A New Network Telemetry technique

In Aviatic Flight Tests

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ABSTRACT

Abstract: In order to address the issue of insufficient telemetry frequencies in flight tests, a telemetry transmission solution is proposed to transmit the principal parameters and HUD video for multiple aircrafts based on bi-directional wireless network. All the key points including the wireless transmission architecture for airborne and ground integration, network resources management, and dynamic configuration of airborne test system are illustrated. The research result has been verified in flight tests, and the experimental methods and results are presented as well.

INTRODUCTION

The existing telemetry transmission system for flight test is a P2P mode, which means one telemetry receiving station can only receive flight parameters of one aircraft. When multiple aircrafts require telemetry monitoring simultaneously, the same number of telemetry receiving stations are needed. Moreover, since there is only a downlink in this mode, the GPS or Beidou real- time carrier-phase differential can not perform. Therefore, a more accurate position of the flight can not be located, and it can not satisfy the high precision positioning requirement in flight test. Furthermore, in this mode it is necessary to manually download, process and analyze the flight parameters and video data, which could lead to long data processing cycles and high work intensity. Overall, this model can no longer meet the test and training task of multi-batch, multi-subject, high-intensity in aviatic flight test at the current stage in terms of capability and efficiency.

To address the problem of simultaneous monitoring of multiple aircrafts, real-time high-precision positioning of multiple bases(multi-flight, ground-based, ship-based), time and space synchronization, pilot assessment and other difficult problems, a compact, intelligent, integrated network telemetry system is designed for flight test to provide real-time flight parameters capturing, multi-flight safety monitoring, and rapid flight result analyzing and other features as well.

NETWORK TELEMETRY TRANSMISSION

Currently traditional telemetry mode dominates flight tests. FM modulation is used in this mode, although it is stable and reliable, but the FM modulation mode has low spectrum efficiency at high transmission rate. Considering the BER and channel interference, the ratio of bandwidth and telemetry rate is about 2.4:1, and the problem of occupying more frequency resources is especially prominent. Therefore, the new Wideband RF network receiver or transmitter adopts new modulation technology to improve the spectrum utilization at high transmission rate. There are many alternative digital modulation modes in the world presently, of which OFDM (Orthogonal Frequency Division Multiplexing) has shown a good application prospect. The main advantage of this modulation is to combat frequency-selective fading and narrowband interference, while improving the spectrum utilization at the same time. OFDM is a military and civilian dual-use technology. In the field of military experimentation, such as the Toulouse flight test base in France, OFDM has been used to transmit flight test data. The US has also developed S-band airborne RF transceiver products using OFDM. In the commercial field, OFDM has been widely used in broadband wireless network and high-definition digital image transmission [1].

COFDM (Coded Orthogonal Frequency Division Multiplexing) is a combination of OFDM and channel coding, and COFDM is based on the idea of carrying information in both frequency time domain. The fading of each unit signal can be considered statistically independent by encoding, thus eliminating the effects of flat fading and Doppler shift, so it can be applied to high-speed moving aircrafts [2].

The telemetry transmission system using COFDM modulation can combine a self-organizing and self-healing wireless mesh network composed of 16 nodes. The nodes within this mesh network can exchange data at the same frequency simplifying the frequency management. This mesh network occupies only 2.5MHz bandwidth (optionally 3.0, 3.5, 5.0 and 6.0MHz). COFDM modulation is served in the nodes, therefore, it has excellent RF penetrating ability and multipath transmission performance.

The mesh network nodes can provide IP data transmission rates over 8.0 Mbits/s (the rate depends on the model of nodes, the number of nodes, and the distance between nodes). This IP rate is used to exchange IP data between nodes. A highly flexible mesh structure features that data between nodes can be exchanged in a P2P or point-to-multipoint manner, and that nodes can also increase the distance of the transmission through relay.

Each mesh node provides two physical Ethernet ports as a switching hub, and a connection to the network wireless link. All node units are connected to each other as a wireless IP network. The system arbitration guarantees avoiding collisions at any time. Nodes can be seamlessly connected to the network without user intervention.

Each network radio station has two-antenna diversity receivers. Only one of these antennas will have data transfer in a short time. The transmission is arbitrated by tokens between radio stations.

ARCHITECTURE OF NETWORKED TELEMETRY SYSTEM

The networked telemetry transmission system consists five parts: the airborne acquisition and recording subsystem, the network telemetry transmission subsystem, the GPS or Beidou subsystem, the ground telemetry receiving subsystem and real-time multi-aircraft security monitoring subsystem. The airborne acquisition and recording subsystem mainly completes HUD video and airborne 429, 422 bus data collection, and the video and parameters data are encoded into network data packets, which are transmitted by the airborne antenna and network radio of the network telemetry transmission subsystem, then received with the Omni antenna of the ground telemetry receiving subsystem. The network radio station sends the received network data packets to the ground security monitoring server through the Ethernet switch, and the server will multicast via the network sending parameters of the aircrafts to the monitoring client to realize real-time ground monitoring and quasi-real-time flight result analysis.

In the meantime, the airborne acquisition and recording subsystem can receive the uplink command data from the ground control center, performing the device state self-check, the device self -start, restart, bit rate setting and other operations. Equipped with the GPS or Beidou, this system can realize RTK to provide accurate trajectory and velocity of the aircrafts.

DATA ACQUISITION

The airborne acquisition and recording system mainly completes the acquisition of the HUD video, ARINC-429 bus, RS422 bus, analog, frequency and discrete parameters. It also receives the positioning information of GPS or Beidou output. All these information is encoded in a composite manner to form Ethernet packets to the airborne network radio station. At the same time, the airborne test unit can receive the uplink data command of the ground control center, completing the device state self-check, the device self -start, restart, bit rate setting and so on. The schematic diagram of the subsystem principle is shown in Figure 1.

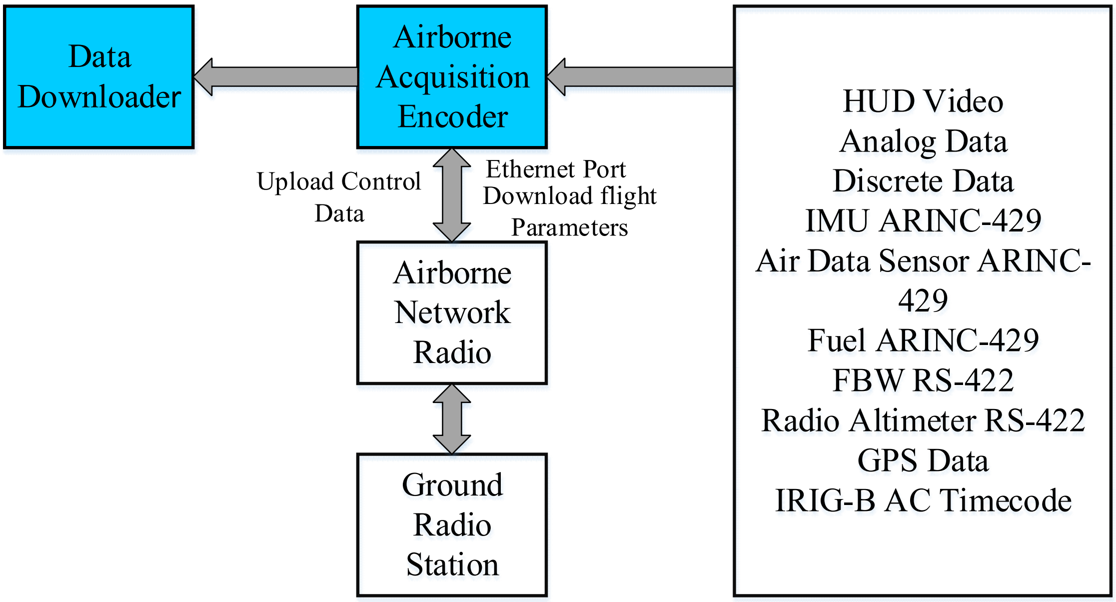

Fig. 1 schematic diagram of the subsystem principle

The airborne acquisition encoder mainly includes the following boards: HUD video acquisition board, ARINC-429 Bus acquisition board, RS422 Bus acquisition board, Analog data acquisition board (integrated with thermocouple acquisition module), frequency and discrete data acquisition board, master control board (integrated with PCM coding module, Data storage module, Ethernet module and IRIG-B AC time code module), motherboard and power board.

The airborne acquisition encoder Ethernet port outputs the encoded video and flight parameters signal using UDP multicast. It can also receive the control instruction of the ground through the wireless network radio station, which can realize the composite output of HUD video and flight parameters, or flight parameters only.

DATA TRANSMISSION OF WIRELESS NETWORK

In order to meet the requirements of multi-platform, high intensity and high efficiency flight mission, and saving the test resources, a networked telemetry transmission system is designed to fulfil one ground telemetry station receives and monitors multi-aircraft simultaneously. The airborne wireless network radio is mainly used for transmitting the network packets stream of the airborne device output, uploading the real-time carrier-phase differential of the GPS or Beidou device to achieve precise positioning of the aircraft, and uploading the ground control command to gain control of the airborne equipment.

The airborne wireless network can combine a self-organizing, self-healing wireless mesh network composed of 16 nodes. The node uses antenna diversity technique, combined with a variety of advanced technologies such as spatial diversity, time division and multiple access, which can significantly enhance the system's anti-fading ability. With the unique COFDM modulation, the signal receiving intensity for the mobile targets is enhanced by 3 to 5 dBm than other ordinary radio devices. The excellent RF penetration and multipath transmission performance ensure that BER can be <10e-6 when the receiving level is -98dbm [3].

In this networked telemetry transmission system, the mesh network topology is used to realize multi-point to multi-point network data transmission. In such a network structure, each node is connected in a multi-hop manner through other adjacent network nodes, which can fulfil the network communication among the aircrafts [4]. In actual flight tests, one ground telemetry stations can receive the flight parameters data of 6 to 10 aircrafts.

The networked telemetry transmission system enables the use of AES128 or AES256 encryption (optional) to ensure the control of the deployed nodes, via a built-in web browser or PC version of the integrated control program. With map display, this program can configure, monitor the mesh network, and control each node.

ANALYSIS OF GROUND REAL-TIME DATA RECEPTION

The telemetry receiving subsystem receives the key parameters data of the aircraft in real time, which is used for flight test engineers and flight commanders to monitor and direct. The system extracts important information through the real-time analysis and processing of all sorts of data. According to these information, flight test engineers monitor the flight test process, judge the completion quality of the subjects, and evaluate the safety risks, which provide guarantees for the efficient and safe implementation of the tasks. The specific functions are as follows:

a) Real-time data receiving function: The system receives all kinds of airborne data and video in real time through the Omni receiving antenna, processes it through the telemetry front end, acquiring various airborne data.

b) Real-time status display and control function: Real-time display of all network radio operating status, airborne test unit working status, and control of the airborne test unit and airborne network radio;

c) Real-time data processing function: The real-time data processing is to provide the required data information for the command and monitoring by processing the raw data. The main functions include the extraction of quantities of flight parameters, the calculation of derived parameters, and the simultaneous processing of multiplexed data, calculations, analysis and processing data according to the requirements of the flight test task tasks.

d) Real-time carrier-phase differential function: The ground GPS or Beidou differential station sends positioning data through the RS422 port, then uses the uplink of the network station to transfer to the network radio on the aircraft. After that the airborne GPS or Beidou device receives data from RS485 Port of the network radio to realize the real-time carrier-phase differential.

Establish a ground control center in the ground. The control center is equipped with one network radio, one network switch, one control computer, control program, and two antennas for each radio. The Wireless encryption communication link enables interoperability. For better transmission, the ground station employs high-power Omni antennas. The antennas are installed as high as possible, to achieve better quality. Antenna A is dedicated to sending data, and antenna B is used to receive data.

The ground Omni antenna receives the wireless signal and convert it into a radio frequency signal and send it to the ground network radio, through the network radio, the signal is transformed into the network data packets, and then send to the ground data server. The server receives the network packets in real time, processing to the physical data according to each parameter's school line. After being parsed with the interface control file, the flight parameters are obtained. Finally the C/S architecture is used to multicast data to each monitoring client through the network, and the data and the curves are displayed in real time.

TEST VERIFICATION

Through the flight test mission of a certain aircraft, we conducted flight test verification on the wireless network transmission system. The original ground test device was modified to the aircraft, and a networked telemetry transmitting antenna was modified in front of the fuselage to transmit wireless network data signal. Ground-receiving equipment is identical to the test equipment used in ground testing.

The HUD video and flight parameters of the aircraft were collected and encoded, then sent through wireless network radio, power amplifier and airborne telemetry transmitting antenna. The ground wireless network telemetry receiving platform decodes the video signal and the key flight parameters after receiving the network packets, then restores and displays it in real time. All the data that is received is also saved to disk.

In the first flight test, it was found that when the aircraft turns, the signal is intermittent and the network data packet loss is large. After analysis and research, this is due to the airborne antenna installed in front of the fuselage, when the aircraft turns, airborne antenna is blocked, causing the data link of the wireless network to be disconnected, resulting in data loss. In the second test, an airborne antenna was added to the upper part of the aircraft. From the time the aircraft took off to the maximum distance of 50km, the ability to receive complete data packets was greatly enhanced, and decoding and recovery showed a continuous video image and flight parameters. After more than 1,000 sorties of flight tests, it is verified that this networked transmission system is stable and reliable, real-time ground/vessel distributed safety monitoring is realized, and one networked telemetry receiving station can successfully receive 6 aircraft flight parameters. The system has effectively improved the efficiency of flight tests and saved frequency resources as well as human and material resources.

CONCLUSION

A new network telemetry transmission system is designed, which achieves bidirectional and long-distance telemetry transmission between the aircraft and the ground control center, realizes the application of a network telemetry transmission for the aviation flight monitoring, simplifies the traditional telemetry transmission system, reduces the telemetry transmission cost, and enables the limited frequency resources to be fully utilized. The real-time monitoring and commanding of aircrafts by receiving the HUD video and key flight parameters in real time can minimize flight risk, improve flight test efficiency and save flight cost. Moreover, in the establishment of multi-aircraft joint flight test, drone flight test data links, etc., network telemetry transmission system has broad application prospects, and will bring enormous economic and social benefits.

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