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FTI Wireless DataBuses Interface

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Abstract

The objective of this paper is to present the evaluation of feasibility of a wireless system for acquiring, recording and monitoring Databuses for flight test instrumentation and the production of a prototype capable of performing these tasks.

Three main phases have been tackled:

-Feasibility study phase: study of feasibility of the wireless technology applied to the acquisition of the common Databuses required for flight test. The result of this study would be the identification of the Databuses which are suitable for wireless management.

-Hardware and firmware architecture definition phase: the definition of the hardware and software architecture of the wireless system that would implement the acquisition of the Databuses identified.

-Prototype production phase: the manufacture, program and configuration of a prototype system that complies with the previous architecture.

Key words: Wireless, Databus, Instrumentation, Flight Test, FTI.

Wireless Application in Flight Test Instrumentation.

In this paper when speaking about wireless applications in Flight Test Instrumentation (FTI) it is referred to installations devoted to the measuring and acquisition of data in an aircraft when is instrumented for a flight test campaign using pieces of equipment that transmit the information in a wireless mode opposite to a wired one. Data gathered from instrumented aircrafts come mainly either form sensors or from databuses that interchange information between computers.

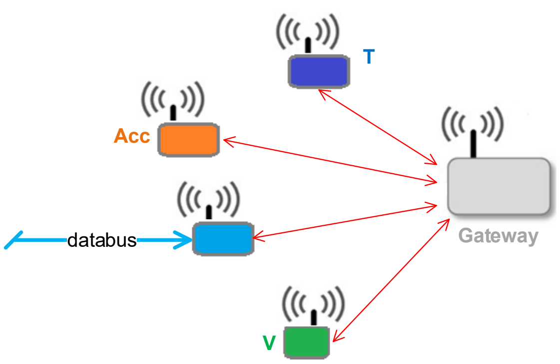

Fig 1 Wireless schematic system

During the last years the wireless technologies have been developing exponentially and their usefulness is being demonstrated in all fields. In the Flight Test environment it has been proven that they may be useful for the acquisition of certain analogic measurements referring to temperatures, voltages, and other discrete signals and there are in the market manufacturers of sensors like Lord Microstrain or BeanAir that transmit the information they sense in a wireless mode as depicted in the figure 1. But no studies or test have been conducted to determine the suitability and feasibility of acquire and transmit complex digital signals, like databus or streaming, being these abundant and widely used in the FTI of military and commercial aircraft, today is a field little explored, mainly due to the absence of specific hardware oriented to this matter.

The amount of data acquired in one flight test aircraft the quantity delivered in data buses is very high and increases every day more. As a figure, in the light and medium transport platforms the required instrumentation of data buses is of 20% of the total measurements but the parameters inside are of more than 85%. In the case of flights dedicated to evaluation for customers or in service anomalies the ratio is much higher being even of the 100%.

The wireless solutions have been demonstrated to have a positive impact in several aspects of the final FTI solutions either when using wireless sensors or for databuses wireless acquisition devices.

- Higher degree of wire reduction. Local acquisition of Databuses would reduce the wiring of a big quantity of parameters.
- Higher degree of autonomy. The FTI system would tend to a plug and play solution reducing the work load of a number of organizations.
- Higher reduction in the installation and uninstallation activities: reduction in the amount of documentation produced by the Design department and in the modifications in the aircraft.
- Reduction of time required to install and deinstall the FTI in the aircraft, with the associated impact in schedule.

Having into account the previous circumstance and that the aircraft systems are everyday more fitted with Databuses dedicated for flight test, having the capacity of acquiring this amount of data wirelessly would improve dramatically the advantages of a wireless FTI system.

Feasibility Study

The ARINC429 databus has been identified as the most suitable for been used in this prove of concept for being acquired by a wireless node.

For reaching this conclusion it has been identified and analyzed the most commonly required communication buses in FTI. In this way it has been summarized the different types and their main characteristics, evaluating the suitability to be acquired and transmitted wirelessly, taking into account the maturity and technological limitations existing in the current wireless transmission systems [Fig.2], as well as its current use in traditional flight test acquisition (wired).

DATA BUS TYPES

The traditional FTI wired installations of modern aircrafts includes tons of orange cables, many of them are dedicated to transporting communications buses to the FTI data acquisition rack.

The following are the bus or information transmission line types most commonly acquired in FTI by wired methods:

ARINC 429

Description

ARINC 429 implements serial line communication and was one of the first standards specifically targeted at avionics applications. Unlike in modern networking protocols, the sender always sends to the line, and the recipients always read from it. The number of maximum number of recipient is 20.

The bus can operate at low or high speed. Low speed uses a variable clock rate and a nominal throughput of 12-14 kbps, while the high speed mode requires a fixed clock rate and allows 100 kbps.

Transmission from the source LRU is comprised of 32 bit words containing a 24 bit data portion with the actual information, and an 8 bit label describing the data itself.

Impact in FTI

Surely ARINC 429 is the most frequently acquired bus in Flight Test, some A/C like A330 MRTT has around one hundred ARINC 429 lines acquired during flight test development, and therefore a wireless system to acquire these buses can contribute to reduce cost, works and weight into the FTI deployment.

CAN

Description

CAN Bus is a message based protocol, designed originally for multiplex electrical wiring within motor vehicles, developed by Bosch as an automotive data bus in 1983, but also can be used in many other contexts like A/C. The CAN-bus has emerged as a future technology, also known as ARINC 825. The CAN Bus can work at Low or High speed, The High-Speed ISO11898 Standard specifications are given for a maximum signaling rate of 1 Mbps with a bus length of 40 m and a maximum of 30 nodes. It also recommends a maximum un-terminated stub length of 0.3 m. The Standard defines a single line of twisted-pair cable with the network topology.

Impact in FTI.

The CAN Bus is used in modern aircrafts like A400M, but now the massive implantation of devices is low, two or three FTI bus lines not seems quite to justify a wireless system. Furthermore the high-speed modes get over the current wireless bandwidth performance, for this reason

CAN bus implantation and wireless bandwidth evolution must be kept and re-evaluated.

MIL-STD-1553B

Description

MIL-STD-1553, the *Aircraft Internal Time Division Command/Response Multiplex Databus*, is widely used in military aircraft. The standard was evolved from the initial data rate of 1 Mbps to the extended and hyper variants, which use newer hardware to offer 120 and 200 Mbps respectively. The MIL-STD-1553B has an extremely low error rate of 1 word fault per 10 million words, on a dual-redundant architecture. MIL-STD-1553B defines the interconnection of up to 31 remote terminal (RT) devices. The cabling defined is set of two pairs of twisted-shielded pair transmission line made up of a main bus and a number of attached stubs.

Impact in FTI

This bus is widely used in wired FTI acquisition systems, commonly a unique set of dual-pair connections is taped. The MIL-STD-1553B bus has a low fail-rate, redundancy and reliability defined in MIL-STD-1553 specification that seems difficult to meet with wireless systems, this together with the minimum bandwidth of 1Mbps does that this bus works too fast compared with the state of art of actual wireless systems.

RS232

Description

The EIA introduced the 232 standard in 1962 in an effort to standardize the interface between DTE and Data Communication Equipment (DCE). The communication typically begins with 1 start bit, 8 data bits, 1 stop bit. This is typical for start-stop communications, but the standard does not dictate a character format or bit order. The standard does not define bit rates for transmission, except that it says it is intended for bit rates lower than 20,000 bits per second. In the real word, and after more than 40 years of RS232 use and evolution is common use bit rates from 9,600 to 230,000 bits per second or more.

Impact in FTI

The maturity of this interfaces after half century in the market achieved that today we can see RS232 ports easily in most of the pieces of equipment inside or outside of aircrafts. FTI installations commonly include tapings of this ports, although it is not the most common, for against, the simplicity of protocol and relative low baud rates would be the feasibility for wireless interfacing.

RS422/485

Description

RS422 and R485 is similar standard differential port for serial communications. The main difference is that in 485 up to 32 transmitter receiver pairs may be present on the line at one time vs the 10 of 422.

Impact in FTI.

As RS232, the RS422/485 ports are easily present in most pieces of equipment inside or outside of aircrafts. FTI installations commonly include tapings of this ports, although is not the most common, for against, the simplicity of protocol and relative low baud rates would be the feasibility for wireless interfacing.

ARINC 664 (AFDX)

Description

Avionics Full DupleX Switched Ethernet (AFDX) is a standard that defines the electrical and protocol specifications (IEEE 802.3 and ARINC 664, Part 7) for the exchange of data between Avionics Subsystems. One thousand times faster than the old ARINC 429, it builds upon the original AFDX concepts introduced by Airbus. AFDX End systems, or LRUs communicate based on VLs (virtual links) with traffic shaping through the use of BAGs (bandwidth allocation gaps), which are the minimum intervals between transmitted Ethernet frames on a VL.

Impact in FTI

The AFDX Bus is used in modern aircrafts, today the massive implantation of devices in FTI systems is low, but surely in the future will be massive. In addition the base of Ethernet does that wireless technology could be easily implemented , however the bit rate increase fast over wired lines (1Gbit now), but wireless systems have limitations, consequently the application will be limited to low transfer rates or streaming lines like video given the latency.

See the following two tables summarizing the characteristics of the database analyzed before and the compilation of the state of the art of the more common wireless transmission protocols that could fit for this project.

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BUS	BANDWITH	FTI IMPACT	REMARKS	FEASIBILITY
ARINC 429	Max 100Kbps	Very high	Simply/Robust	Very high
CAN	Max 1Mbps	Low	Robust	Medium
MIL-1553B	1Mbps >	High	Redundant	Low
RS232	> 230Kbps	Low	Simply	High
RS422/485	> 230Kbps	Low	Simply/Robust	High
AFDX	>1Gbps	Low	Complex	Medium

Table 1. Bus Evaluation Table

TECHNOLOGY	AUTONOMY	BANDWITH	RANGE	SYNCHRO NIZATION	DATABUS ACQUISITION	BEHAVIOUR IN A/C	COMMON USE
ZIGBEE	Weeks	250Kbps	>100mts	32 μs	Candidate	Advisable	Commonly used for sensors and IoT connections
BLUETOOTH	Days	250Kbps	10mts	N/A	Discarded	Not recommend	
WIFI	Hours	From 1 to 10Mbps	100mts	30ms	Discarded	Not recommend	Commonly used for PAN. TCP/IP protocol.
ULTRAWIDE BAND	Hours	6Mbps	10mts	30ms	Discarded	Not recommend	Used for indoor applications

Table 2 State-of-Art suitable for instrumentation purposes

SUMMARY

Actually the state of art or wireless technologies focused to sensor networks and measurements handle bandwidths of about 250Kbps, some recent protocols out of IEEE 802.15.4 achieve some improvements and would reach theoretical bandwidths up to 1Mbps. With this maturity the feasibility of transmit by wireless the data buses commonly present FTI systems is limited first to the bandwidth.

Having into account the state of the art of the present wireless technologies and after the analysis of the different databuses more often used in instrumented aircrafts the optimal databus for evaluation of wireless feasibility is ARINC 429, as commented this bus is widely used and could be a substantial improvement to FTI systems.

The next candidates would be RS232-RS422/485, this not is widely used but in some conditions could be an advantage to install wireless, the maturity of wireless technology make it possible.

A special remark to AFDX networks, this could be investigated due to the proximity to Ethernet LAN Wi-Fi systems, some disadvantage like latency and others should be investigated, but could be possible the feasibility for limited environments, like Video Streaming or others.

Hardware and Firmware Architecture

The requirements for the system are described in the table below.

The architecture, figure 3, of the system has been selected in a node-gateway policy.

REQUIREMENT	TARGET	COMPLECTION
Nb of Bus	2 HS	1 HS
Global Bandwidth	512Kbit/s	250Kbps
Max latency	To be measured	To be measured
Max sampling per parameter	60%bus payload managing	100%
Battery restriction	Battery and external supply	Got
Autonomy	hours (no first objective)	Got (first prototype)
Transition retry protection	YES	Got
Storage at the sensor node level	NO	N/A
Storage at the receiving Gateway	YES	Started
Max nb of nodes	1 node as study concept	Got
Receiving node real time output protocol	IENA	Started (no difficult envisaged)
Storage format	RAW	Got
Time synchronization	PTP / GPS	PTP compatible
Time synchronization accuracy	32 µs	To be measured
Time stamping	YES	Got
Time stamping resolution & accuracy	1 ms	Got (by design)
Environment	N/A as study concept	Next Step
Dimension	Max 100X70 mm	90X40 (first prototype)
Antenna	Embedded as first target	Got

Table 3 Requirements and Complexion Status

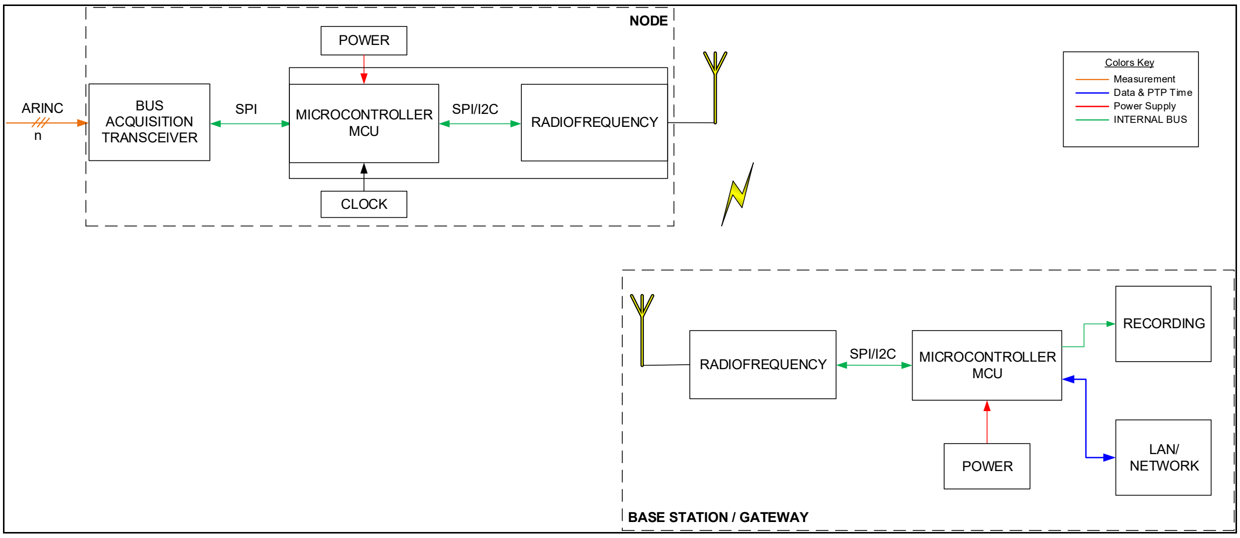

Fig 3.Wireless Node-Gateway Architecture

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In this probe of concept it has been defined one node and one gateway in the system but the quantity could be increased making profit of more transmission channels defined in the standard.

The node interfaces the ARINC429 databus and acquires, time stamps, processes and transmits the data to a base gateway where data is sent to recording and put available to be sent to the network in IENA format assuring total compatibility with other elements of the flight test instrumentation network. Additionally the gateway has two additional functionalities: the time is obtained from the network in PTPV1 protocol and managed to be sent to the node and signals of control, acknowledge and status between the base and the node are managed.

To comply with this architecture three main components are involved: the ARINC 429 transceiver, the microcontroller that manage the format translation, the data timestamping and the transmission protocol, the clock which drives the time stamp of the acquired data and the radiofrequency stage in charge of transmitting the data using the maximum possible, the optimum, bandwidth. There will be minor elements such us connectors or housing also important for future onboard requirements but not paramount now.

The interface protocols used for communication between the electronic components have been SPI and I2C, robust and widely used in this kind of electronic components and compliant with the requirements of the acquired signals and the instrumentation global requirements.

It has been selected the following elements:

- Arinc429 Transceiver. Manufacturer Holt Integrated Circuit with SPI interface.
- RF Tx-Rx Transceiver with microcontroller integrated. Manufacturer ATMEL 2.4Ghz AVR series with MCU integrated. This piece of equipment integrates the microcontroller and the radiofrequency part.
- Real Time Clock. Extremely accurate RTC with integrated crystal. Manufacturer MAXIM.

TRANSMITTING NODE

The transmitting node main functions are: data acquisition, data time stamping and data transmission.

The components are:

ARINC 429 Transceiver

The bus transceiver interfaces the ARINC429 bus. It acquires the bus and translate it into an SPI stream suitable for been manage by the microcontroller.

The transceiver supports different configurations. It is able of parsing, label filtering, the bus labels or can acquire the whole bus stream. The bus speed has to be configured.

The transceiver has the capacity of acquire one bus, either high or low speed bus, but in the market can be find other chips for acquiring different number of inputs.

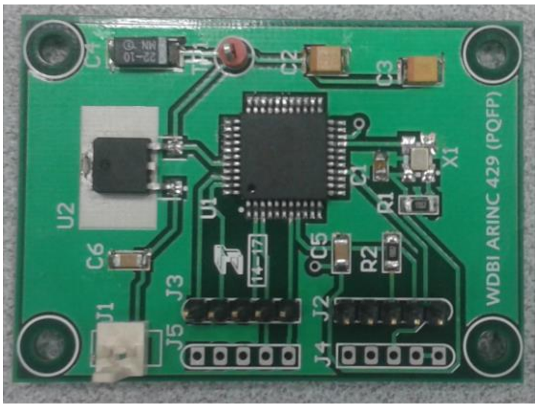

Fig 4.Node Mother Board Equipped

Microcontroller and RF

The SPI signal that caries the logical information of the bus is processed by the selected microcontroller.

The data processing, programmed in C language, enables the packetization of the data and its delivery to the RF stage.

Real Time Clock

The extremely accurate clock allows the system to synchronize or time-stamp events to a time reference that can be easily understood by the user.

This clock has been selected with a SPI interface due to the type of processor being used. The crystal oscillator is one of the most accurate circuits available for providing a fixed frequency, a 32,768Hz crystal is used for most RTCs. By dividing down the output of the oscillator, a 1Hz reference can be used to update the time and date. The accuracy of the RTC is dependent mainly upon the accuracy of the crystal. Tuning-fork crystals have a parabolic frequency response across temperature. This circuit manufactured by Maxim Integrated offer an error of 2ppm that is about 1 minute per year and is compensated in temperature with an integrated temperature sensor.

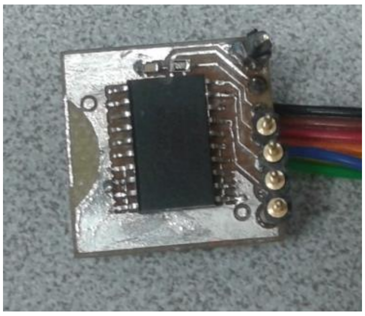

Fig 5.Clock

RECEIVING GATEWAY

The gateway main functions are: data reception, data recording, data distribution and time acquisition from the PTPV1 source.

The components are:

<u>Microcontroller and RF</u>

It receives the transmitted data and produce the data stream, in IENA format, that is going to be, in one hand, delivered to the network and in the other hand sent for recording.

<u>SD Recording Module</u>

A module for recording is available in the gateway in case no other recording device there is in the system. The recording is done in raw format.

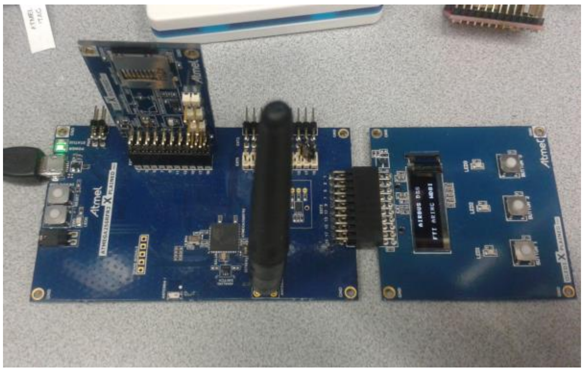

Fig 6.Gateway Mother Board Equipped

FIRMWARE

The data management: acquisition, transformation and processing, from acquisition from the ARINC429 source to the reception in the Gateway and recording in the SD card have been performed by programming both microcontrollers in C program language.

This is a complex task due to it requires a considerable long coding for controlling all the hardware elements involved system and the customization of some protocols and the composition of some data formats (IEEE, IENA, SPI, SD…).

Initially the ARINC429 data are obtained in its standard electrical levels. The levels are translated to TTL, which are electrical levels more suitable for the process of the following stage.

The microcontroller communicates with the ARINC429 transceiver and the clock using the SPI protocol:

- It obtains the data from the transceiver when are available in the bus.
- It obtains the time from the clock.

The following action is ordering and dating the data and their process in the proper format for transmission.

The final format, the structure of the message in the figure 7, contains not only the data and their acquisition time but also other relevant information for the transmission of the message and its identification in the gateway when received.

When the message is received in the gateway the contrary process is done: the frame is identified, its origin, it is processed and an acknowledge message is sent. After that it is translated in SPI protocol to be recorded in the SD card and in IENA format for delivering to the network.

It has also been implemented a transmission retry process for assuring the minimum lost o packets.

16	8	16	16	16	8	8	16	16	4	4	0/16	Variable	0/32	16
Frame Control	Sequence number	PAN ID	Destination Address	Source Address	Frame Control	Sequence number	Source Address	Destination Address	Source Endpoint	Destination Endpoint	Multicast Header	Variable	MIC	CRC
MAC Header					Network Header							Payload	MIC	CRC

Fig 7.Protocol Example

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Conclusion

This project is a proof of concept that has demonstrated the feasibility of having a wireless system able to manage data coming from databuses.

It is clear that there are a wide variety of uses cases in which having small footprint instrumentations based in wireless solutions can reduce the cost of the flight campaigns drastically, saving in several areas involved in the campaign.

From the production of this demonstrator to the time of this paper the availability of pieces of equipment that can manage data wirelessly have increase and the technologies involved have evolved equally having nowadays wireless hardware, designed and oriented to this applications, able to manage payloads of several Mbps.

In this context, it is worth continuing exploring this solutions and investing in their development.

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