Research on 1553B Airborne Data Bus Technology

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Abstract. 1553B data bus is a very important airborne bus in military aircraft, and is the pillar of joint avionics. Even in advanced integrated avionics system, 1553B data bus is also used as part of the subsystem bus. This paper mainly introduces the basic structure, communication control and transmission data format of 1553B airborne data bus, and expounds its characteristics of time division command and response multiplexing.

Keywords: 1553B Data Bus · Communication Control · Transmission Data Format

1 Introduction

The airborne computer plays an important role in the aircraft avionics system and it needs to complete the functions of decoding, scheduling, management, control and others. Neither an independent airborne computer based on black box mode nor a high-performance advanced airborne computer based on common function modules can exist independently. It must receive the information of relevant sensors or systems, and transfer settlement data and control information to other airborne computers. The channel transmitting information just is the airborne data bus. If the airborne computer is likened to the brain of the avionics system, the airborne data bus is the nerve of the system. The airborne data bus is the common data channel connecting various types of airborne equipment. The connection between aircraft's various equipment and the system connection are attributed to the bus channel, through the airborne data bus each equipment can carry on the orderly information transmission, so as to realize the information synthesis and function synthesis.

The 1553B airborne data bus is currently the most used bus for military aircraft. 1553B bus mainly adopts time-division multiplexing and instruction response system, which can not only realize the reliable transmission of information between multiple devices on a bus, but also enable each device hanging on the bus to send and receive data. The data transmission bandwidth of 1553B bus reaches 1 Mbps. The more prominent feature is its scalability. If you want to increase a data transmission in the system, as long as the bandwidth allows, there is no need to add additional hardware transmission lines. 1553B bus plays an important role in avionics network. It is the pillar of joint

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avionics. It not only supports information transmission between subsystems, but also provides reliable technical support for realizing unified information scheduling in system layer [5].

2 1553B Bus Basic Structure

The 1553B bus uses a half-duplex transmission mode, allowing data to be transmitted in both directions, but at a certain time, only allowing data to be transmitted in one direction, is actually a kind of directional switching simplex communication. All subsystems are attached to the bus, and data from any one subsystem travel along the bus. According to the different functions of each subsystem, the terminals attached to 1553B bus are divided into three types: bus controller (BC), remote terminal (RT) and bus monitor (BM). The structure of 1553B bus is Fig. 1.

2.1 Bus Controller (BC)

Bus controller (BC), the controller and manager of the bus, as well as the initiator of all communication actions, is the only terminal on the bus designated to perform the task of initiating information transmission. There is only one BC at any one time. For example, it issues data bus commands, participates in data transmission, receives state responses and monitors the state of the system, and controls and mediates the data bus.

2.2 Remote Terminal (RT)

Remote terminal (RT) is an interface between a subsystem and a data bus that helps the subsystem receive or send data from the bus. For example, data exchange between inertial computer and data bus requires this terminal RT, which transmits data under the control of BC and responds to the command from BC. Each RT must have a unique address.

2.3 Bus Monitor (RT)

Bus monitor (BM), which monitors or selectively extracts information transmitted on the bus to complete the recording and analysis of data sources on the bus. BM only listens to messages from the bus, has no ability to send data, and does not participate in communication [3].

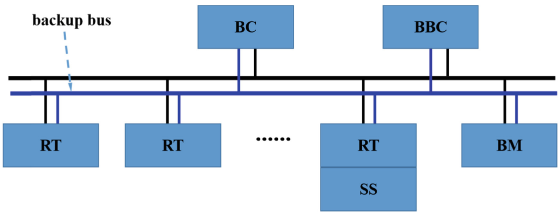

Fig. 1. 1553B bus structure.

2.4 Structure Format

In order to facilitate the system's universality and make the bus controller BC, remote terminal RT and bus monitor BM have flexible substitutability in the work, the three devices are usually designed as standard function modules. However, BC does not need such functions as state word formation, while BM does not need sending and subsystem control functions.

In order to ensure the reliability of 1553B bus, double redundancy fault tolerance is generally adopted. The standby bus is added on the basis of the main bus, which is in hot backup state. The communication state monitoring and switching logic of master bus and backup bus are realized by bus controller. Secondly, a backup bus controller, BBC, is set up in the structure as the redundancy backup of BC. BBC monitors BC, and when it breaks down, the BBC takes over.

When the number of connected terminals on the bus is not large, the single-bus dual redundancy structure is generally adopted. However, when the number of terminals connected to the main bus exceeds 31, the structure of multiple buses should be adopted, and each bus adopts redundancy configuration respectively. Each bus has its own BC and has no dependencies with each other. Take the avionics system of F-16C/D aircraft as an example, the A and B buses are parallel structures. Two bus controller terminals are embedded in the fire control computer, serving as BC of A bus and B bus respectively and the data of the two buses can be coordinated through the two BCs. And the plug-in management processor acts as the backup bus controller.

3 1553B Bus Transmission Control

3.1 Periodic Task Transmission

Each subsystem usually sends data to other subsystems at a certain data update frequency. Subsystems have different update frequencies with different functions and importance. The period that updates the slowest data of all subsystems attached to the bus is called the large period and the fastest one is called a small period. After proper adjustment, a large period is divided into $N = 2^n$ smaller periods. Then, the least frequently updated data is transferred once in a large cycle and the data with the highest update rate is transferred once every small period. This ensures that all periodic data transfers occur at least once in a large period. The subsystem data transmission cycles are listed, and the table written in columns is called the bus communication table. In the actual data transmission process, BC only needs to start the corresponding data transmission periodically according to the period in the bus communication table.

3.2 Multitask Transmission

When two or more cycles of data occur at the same point in time, the bus controller adopts a queuing method to control the transmission of multiple data at the same point in time. Prioritize multiple transmissions at the same point in time during data transmission, BC starts data transmission one by one in the arranged order. This queuing method can solve the problem of sending multiple data at the same point in time.

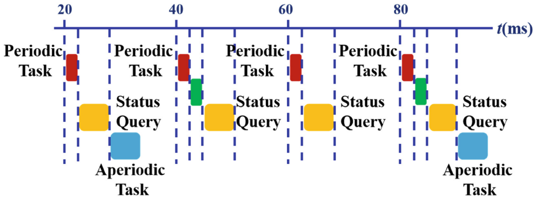

Fig. 2. 1553B bus transmission control.

3.3 Aperiodic Task Transmission

In a bus system, in addition to transmitting periodic data, there are also some aperiodic data to be transmitted. In each small period, when the periodic transfer task is complete, there is some idle time. In order to avoid wasting bus time, the idle time is used to complete aperiodic data transfer. Insert an asynchronous request status queries action in the idle time of the period. If the asynchronous request is queried, an aperiodic data transfer is performed. If the asynchronous request is not queried, no data transfer is performed. In this case, the query asynchronous request is made every period, and execution depends on whether event data occurs [1].

The 1553B bus transmission control is in Fig. 2.

In the transmission control of 1553B bus system, for the transmission task of periodic data, BC uses the bus communication table to start the transmission task periodically. When there are multiple transmission tasks at the same time, the queuing strategy is used to process them. The idle time during the cycle is used to transfer aperiodic data.

In this way, in a large cycle, all terminals on the bus are queued in a centralized manner to ensure that only one line of data is transmitted on the bus at a certain time, and all kinds of terminal data are queued up on the bus in an orderly way.

4 1553B Bus Transmission Protocol

The basic unit of data transfer between terminals on a bus is the message. A message is an ordered collection of 1–32 words, each of which is 20 bits long. The Manchester II code is used for the word encoding [4].

4.1 Manchester II Code

Manchester II code coding rules: each bit period in the middle of a jump (polarity conversion), binary “0” represents a negative level to positive level jump; the binary “1” represents a positive level to negative level jump.

4.2 Word Format

1553B includes three types of words, namely instruction word, data word and state word. The length of the word is 20 bits, including 3 synchronization headers, 16 bits of information, and 1 bit parity.

4.2.1 Data Words

Data words are used to transfer data between avionics subsystems. For example, the atmospheric data of altitude, speed, angle of attack and temperature are transmitted by the atmospheric data system, as well as the attitude heading, acceleration, speed, position and other information are transmitted by the inertial navigation system and these data must be organized in the format of data words. The format is in Fig. 3.

There are three synchronization bits to distinguish word types, a parity bit, and 16 data bits in the middle to transmit useful information. The synchronization header of the data word is an invalid Manchester code waveform. When the width is three bits, the waveform of the first 1.5 bits is negative and the waveform of the last 1.5 bits is positive. The 16 data bits are uncertain according to the content to be transmitted by the subsystem. Ane the parity bit adopts odd parity. Data words can be sent and received by any terminal, including the bus controller can also send and receive receipts.

4.2.2 Instruction Words

The instruction word can only be issued by the bus controller BC. The synchronization header of the instruction word is also an invalid Manchester code waveform, occupying the first three data bits. The waveform is positive for the first 1.5 bits and negative for the last 1.5 bits. An instruction word consists of four fields besides synchronization and parity, two basic data bits. The format is in Fig. 4.

The terminal address is the unique address corresponding to each terminal connected to the bus. Since the terminal address is represented by a 5-bit binary number, the address range in binary is from 00000 to 11111. (The common address 00000 is not used as the exclusive address of the remote terminal. Therefore, a maximum of 31 remote terminals can be connected to the 1553B bus. The remote terminal responds only to the information that identifies its own address on the bus.)

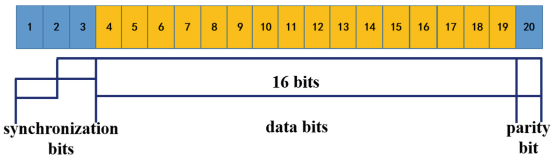

Fig. 3. Data words format.

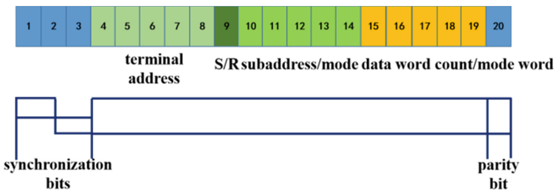

Fig. 4. Instruction words format.

The sending and receiving bits specify the direction of the information flow. The logical 1 indicates that the RT is to send data, and the logical 0 indicates that the RT is to receive data.

The third field is subaddress/mode, which commands a subaddress of the terminal to send or receive data. If the value of this field is between 00001 and 11110 (1 to 30), command a subaddress of the terminal to send or receive data, that is, specify which cache of the terminal is associated with the transmitted information. If the value of this field is 0 or 31, it indicates that the instruction is a mode operation instruction, which does not initiate data transfer, but commands the terminal to perform a specified operation.

The fourth field is the data word count/mode word, which is a reuse field that represents the number of data words or the mode code. If the subaddress is selected in the subaddress/mode field, this field specifies the number of data words. The 1553B can transmit up to 32 data words. If the mode instruction is selected, this field carries the mode code, which tells you exactly what operation to do.

4.2.3 Status Words

A status word can only be issued by a remote terminal in response to a command issued by the bus controller. After receiving a command, a status word must be sent back to the bus controller to represent a current working state of the remote terminal. The format is in Fig. 5.

The first three bits of the status word are synchronization headers, which act like synchronization headers for function with instruction words. Since the state word and the instruction word are transmitted in opposite directions, there is no confusion. The definition of the terminal address is consistent with the definition of the terminal address in the instruction word. When the remote terminal detects that the message it receives is invalid or an invalid instruction, the message error bit is set to "1" as part of the status word. The test bit is an optional bit and the state is always logical 0. The test bit is an optional bit and the state is always logical 0. The next field is the service request. Since the status word is sent by the remote terminal to the bus controller, the position is logical "1" when the remote terminal needs service. (This bit is used only to stimulate data transfer operations that occur randomly rather than periodically.) In 1553 b bus system, the each remote terminal has its own an address, when sending data bus controller is in accordance with the address to send, we can understand as the bus controller and remote terminal one-on-one. The receive broadcast bit is used to indicate that the last instruction received by the remote terminal was a broadcast instruction word.

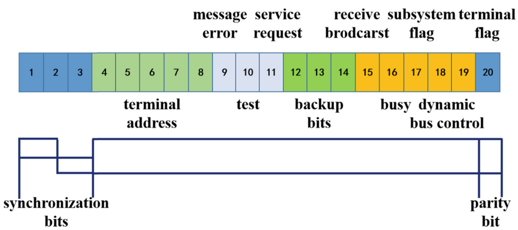

Fig. 5. Status word format.

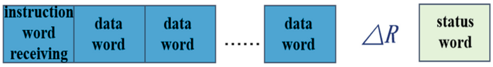

Fig. 6. The formats of general message BC → RT.

When the system is in broadcast mode, this is logical "0". (Broadcast mode allows a bus controller or a remote terminal to send messages to multiple remote terminals) If this bit is logical 1, it indicates that the remote terminal is busy and cannot move data into or remove data from the subsystem as required by the bus controller. The subsystem flag bit is used to indicate to the bus controller that there is a subsystem failure state and to tell the BC that the data provided by the remote terminal may not be valid. The dynamic control bit is logical 1, indicating that the remote terminal receives dynamic control. If the terminal flag is logical 1, it indicates that the remote terminal may have an internal fault.

4.3 Message Format

In 1553B bus system, all data transmission is organized in the form of messages with a maximum length of 32 words. 1553B messages can be divided into three categories: general messages, broadcast messages, and maintenance and management.

4.3.1 General Messages

General message is the data transmission between subsystems. According to the different transmission objects involved, it can be divided into three kinds: BC → RT, RT → BC, RT → RT.

BC → RT
Data transmission message format BC → RT from bus controller to remote terminal. In this message, the bus controller first outputs a receive instruction word to the remote terminal. The instruction word contains the address of the remote terminal to receive the message, that is, which terminal to receive it. Then it sends (1–32) a certain number of data words without interval. After receiving the instruction word and data word, the remote terminal sends back a status word to the bus controller within a fixed interval of 4–12 µs for the bus controller to judge the correctness of message transmission. The formats of general message BC → RT is in Fig. 6.

RT → BC
In the message from the remote terminal to the bus controller RT → BC, the bus controller first sends a sending instruction word, which must contain the unique address of sending information RT, and then within the specified time interval (4–12 µs), the remote terminal must return its status word and the specified number of data words. The bus controller determines the correctness of data transmission according to the received state word. Similarly, there is no time interval between the state word and the data word. The formats of general message RT → BC is in Fig. 7.

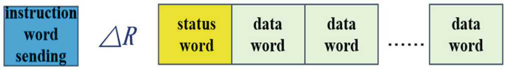

Fig. 7. The formats of general message RT → BC.

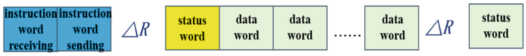

Fig. 8. The formats of general message RT → RT.

RT → RT

The third message format of data transmission is the way from a remote terminal to another remote terminal. The transmission of data on bus is controlled by the bus controller. When two terminals for data transmission, the bus controller sends a receiving instruction word to the receiving terminal first, and then continuously sends instructions to sending terminal a sending instruction. When the sending terminal receives the command word, it must transmit the status word and all the data words that it is required to send on the bus. When the receiving terminal receives the specified number of data, it returns a status word to the bus controller. This is the way of completing the message transmission between the two terminals. The formats of general message RT → RT is in Fig. 8.

4.3.2 Broadcast Messages

Broadcast message, which is a high transmission efficiency of information transmission, allows the bus controller or a terminal to send messages to multiple remote terminals. Broadcast message format and general message format are basically the same. The difference is that in the instruction word "terminal address" is all set to logic 1, and this address is the secondary system used to broadcast message transmission. In addition, the number of remote terminal for receiving information is bigger. Receiving broadcast messages of terminal is prohibited to send status word, so that you can avoid to receive broadcast messages. All terminals sending status words at the same time clog the bus. However, when transmitting broadcast messages between remote terminals, the sending terminal must return a status word [2]. The formats of broadcast message is in Fig. 9.

4.3.3 Maintenance and Management Messages

The third type of message is maintenance and management message, which is mainly used for the bus controller to manage the information flow and related hardware in the system. Maintenance and management messages are basically the same as general messages, starting with an instruction word. The terminal receiving the command word should feedback the corresponding status word and data word. Different from the general message is the number of data words and there can be no data words, there is only one at most. Maintenance and management messages are issued by setting the sub-address of the instruction word to all ones or all zeros, and the specific instruction information

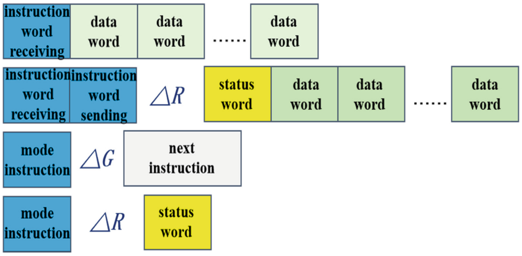

Fig. 9. The formats of broadcast message.

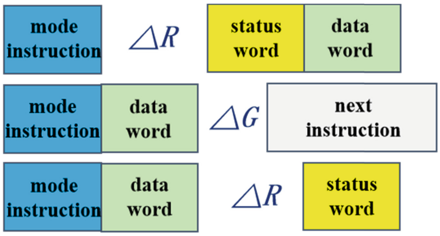

Fig. 10. The formats of maintenance and management message.

will be indicated by 5 bits in the data word count field. The formats of maintenance and management message is in Fig. 10.

Messages transmitted on the 1553B bus system begin with an instruction word, followed by a status word and a data word. The instruction word is issued by the bus controller, which can organize the transmission of information. So either to transmit data or to command a remote terminal to perform an operation, it first sends an instruction word. At this time, all remote terminals will detect the instruction word, and when receiving the effective and matched with their own address, they will send back a status word to the bus controller, and complete the operation according to its requirements, that is, give a response according to the requirements of the instruction. This corresponds to another key word in 1553B bus instruction/response.

5 Conclusions

Since the 1970s, 1553B bus has been successfully used in a variety of military aircraft. It is the communication cornerstone of the joint avionics system, which is used in F-16, F-18 and other aircraft in the United States. Even in the most advanced aircraft such as F-22 and F-35, which advocate integrated avionics, 1553B bus is still used in subsystems such as aircraft management and add-on management. In addition, it is also used in the space shuttle, warships, tanks and many other applications. The 1553B bus has the features as follow.

- The 1553B bus has the good real-time performance.
  The transmission rate of 1553B bus is 1 Mbps, each instruction contains up to 32 words, and it takes a short time to transmit a fixed message. Data transfer rate is higher than normal communication network.
- The 1553B bus has the reasonable and effective transmission control.
  1553B bus system adopts instruction/response transmission operation mode, and all message transmission on the bus is controlled by the instructions issued by the bus controller, which is suitable for centralized distributed avionics system. The special mode instruction can not only enable the system to complete the task of data communication control, but also check the fault and complete the fault tolerance management function.
- The 1553B bus has the good reliability and security.
  In 1553B bus system, no matter what kind of passage or processing method is adopted, the time involved in the process of processing, or even each bit of each word, is to be done in the overall design process of the system. And this design in the present situation, uses a static setting method. It is not allowed to happen by the dynamic situation so it is in line with the security, reliability consideration.

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