A WIRELESS NETWORK-BASED RFNET SOLUTION FOR FLIGHT TEST

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ABSTRACT

An rfNET solution based on IEEE 802.11 wireless network is presented to perform one-way remote transmission of airborne instrumentation data and multi-channel video images in flight test by modifying the wireless network bridge and UDP protocol. Its architecture and structure is introduced briefly and the results of ground transmission test and flight demonstration transmission are provided. It also points out the major problems of this solution for engineering application and their solutions.

KEY WORDS

Flight Test Telemetry Wireless Network IEEE 802.11 IRIG-106 iNET vNET rfNET

INTRODUCTION

Remote transmission of airborne instrumentation data and video images in flight test is one of the critical techniques researched all the time in flight test community. For decades, the American telemetry standard IRIG 106 has been commonly used in the world. Data are transmitted in PCM （Pulse Code Modulation）format in S or L band. The technique is complex, the equipment used are expensive and the transmission rate is limited, which can no longer satisfy the increasing requirement for transmitting instrumentation data and video images in flight test.

In resent years, telemetry transmission in flight test is developing toward network with the development of wireless communication. The concept of INET (Integrated Network Enhanced Telemetry) was proposed and relevant research has been carried out internationally. INET is composed of three major parts: vNET (Flight Vehicle Data Acquisition Network), rfNET (RF Telemetry Transmission Network) and gNET (Ground Data Network). Among them, vNet and gNET are developing faster while rfNET is still in the stage of research and test.

An IEEE 802.11 wireless network-based rfNET is presented hare to perform one-way remote transmission of airborne instrumentation data and multi-channel video images in flight test by modifying the wireless network bridge and UDP protocol. Satisfactory results were achieved in both ground transmission test and flight demonstration transmission.

WIRELESS NETWORK-BASED RFNET SOLUTION FOR FLIGHT TEST

The rapid development of wireless network has attracted great interests in the international telemetry community. The IEEE 802.11b subject has been set up successively for years in the International Telemetry Symposium to study and discuss the application of wireless network in flight test and satisfactory achievements have been achieved. The findings presented in many papers show that wireless network is applicable to the transmission of flight test data from some high-speed moving targets such as aircraft..

Based on the current one-way transmission of telemetry data from aircraft to ground in flight test, a new concept and its solution are proposed for one-way remote transmission of airborne instrumentation data and video images with IEEE 802.11 wireless network equipment and by modifying UDP protocol

The wireless network-based rfNET system for flight test is composed of an airborne part and a ground part. The airborne part includes a data acquisition unit with network output function, an image acquisition unit, a wireless network bridge, a power amplifier and a transmitting antenna. The ground part includes a high-gain directional wireless network antenna, a wireless network bridge, an exchange and a computer. The block diagram of the solution is shown in Fig. 1.

From the viewpoint of computer network system, there is no difference between the solution shown in Fig. 1 and a wireless network system. It is a simple point-to-point transmission system. Its differences from a wireless network are as follows: Firstly, the wireless network bridge and UDP protocol are modified to accomplish true one-way transmission both in physical link and transmission protocol. Secondly, a power amplifier (8W) is added behind the airborne wireless network bridge and an S-band airborne telemetry transmitting antenna is used. A wireless network high-gain directional antenna is used in the ground receiving part to ensure the transmission range required in the current IRIG 106 standard. The third point is that its operating band can be IRIG 106 L or S band for flight test, or even the future 5G band, in stead of the band specified in IEEE 802.11b only.

From the viewpoint of telemetry system, the major difference between the solution shown in Fig. 1 and an IRIG 106 telemetry transmission system is that data are no longer in PCM format. Neither PCM encoded output is required for the airborne data acquisition unit nor expensive PCM synchronizer, demodulator and telemetry front-end equipment are required on the ground. The data format complies with the network standard. Flight test data can be processed with a general-purpose computer network and proprietary software. Furthermore, it can perform the remote transmission of airborne instrumentation data and video images from multiple channels.

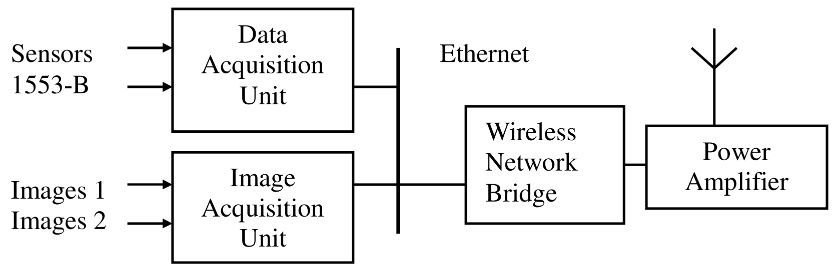

Fig. 1a Block Diagram of the Airborne Part of the Wireless Network-based rfNET for Flight Test

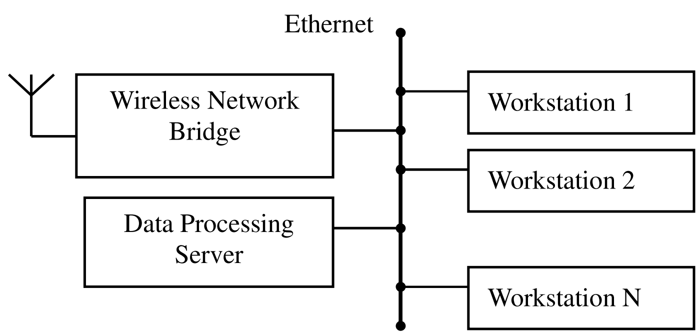

Fig. 1b Block Diagram of the Ground Part of the Wireless Network-based rfNET for Flight Test

The first point is one-way transmission. It is known that wireless network is bi-directional. Even in UDP mode, the receiving end is required to send a request for data transmission and the information about the data received to the transmitting end, which is actually bi-directional. To perform true one-way transmission, UDP protocol must be modified accordingly when the physical link does not support bi-directional transmission.

The solution to this issue is to remove the original receiving function from the transmitting end. Because a one-way transmission system is of a 4-layer structure, it is impossible to remove the data packet received from the network layer and the application layer according to the definitions of OSI network model. So, we have eventually removed the data packet from the WLAN drive layer and the hardware layer to accomplish one-way transmission. We must mask the transmission function at the receiving end. However, when data is received, the hardware layer will automatically generate ACK to advice the transmitting end of it, which is against the requirement for one-way transmission. So, we have to mask the ACK sending function in the hardware layer. Without ACK, the transmitting end will re-send the data packet continuously. Therefore, the function for re-sending and waiting for ACK timeout must be masked in the transmitting end. Also, we have changed the rate at the transmitting end. The rate is controlled so that the system sends data packet at a constant rate.

Test and measurement show the modified UDP protocol can perform true one-way transmission at a stable data rate. So this problem is solved satisfactorily.

The second point is transmission range. To increase the transmission range and reduce the interference from other wireless networks in the vicinity of the test range, a high-gain and powerful directional antenna is used in the ground wireless network station and a power amplifier (8W) is used in the airborne part so that airborne network data are transmitted remotely.

METHOD FOR GROUND TEST AND FLIGHT DEMONSTRATION AND THEIR RESULTS

A ground test of the solution mentioned above was performed. For the test, the modified wireless network bridge, an 8W power amplifier and an S band telemetry transmitting antenna (0db gain) were used at the transmitting end to form a vehicle-borne wireless network mobile station and simulate aircraft moving nodes. A high-gain directional wireless network antenna (24db gain) and a wireless network bridge were used at the receiving end. The operating frequency was the wireless network Channel 1 (2412MHz) near S band. Transmission was performed with the modified one-way UDP protocol and in point-to-point mode. Test and measurement showed that one-way transmission could be accomplished in the visual range. The maximum transmission rate was up to 6Mbps. A 24km fixed visual point was selected for the test. Firstly, stable transmission of one-channel airborne instrumentation data and one-channel image data was accomplished by adjusting the antenna direction. Then, the transmission efficiency was recorded and monitored by attenuating the transmitting power at the receiving end. The transmission range in flight test was also estimated. The test results are given in Table 1.

Table 1 Results of Ground Test

Receiving Efficiency	No Loss of Data Packet (No Loss of Image Frame)	Major Loss of Data Packet (No Image Display)
Transmission Contents	1-Channel data + 1-Channel Images	1-Channel data + 1-Channel Images
Transmission Rate	2Mbps	2Mbps
Transmission Power	8W ~ 8W-12db	8W-13db
Transmission Range	24km	24km

It was estimated with the results of the ground test that the transmission range could be up to 200km when the aircraft is flying at 10km altitude.

When the ground test is satisfactory, we made a flight demonstration together with other flight test tasks. The specific implementation is that the transmitting equipment used on the vehicle-borne wireless network mobile station was removed and installed on a test transport airplane with a transmitting antenna mounted on the front lower body of the airplane. The ground receiving equipment is identical to that used for the ground test. Manual tracking of the airplane was made by the test personnel according to the GPS information received through telemetering from the test aircraft. The results of the flight demonstration when the aircraft was flying at 8000m altitude are shown in Table 2.

Table 2 Results of Flight Demonstration

Receiving Efficiency	No Loss of Data Packet (No Loss of Image Frame)	Major Loss of Data Packet (No Image Display)
Transmission Contents	1-Channel data + 1-Channel Images	1-Channel data + 1-Channel Images
Transmission Rate	2Mbps	2Mbps
Transmission Power	8W	8W
Transmission Range	202km	208km

The results of the flight demonstration proved that both the transmission rate and the transmission range of this solution satisfy the IRIG 106 standard which is commonly used for flight test at present.

MAJOR PROBLEMS FOR ENGINEERING APPLICATION AND THEIR SOLUTIONS

There are some technical problems to be solved for engineering application of the solution mentioned above.

The first one is the frequency band to be used. The frequency band (2400 to 2483MHz) specified in the wireless network protocol can not be used to perform the high-power remote transmission in IEEE 802.11b wireless network protocol. The solution to it is to change the frequency of the existing IEEE 802.11b wireless network bridge (card) and the wireless network receiving equipment to the S band（2200 to 2400MHz）used currently for flight test. S band is adjacent to the frequency band of IEEE 802.11b wireless network. The technique for frequency change is matured and easy to accomplish. It can also be changed to the new 5G band for flight test.

The second problem is the tracking of flying target. It can be solved by means of the current telemetry automatic tracking or GPS tracking. For a single aircraft, one high-gain directional antenna can be used for automatic tracking. For multiple targets, multiple high-gain directional antennas can be combined to form a high-gain omni-directional antenna. This technique is also relatively matured.

The third problem is the data loss for some high maneuverable and high-speed moving nodes such as fighters. This problem has been solved by rational combination and configuration of multiple transmitting antennas for telemetry data transmission in S band, which can be used in this solution.

The last problem is the security of data transmission which has also been solved in the application of wireless network. The security of data meets the requirement for the transmission of flight test data.

CONCLUSIONS

The wireless network-based rfNET concept and technical solution for flight test are completely feasible through ground test and flight demonstration. It is not difficult to solve the problems for engineering application. This solution gives a new way for remote transmission of instrumentation data and video images in flight test and changes the current telemetry transmission mode with IRIG 106 standard and in PCM data format. It simplifies the equipment used for the transmission of airborne instrumentation data and images, thus lowering the cost. It is especially suitable for the transmission of airborne instrumentation data and images in large transport airplanes and aircraft with existing network data systems.

Also, it should be pointed out that network technology is an integral strategic guide. The ground telemetry data processing system has been implemented in network and the airborne instrumentation system is developing towards network. It is also an inevitable trend for the transmission of airborne instrumentation data and video images to the ground by network. INET enjoys a promising prospective.

REFERENCES

[1] Bai Xiaoxian, "Network-based Flight Test Instrumentation System and Its Application", Instrumentation and Control Technology, Vol. 2, 2004

[2] William T. Kasch " Performance of the IEEE 802.11b WLAN Standards for Fast Moving Platforms" ITC 2003 USA

[3] Mei Y.Wei "Tracking Multiple Airborne 802.11b WLAN To Extend The Internet to Aircrafts in Flight", ITC 2003 USA

[4] Kip Temple(Air Force Flight Test Center), "An Airborne Network Telemetry Link", ITC 2006 USA