A Testing Method of Measuring Time Delay of the Flight Test AFDX Avionic System Caused by Data Acquiring Network

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ABSTRACT

Full Duplex Switched Ethernet AFDX is gradually replacing the traditional 1553B as the architecture of the new generation avionics system. AFDX bus has the characteristic of Ethernet delay. However, special needs for measuring avionics AFDX network delay are required to meet in flight test. According to the characteristics of flight test, this paper proposes a method of data acquisition network delay measurement for AFDX avionics system to solve the puzzle of delay measurement. The experiments on a test aircraft demonstrate that the method can improve the calculation accuracy of an avionics system and it’s effective in engineering applications.

Key Words: Avionics, AFDX protocol, Delay, Flight test, Acquisition

INTRODUCTION

Advanced aircrafts such as the Boeing 787, A400M, C-17, and AN-70 and so on, all adopt Full Duplex Switched Ethernet AFDX based on the standard ARINC 664. And AFDX is the dominant avionics bus of the future. For the new developed airliner C919 will use AFDX as the data exchange bus between avionics systems, it is necessary to make a deep research on the network acquisition, data processing and network delay based on AFDX.

With the ever-improving of flight test technology, the test subjects require more on the precision of the data analysis. There is no time stamp of the AFDX packets for the standard AFDX protocol, thus it is difficult to measure the time delay of the AFDX network messages in flight test. For flight test, the AFDX messages are transmitted between each network node. It is particularly necessary for some important test subjects in flight test to make it clear the acquisition network delay of AFDX for significantly improving the precision of data analysis, and thus need to measure and analyze the transmission delay of the process that messages from a generating End System to a receiving Testing End System. Thereby, it is a must in flight test to solve the practical problem that implements the measurement and analysis of the acquisition network delay for the related AFDX avionics system.

1 AFDX Avionics System

1.1 Overview

Avionics Full Duplex Switched Ethernet (AFDX) is a standard. AFDX bus is conceived by Airbus based on the Commercial Switched Ethernet. And according to the demands of avionics, Airbus brings a number of improvements in terms of real-time communications, reliability and so on. ARINC664, Part 7 published in June 27th, 2005 has defined the AFDX standard. An AFDX network comprises the following three components:

1) Avionics Subsystem: Each Avionics Computer System includes an embedded End System that connects the Avionics Subsystems to an AFDX Interconnect.
2) AFDX End System: The End System acts as an "interface" between the Avionics Subsystems and the AFDX Interconnect.
3) AFDX Interconnect: A full-duplex, switched Ethernet interconnect.

1.2 AFDX Message Processing Flow

Figure 1 depicts the AFDX message processing flow. A message M is sent by sending Port 1 of the Avionics subsystem 1. End System 1 encapsulates the message in an Ethernet frame and sends the Ethernet frame to the AFDX Switched Network on Virtual Link. The AFDX switches deliver the Ethernet frame to both End System 2 and End System 3. The End System 2 and the End System 3 are configured to deliver the message by receiving Port 5 of the Avionics subsystem 4 and by receiving Port 6 of the Avionics subsystem 6 according to the received Ethernet frame.

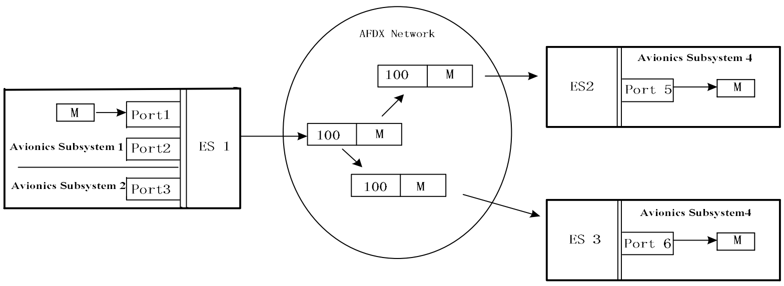

Figure 1 AFDX Message Processing Flow

2 The AFDX Tests in Flight Test

Flight test is that conducts various tests under real-world conditions. The test information related to time (including the time system of mission system, the time system of testing system, the delay of data acquisition, the accurate acquisition time of parameters and so on) is particularly concerned in flight test, which is the necessary information to analyze whether the data satisfy the designed requirements. Meanwhile, in flight test, the testing of the objects generally under without changing the original system structure of the test objects. As a consequence, it is required to adopt advanced testing methods and technologies to test the objects in flight test.

2.1 The AFDX Testing Subsystem

According to the AFDX network architecture, the AFDX testing system must ensure that the implementation of the acquisition and recording of the AFDX data without affecting the message transmission structure and characteristics of the original avionics system. For acquiring and recording the AFDX communication messages in flight test, it is a must to communicate with the AFDX Network in real-time and connect with the AFDX Network. The AFDX testing system connects to the AFDX network as an AFDX End System of the avionics system to implement network communications. Meanwhile, according to the principle of flight test, the Flight Test Instruments (FTI) as shown in Figure 2 can only receive messages but not send messages.

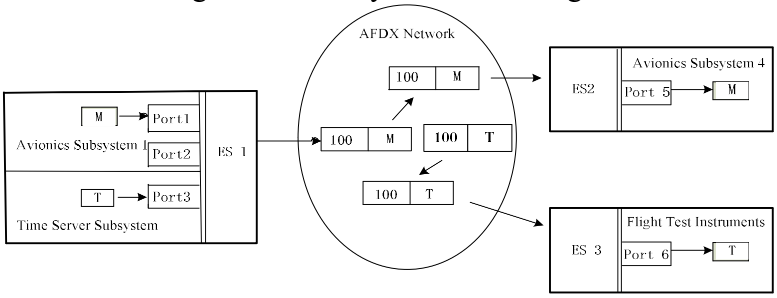

Figure 2 AFDX Flight Test Instruments

The AFDX Flight Test Instruments are capable to acquire and record AFDX avionics data directly. According to the testing requirements of the test aircraft, the airborne AFDX testing system should be able to acquire and record AFDX data at the same time, do integrity-checking on the received AFDX packets, and filter the received AFDX packets under the predefined filter conditions. The AFDX frames that matched will be attached with a time-stamp of the arriving time frame by frame, and the processed data are packed and then stored into the Solid State Storage Module of the data acquisition recorder. And after the flight test is complete, the data are restored by the unloading equipments on the ground and analyzed by the engineers.

2.2 The AFDX Frame Format in the FTI

Figure 3 shows the AFDX standard frame format. It is a puzzle to measure the AFDX network delay because there is no time-stamp in the AFDX standard frame and we cannot change the original avionics system structure in flight test. Thereby, it is unable to measure and analyze the network delay without unified time-stamp information.

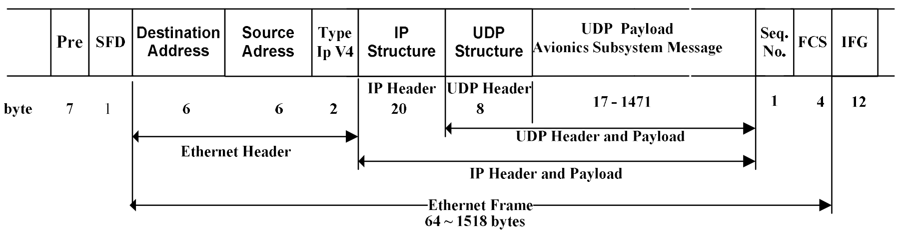

Figure 3 AFDX Frame Format

2.3 The AFDX Acquisition and Recording Format in the FTI

The AFDX bus data recorded by the airborne FC acquisition recorder are integrated AFDX frames which accord with the AFDX protocol. The recorder only records the AFDX frames and the testing system attaches the time-stamp of the arriving time of the AFDX frame at the same time. In flight test, generally, the time system of the acquisition time is the time system of the testing system. Finally, the data are restored by the unloading equipments on the ground, and the format as shown in Figure 4.

Acquisition Time	AFDX Frame	Acquisition Time	AFDX Frame	……	Acquisition Time	AFDX Frame

Figure 4 Format of the AFDX acquisition recorder

3 The Method of the AFDX Acquisition Network Delay Measurement in Flight Test

The AFDX avionics system network has the same communication characteristics of general network. Communications messages are sent by the Avionics Subsystem End System, and then attached with time-stamp to acquire and record once arriving at the FTI through the AFDX Interconnect. This process is bound to have network delay. In term of flight test, the most accurate message time-stamp should be the time that communications messages sent from the avionics subsystem. However, as mentioned above, the communications messages do not have a time-stamp when sent by the avionics subsystem, thus the communications messages acquired in flight test are bound to have network delay.

3.1 The AFDX Acquisition Network Delay in Flight Test

As depicted in Figure 2, AFDX message M being sent to the AFDX Interconnect through the Avionics Subsystem 1 and received by End System 2 of the Avionics Subsystem 4. In this process, if the sending time from End System 1 is mTIMEsource and the arriving time at End System 2 is mTIMEfti, then the avionics system's network delay of AFDX message M that concerned in flight test is mTIMElier as equation (1).

$$mTIMElier = mTIMEfti - mTIMEsource \qquad (1)$$

In the standard AFDX Network, the puzzles faced when measures delay in flight test as follows:

1) There is no time-stamp for the standard AFDX frame and no mTIMEsource in unified time system sent by the Avionics Subsystem when the AFDX message M is acquired and recorded by the FTI.
2) The time-stamp of the arriving time of the frame attached when the FTI acquires and records AFDX message M is generally the time system of airborne testing system, and it is not agree with the time system of avionics system. To obtain the accurate delay, they must be under the same time system.

3.2 The Method of Acquisition Network Delay Measurement for the AFDX Time Messages

As mentioned above, we design the AFDX FTI for flight test and analyze the key problem of measuring delay for AFDX avionics system. To solve these problems, we propose a method of time messages delay measurement based on the time system of the testing system in flight test as shown in Figure 5. In the End System of avionics system 1 that concerned in flight test, we design the Time Server Subsystem which is connecting to the End System 1, and transmit the time messages of the testing system to the Time Server Subsystem and the FTI at the same time. Thereby, the Time Server Subsystem and the FTI are under the same time system.

The time server subsystem receives the time message of the time system of the testing system while generates a smallest AFDX communication message frame, then inserts the time message TIMEtestsource into this AFDX frame, and transmits this message to the FTI through End System 1 in certain cycle within the performance constraints of the AFDX Interconnection. The FTI receives and records the time message frame of the Time Server Subsystem (the acquisition time is TIMEtestfti) and the message M of the avionics system.

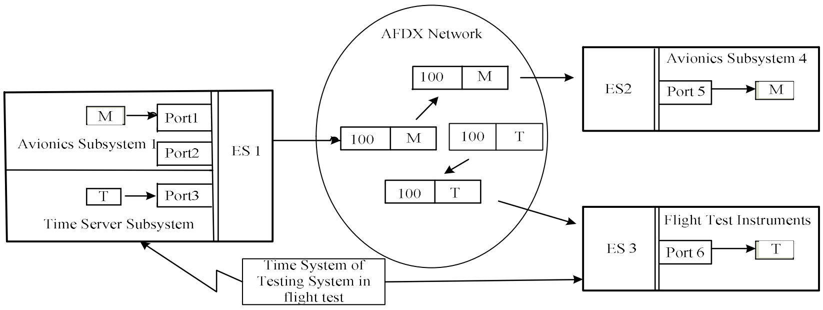

Figure 5 Delay measurement of the AFDX time message

By analyzing the time message frames TIMEtestsource and TIMEtestfti, we can figure out the network delay mTIMElier that from the ES1 to the FTI as equation (2):

$$mTIMElier = TIMEtestfti - TIMEtestsource \quad (2)$$

Several key points that influence the network delay are the transmitter state of the communications messages, the real-time traffic of the network switch and the receiver state of the communications messages. The message M of the Avionics Subsystem 1 and the message T of the Time Server Subsystem are in the same end system ES1, and the transmission and interchange of network are same as well. Thereby, we can obtain the network delay of message M by analyzing the network delay of message T and thus implement the acquisition network delay measurement for AFDX avionics system.

EXPERIMENTAL RESULTS

On one test aircraft, the bus architecture of the Avionics system adopts the AFDX Bus to replace the traditional 1553 Bus. Each mission avionics subsystem connects to the AFDX Interconnect to communicate mission messages through the End System. We build the airborne avionics system based on the AFDX standard to implement the interaction of avionics mission information. One avionics subsystem is particularly concerned in flight test, and we use the proposed method to measure the AFDX acquisition network delay for this end system and figure out the time delay of the test data as shown in Figure 6.

The experiments demonstrate that the acquisition network delay for AFDX avionics system is related to the real-time traffic of system network. The network delay is not immutable and is changing with the total traffic of network. By analyzing the AFDX delay results of the test aircraft and combining with the AFDX test data, we can figure out the accurate time of the key messages and obtain more precise parameters states of the avionics system on key points. Meanwhile, we can evaluate the delay error of all communications messages of this End System for the whole sortie. By combining the results with the testing parameters that airborne testing system recorded can improve the calculation and verification precision of the key parameters of the avionics subsystems in flight test, and then improve the testing calculation precision of one avionics subsystem in flight test.

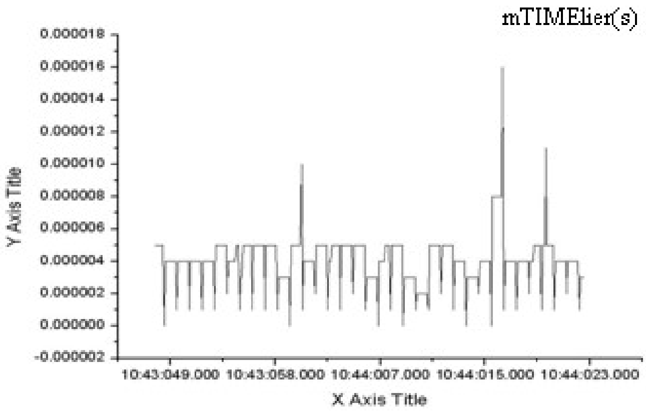

Figure 6 Results of the AFDX network delay for one test aircraft

CONCLUSIONS

This paper introduces the puzzle that measures the acquisition network delay for AFDX avionics system in modern flight test, analyzes the characteristics of AFDX avionics system, and proposes a method of the AFDX time message delay measurement and implements it. This method solves the problem that unable to measure the acquisition network delay of the avionics system without timestamp in AFDX frame. We have already measured the AFDX acquisition network delay on one test aircraft and the experiments demonstrate that the method improves the testing calculation precision of AFDX avionics system.

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