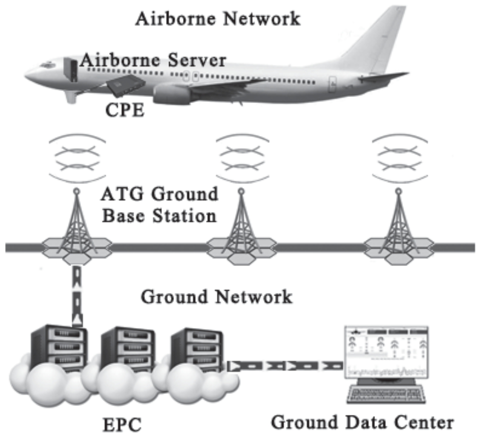


Fig. 1. Network structure of the ATG communication system

In order to verify the feasibility of real-time downloading and analysis of QAR data using the ATG communication technology, the CAAC formally approved in July 2017 that we can conduct real-time analysis and application tests of QAR data using the ATG communication system with the frequency bands of air to ground as 973±2.5MHz and ground to air as 1038±2.5MHz.

II. Construction of ATG Communication System and Aircraft Modification

The first step of real-time QAR data download and analysis test is to build a test environment. It has two parts: one is to build the ATG communication system; the other is to install airborne ATG equipment for the tested aircraft.

A. Construction of The ATG Communication System

The ATG communication system is constructed using 4G-LTE FDD communication technology, and the up-link and down-link spectrum bandwidth are 5 MHz each.

The antenna, the remote radio unit (RRU) and the Building Base band Unit (BBU) are installed on the communication tower of China Mobile Communications Group Co., Ltd (CMCC) while the base station is building. The signal coverage radius of each base station is 160KM. The base stations adopt three sector mode, and each sectors are arranged around circular rings with equal spacing to ensure that each station has one sector aligned with the main flight direction of the air route. Multiple antennas which support Multiple-Input Multiple-Output (MIMO) and adaptive technology transmission are deployed in each sector. The antenna has a specific tilt angle, which keeps 8-12 degrees, and has good sidelobe suppression ability [6]. While reducing the impact to the 4G LTE ground communication system, ensures that the signal covers the altitude of 3000-15000 meters in the air route.

Until 2016, 52 ATG ground base stations have been built, covering three air routes: Beijing-Chengdu, Beijing-Shanghai and Beijing-Guangzhou. The EPC which function is to receiving and switching data of each base station has been built in Beijing. It manages the net, receives the data transmitted from the base station and send it to the ground data center for data processing and analysis. Besides, it also has the functions of user's mobility management, authentication and contract signing. The ground data center for application development which is connected with EPC by ground transmission net through private network has been built in China Academy of Civil Aviation Science and Technology (CAST).

B. Aircraft Modification

The modification of ATG airborne equipment for 2 airliners which registration number are B-6556 and B-6631 of Air China has been finished. QAR data are collected by using the scheme of direct connection between ATG airborne server and WQAR equipment's network ports, because these two aircraft have installed WQAR equipment and have Ethernet interface already. The Airborne Full Media Sever (AFMS) and The CPE are both placed in the aircraft electronic equipment cabin, and they are connected through Ethernet cables. The ATG communication antenna is installed in the belly of the aircraft and connected with the airborne communication equipment through feeder lines.

C. Testing Air Routes

The Beijing-Chengdu round-trip air route was chosen as the testing route with a mileage of 1697 Km and a flight time of about 2 hours and 30 minutes. A total of 14 ATG ground base stations are constructed under this air route. After construction of the ATG communication system, the network communication capability was tested via 8 flights. The results show that the peak throughput of up-link (air to ground) data of each ATG base station can reach 11.74 Mbps, and the average rate is 6.37 Mbps. The peak throughput of down-link (ground to air) data of each ATG base station can reach 16.46 Mbps, and the average rate is 8.65 Mbps.

III. Network Performance Test of QAR Data Real-time Transmission Using ATG

The network transmission performance of QAR data transmitted by ATG network is the basis of real-time QAR data analysis application, so it is necessary to test it. The test and verification workflow as shown in Fig. 2.

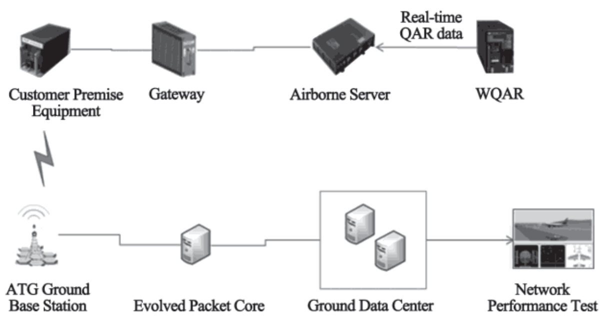


Fig. 2. Test process of QAR data real-time transmission

The WQAR sends one QAR packet per second with User Datagram Protocol (UDP) protocol, and each packet contains 256 Words parameters. The airborne server monitors and receives QAR real-time data packets sent by WQAR, and encrypts the data packets by RSA and CRC, then sends the data to the ground data center through ATG communication network, and records the sending time of QAR data package of the airborne server. The ground data center makes CRC checks for them after received QAR real-time data packets, then decrypt them using RSA. After that, it sends the reply messages of successfully receives to CPE and stores the received QAR data packets as data files finally. The integrity, consistency and transmission delay of QAR data transmitted by ATG communication network are verified by comparison. The specific test methods are as follows:

1) Data integrity: after the ground data center stores the received QAR data packet as a data file, the file is compared with the QAR data file records stored in the ATG airborne server, which verifies the integrity of QAR data.

2) Data consistency: after receiving QAR data packets, the ground data center compares them with the QAR data transmitted to the CAAC Flight Operations Quality Assurance Monitoring Stations after landing to verify the consistency of QAR data.

3) Transmission delay: The ground data center timestamps each downloaded QAR real-time data and records the time when it receives the QAR data. When the CPE receives the response message from the ground data center, it timestamps the received response message. According to the two timestamps, the round trip delay of each QAR data transmission between the ground and the air is calculated.

The network performance of real-time QAR data transmission using ATG was tested on 34 flights of the airliners which registration number is B-6556 from April 17, 2018 to June 14, 2018. The statistical data of test results are shown in the table I.

TABLE I. NETWORK PERFORMANCE OF QAR DATA TRANSMISSION USING ATG NETWORK

Number of flights	Total QAR Packet	Average QAR Packets Received per Flight	Unsuccessful transmission of data packets	Packets with inconsistent data content	Maximum round trip delay (milliseconds)	Minimum round trip delay (milliseconds)	Average round trip delay (milliseconds)	proportion of return delay < 300 milliseconds (%)
34	279480	8220.4	8	0	4308.5	25.2	71.45	98.77

A total of 279480 QAR data were sent by 34 flights. Except 8 of them were not successfully transmitted to the ground, the others were successfully received. The integrity of QAR data transmitted by ATG network is 99.99% and data content consistency rate is 100%. The average round trip delay of QAR data transmission is 71.45 milliseconds, the minimum delay is 25.2 milliseconds and the maximum delay is 4308.5 milliseconds. Among the average round trip delay, 0.37% had greater than 1000 milliseconds, 99.63% had less than 1000 milliseconds and 98.77% had less than 300 milliseconds.

IV. DECODING OF QAR REAL-TIME DATA

A. Format Definition of QAR Data

The format definition of QAR data conforms to the standard established by Aeronautical Radio Inc. (ARINC). At present, three main specifications are used: ARINC573, ARINC717 and ARINC747.

The ARINC573 specification records a frame of information every 4 seconds. Each frame contains four sub-frames, i.e. one sub-frame per second. Each frame contains 64 words; each word contains 12 bits. The sync-words are used to distinguish four sub-frames in each frame. Sync-words are recorded in the first word of each sub-frame. The rest words are used to store flight parameters that need to be recorded. [7].

The ARINC717 specification is an extension of ARINC573, which uses the "super-frame" format. In order to expand the recording parameters, the recording speed is increased to 128/256 Words per second (WPS) [8].

The ARINC747 specification is the latest standard. It records flight parameters on solid-state components using memory chips as recording media, which facilitates reading and decoding of recording parameters. The recording speed can reach 64/128/256/512WPS [9].

B. Decoding process of QAR data

The QAR data downloaded in real time is the data encoded by the above specifications, which cannot be directly recognized and subsequently analyzed. It needs to be decoded into unit, intuitive, engineering data that can be used by subsequent analysis software and analysts before it can be analyzed and utilized [10]. Manual decoding or software automatic decoding can be used. According to the production age, different types of aircraft adopt different specifications. The decoding process requires a thorough understanding of the whole process of flight data acquisition, processing and storage of this type of aircraft, as well as the storage methods and transmission specifications of parameters by various recorders and data buses. In order to understand the types of flight data and the corresponding engineering data conversion methods, it is necessary to obtain the flight parameter description files of the recorder [11]. The decoding process is shown in Fig. 3.

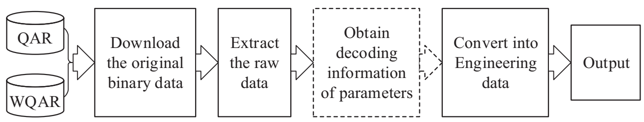
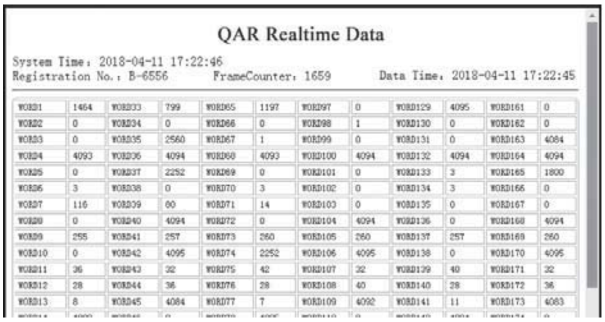


Fig. 3. The decoding process of QAR data

1) Getting original binary data:

Firstly, the original binary data of QAR needs read. The original QAR real-time data displayed in decimal during a flight of aircraft which registration number is B-6556 is shown in Fig. 4.



QAR Realtime Data

System Time: 2018-04-11 17:22:46
Registration No.: B-6556 FrameCounter: 1659 Data Time: 2018-04-11 17:22:45

WORD1	1464	WORD33	799	WORD65	1197	WORD97	0	WORD129	4095	WORD161	0
WORD2	0	WORD34	0	WORD66	0	WORD98	1	WORD130	0	WORD162	0
WORD3	0	WORD35	2560	WORD67	1	WORD99	0	WORD131	0	WORD163	4084
WORD4	4093	WORD36	4094	WORD68	4093	WORD100	4094	WORD132	4094	WORD164	4094
WORD5	0	WORD37	2252	WORD69	0	WORD101	0	WORD133	3	WORD165	1800
WORD6	3	WORD38	0	WORD70	3	WORD102	0	WORD134	3	WORD166	0
WORD7	116	WORD39	60	WORD71	14	WORD103	0	WORD135	0	WORD167	0
WORD8	0	WORD40	4094	WORD72	0	WORD104	4094	WORD136	0	WORD168	4094
WORD9	255	WORD41	257	WORD73	260	WORD105	260	WORD137	257	WORD169	260
WORD10	0	WORD42	4095	WORD74	2252	WORD106	4095	WORD138	0	WORD170	4095
WORD11	36	WORD43	32	WORD75	42	WORD107	32	WORD139	40	WORD171	32
WORD12	28	WORD44	36	WORD76	28	WORD108	40	WORD140	28	WORD172	36
WORD13	8	WORD45	4084	WORD77	7	WORD109	4092	WORD141	11	WORD173	4083

Fig. 4. Original QAR real-time data displayed in decimal during a flight

2) Calculation of raw data:

The raw data for calculating engineering data need extracted from the original binary data according to the start and stop position of each parameter and the information of parameter type.

According to the data record mapping table provided by the manufacturer, locate the recording position of the parameter, including the sub-frame number, slot position, start and stop position, whether it is a super frame or not. If the parameter is a super frame record, the location information also includes the sub-frame number where the super frame is and the super frame cyclic serial number. Taking a parameter as an example, it is assumed that the parameter is recorded in the sixth slot of the sub-frame and read out as FEB from the received QAR data packet; Got the starting and ending bits are 2 and 5 which query from the data record mapping table, then convert FEB to binary 111111101011, so the positioning bits 2-5 are read out as 0101, that is, the original binary value of the parameter. Then the raw data can be calculated according to the data encoding types defined in the aircraft parameter specification manual, such as BCD code, BNR code, DIS/COD, etc. Assuming that it is a BNR code, 0101 is its raw data, or if it is a BCD code, 5 is its raw data.

3) Conversion of Engineering data:

In QAR data, different signals have different parameter type, and different parameter type corresponds to different engineering data conversion mode. For traditional manual decoding, the engineering data conversion information of each parameter in the parameter description file provided by recorder or aircraft manufacturer should be consulted, then the raw data are converted into engineering values by using these engineering transformation formulas and coefficients of corresponding parameters.

According to different types of parameters, different conversion formulas are corresponded while the process of converting raw data into engineering data. For QAR data, it can be roughly divided into discrete data, analog data and digital data according to the different electrical signals received during storage and the different characteristics of parameters.

a) Discrete data: discrete data are some digitized parameter connected to an airborne data acquisition component, which are generally represented by one or more bits in a data word. For example, the state of landing gear's Air/Ground switch is represented by the 6th bit code in a word. According to the parameter description file provided by the recorder or aircraft manufacturer, if 1 is set in the air, it will display "air" and if 1 is set in the ground, it will display "ground".

b) Analog data: analog data is the output of some sensors, which are connected to Data Management Unit (DMU) through independent ports. It generally has a linear or non-linear relationship between recorded value and true value. It can be expressed by polynomials, such as:

$$\text{Result} = \text{A} + \text{B}x + \text{C}x^2 + \text{D}x^3 + \ldots + \text{M}x^n \quad (1)$$

Or:

$$\text{Result} = \text{A} + \text{B}x_1 + \text{C}x_2 + \text{D}x_3 + \ldots + \text{M}x_n \quad (2)$$

Among them: A, B, C, D... M is a resolution data which according to the manual. In formula (1), x is the raw data in decimal which converted from original binary data. The linear relationship between them is satisfied when the coefficients of higher order terms (B = C = D =... = When M = 0) is 0. In formula (2), x_1, x_2, x_3 … x_n is the raw data in decimal which converted from multiple original binary data. It may be stored in different bits of a same word or in multiple words.

c) Digital data: digital data mainly includes BCD and BNR data format, its decoding algorithm can be expressed as:

$$\text{Result} = \text{C}x \quad (3)$$

Where: x represents the raw data in decimal and C represents the resolution data.

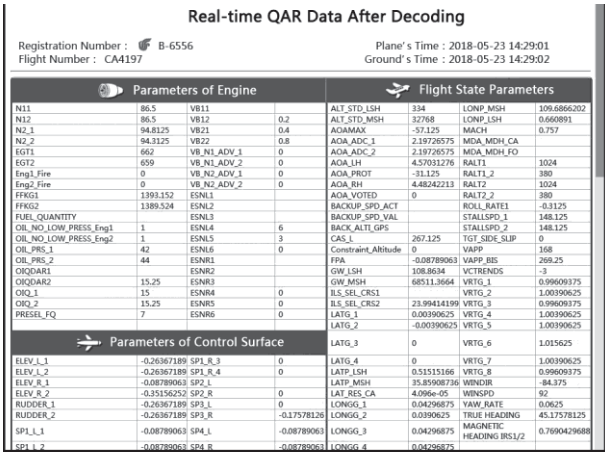
For automatic decoding software, the process of engineering data conversion can be divided into three steps: Set up the decoding parameter library, set up the relationship between aircraft registration number and decoding parameter library, and create decoding parameter templates. Before software decoding, we need to query the parameter description file provided by the recorder or aircraft manufacturer according to aircraft which the QAR data downloaded, set up a decoding parameter library for this aircraft type, and establish the mapping relationship between the aircraft registration number and the applicable decoding parameter library in the decoding software. When the registration number of the aircraft is obtained, the software automatically associates the original decoded file with the corresponding decoded parameter library file, and converts the raw data into decimal engineering data.

In the process of decoding, we can choose which parameters to decode. For example, all parameters, that means, all parameters contained in the decoding parameter library will be decoded. It can also select only the parameters that need attention for decoding, such as engine-related parameters. Or establish a parameter template based on a specific fault, such as when the fuel consumption of one engine is significantly higher than that of the other engine of the same aircraft in a certain period of time, it may cause high fuel consumption. So these parameters can be established as a fault templates and intensive monitoring them in a short time.

C. Development of Automatic Decoding Software Based on QAR Real-time Data

At present, the AirFASE, AGS and GRAF are the most widely used automatic decoding and analysis software for QAR data [12]. They are all used for QAR data downloaded after flight and still needs manual input of original data, selection of decoding parameter library, decoding, selection of output conditions, output folder and other operations. If we want to continuously monitor QAR data, we need to decode each flight's data one by one every day, and the workload is very heavy. Moreover, a lot of data lost or reduced their value of use, because the analysis of QAR data is carried out after flight.

Since the identity number of the CPE installed by us on each aircraft is unique, the relationship between this identification number and the aircraft type that the CPE installed can be established. So, we can establish a mapping table in the decoding software in advance. Then, according to the method of QAR data decoding, we developed the automatic decoding software for Boeing B737 and Airbus A321, which shown in the figure 5. The utilization of QAR data that decoding while downloading, and analyzing while decoding is realized.



Real-time QAR Data After Decoding

Registration Number : B-6556
Flight Number : CA4197

Plane's Time : 2018-05-23 14:29:01
Ground's Time : 2018-05-23 14:29:02

Parameters of Engine				Flight State Parameters			
N11	86.5	VB11		ALT_STD_LSH	334	LONP_MSH	109.6866202
N12	86.5	VB12	0.2	ALT_STD_MSH	32768	LONP_LSH	0.660891
N2_1	94.8125	VB21	0.4	AOAMAX	-57.125	MACH	0.757
N2_2	94.3125	VB22	0.8	AOA_ADC_1	2.19726575	MDA_MDH_CA	
EGT1	662	VB_N1_ADV_1	0	AOA_ADC_2	2.19726575	MDA_MDH_FO	
EGT2	659	VB_N1_ADV_2	0	AOA_LH	4.57031276	RALT1	1024
Eng1_Fire	0	VB_N2_ADV_1	0	AOA_PROT	-31.125	RALT1_2	380
Eng2_Fire	0	VB_N2_ADV_2	0	AOA_RH	4.48242213	RALT2	1024
FFKG1	1393.152	ESNL1		AOA_VOTED	0	RALT2_2	380
FFKG2	1389.524	ESNL2		BACKUP_SPD_ACT		ROLL_RATE1	-0.3125
FUEL_QUANTITY		ESNL3		BACKUP_SPD_VAL		STALLSPD_1	148.125
OIL_NO_LOW_PRESS_Eng1	1	ESNL4	6	BACK_ALTI_GPS		STALLSPD_2	148.125
OIL_NO_LOW_PRESS_Eng2	1	ESNL5	3	CAS_L	267.125	TGT_SIDE_SLIP	0
OIL_PRS_1	42	ESNL6	0	Constraint_Altitude	0	VAPP	168
OIL_PRS_2	44	ESNR1		FPA	-0.08789063	VAPP_BIS	269.25
OIQDAR1		ESNR2		GW_LSH	108.8634	VCTRENDS	-3
OIQDAR2	15.25	ESNR3		GW_MSH	68511.3664	VRTG_1	0.99609375
OIQ_1	15	ESNR4	0	ILS_SEL_CRS1		VRTG_2	1.00390625
OIQ_2	15.25	ESNR5	0	ILS_SEL_CRS2	23.99414199	VRTG_3	0.99609375
PRESEL_FQ	7	ESNR6	0	LATG_1	0.00390625	VRTG_4	1.00390625
				LATG_2	-0.00390625	VRTG_5	1.00390625
Parameters of Control Surface				LATG_3	0	VRTG_6	1.015625
ELEV_L_1	-0.26367189	SP1_R_3	0	LATG_4	0	VRTG_7	1.00390625
ELEV_L_2	-0.26367189	SP1_R_4	0	LATP_LSH	0.51515166	VRTG_8	0.99609375
ELEV_R_1	-0.08789063	SP2_L		LATP_MSH	35.85908736	WINDIR	-84.375
ELEV_R_2	-0.35156252	SP2_R	0	LAT_RES_CA	4.096e-05	WINSPD	92
RUDDER_1	-0.26367189	SP3_L	0	LONGG_1	0.04296875	YAW_RATE	0.0625
RUDDER_2	-0.26367189	SP3_R	-0.17578126	LONGG_2	0.0390625	TRUE HEADING	45.17578125
SP1_L_1	-0.08789063	SP4_L	-0.08789063	LONGG_3	0.04296875	MAGNETIC HEADING IRS1/2	0.7690429688
SP1_L_2	-0.08789063	SP4_R	-0.08789063	LONGG_4	0.04296875		

Fig. 5. The automatic decoding software of real-time QAR data

When the ATG ground data center receives the data packet, it preprocesses the data packet first, extracts the identity number information of the CPE, finds out the installed aircraft type of the CPE through the look-up table method, and then decodes the downloaded QAR real-time data automatically and in real time according to the corresponding decoding parameter library. By recording the time before and after decoding, the time consumption of decoding is calculated. Statistics show that it took about 25 milliseconds for automatic decoding software to decode 275 words QAR data which downloaded by ATG communication network per second.

V. APPLICATION DEVELOPMENT BASED ON QAR REAL-TIME DATA

The QAR engineering data after decoding is the basis of application development for real-time QAR data analysis. Based on this, we have developed real-time flight track monitoring system, real-time flight simulation and warning system, real-time engine status monitoring system, real-time eddy dissipation rate (EDR) evaluation system and other applications. Specifically, as follows:

1) Real-time flight track monitoring system: Using the data of longitude, latitude, altitude, speed, azimuth, flight number and so on, the flight trajectory of an aircraft can be drawn on a two-dimensional GIS map in real time. we can set the threshold of some parameters in system. When the parameters such as roll angle, pitch angle, yaw angle and height that output by QAR data real-time decoding module are exceed the threshold, the alarm can be prompted by words or sound. The interface of the application software is shown in Fig. 6.

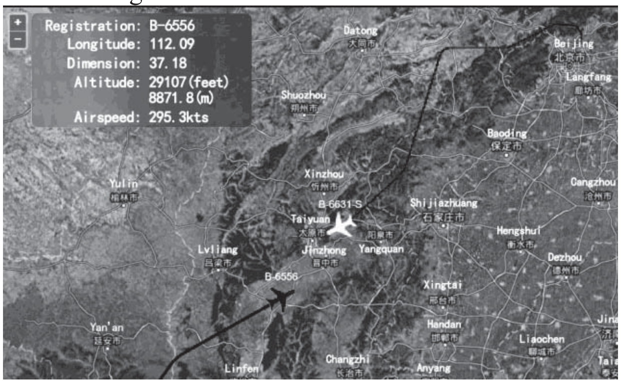


Fig. 6. Real-time flight track monitoring system

2) Real-time flight simulation and warning system: using engineering data such as parameters of control surface, manipulation parameters, flight state parameters and engine's parameters obtained by real-time decoding, various three-dimensional models that like cockpit buttons, indicator lights, dashboards and aircraft models on software interface are driven. The flight status of the aircraft can be displayed in real time in the form of virtual cockpit simulation, and the viewing function from different perspectives are provided. Threshold values of some parameters can be set. When the values of parameters exceed the limit, warnings can be prompted by text or sound. The interface of the application software is shown in Fig. 7.

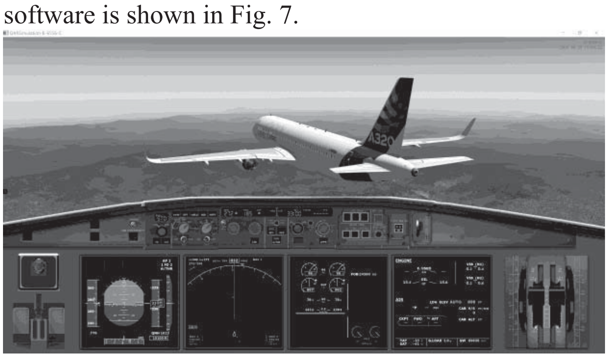


Fig. 7. Real-time flight simulation and warning system

3) Real-time engine status monitoring system: engine parameters such as N1, EGT, speed, thrust, fuel volume, lubricating oil volume, fuel pressure, exhaust temperature and so on after decoding, are drawn in the form of graphics, data lists and curves to visually display the working status of the left and right engine and its components on the screen. Alarm for events that exceed a set threshold. It can diagnose the key components and parts of the engine on-line regularly, grasp the health status of the engine during flying, and improve the maintenance efficiency. The interface of the application software is shown in Fig. 8.

Fig. 8. Real-time engine status monitoring system

4) Real-time eddy dissipation rate (EDR) evaluation system: using the parameters of position, acceleration, altitude, relative humidity, air pressure, air speed, wind direction and wind shear and so on after decoding and calculated with meteorological model, the eddy dissipation rate is generated by graphical method such as standard pressure change map based on sea level, which can be sent to subsequent flights to help them choose safety and comfortable flight altitude or route. The interface of the application software is shown in Fig. 9.

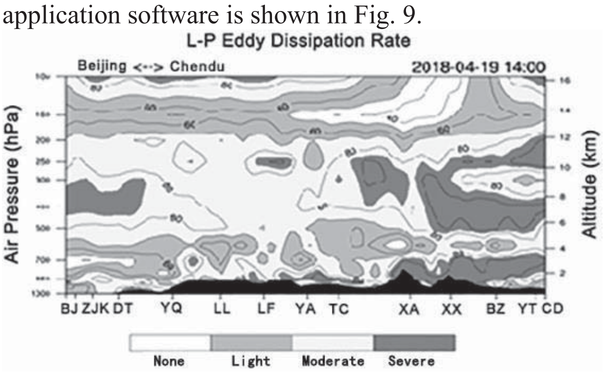


Fig. 9. Real-time eddy dissipation rate (EDR) evaluation system

VI. Conclusion

The development of the ATG wireless broadband communication technology has brought opportunities for QAR data real-time transmission and effective utilization. Through the construction of ATG wireless broadband communication system and a large number of QAR data transmission tests by real flights, the integrity, consistency and transmission delay of QAR data real-time downloading are verified, and these network performances are all within the acceptable range of real-time analysis applications. Real-time downloading and decoding of QAR data can not only eliminate the heavy work of importing and analyzing QAR data manually after flight, but also bring revolutionary changes to the analysis and utilization of these information. It makes the utilization of QAR data change from the traditional management methods of ex post analysis, passive response and lag processing to the efficient methods of pre-analysis, active discovery and timely processing, which greatly can enhances the practicability of QAR data analysis. By developing a targeted FOQA monitoring system, it can help us to monitoring the status of aircraft in real time, supervising flight safety, detecting potential safety hazards in time, and achieve efficient management and emergency disposal. It is an important technical means to enhance aviation safety.

The real-time flight track monitoring system, real-time flight simulation and warning system, real-time engine status monitoring system and real-time eddy dissipation rate (EDR) evaluation system developed by QAR data further proved the effectiveness of real-time QAR data decoding. It will plays an important role in real-time monitoring of flight safety, operation management and aircraft maintenance.

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