WIRELESS TECHNOLOGIES TO BE USE FOR MEASUREMENT OF WING AERODYNAMIC CHARACTERISTICS

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Abstract. Measurement information system (MIS) is designed for performing measurements of wing aerodynamic characteristics. MIS consists of wireless sensors network (WSN) and a measurement processing device. The measurements of aerodynamic characteristics are usually performed in the wind tunnel where MIS is equipped. In particular cases it is purposeful to perform measurements during real flight that makes some difficulties in MIS integration into an aircraft.

Present paper describes a method for measurement of wing aerodynamic characteristics during flight. For this purpose MIS is designed with on-board integrated wireless sensors. For this WSN not licensed 2.4 GHz frequency band IEEE 802.15.4 standard is used Application of wireless sensors enables a person (who measures) to flexibly adapt to the particular measurement environment and to perform measurements of aerodynamic characteristics for a chosen part of an wing.

Keywords. wing, measurement information system, wireless sensors.

1 Introduction

The same flight safety requirements are applied to aircrafts despite their size and flight speed. The relevance of reducing such aircraft design, production and tests expenses maintaining the same level of flight safety is increasing due to the rapid development of low speed aviation. Whereas wing aerodynamic characteristics mostly cause aircraft flight features, it is extremely important to analyse wing aerodynamic characteristics in greater details [2, 3, 7]. Application of direct wing measurements results obtained from low speed aircraft design process in the aerodynamic tunnel is limited. The main reason is that unique complex measurements are necessary to perform in every wing case when various types of wings are used. Because of that it is purposeful to perform a part of aerodynamic characteristics measurements in real-time flight. To achieve this aim it is necessary to design a wing aerodynamic characteristic measurement system used in real-time flight.

In 1968 R.H. Johnson in his article “Sailplane Flight-Test Performance Measurement” proposed aerodynamic characteristics measurement in real-time flight method [4]. This system measures pressure difference between a dynamic pressure and a pressure induced by wing. In this case wing efficiency may be evaluated and wing section drag coefficient measured at point environment may be calculated as well.

The analogue measurement system proposed by R.H. Johnson, present measurement results in the cockpit instruments. In 2003 Sumon Kumar Sinha and Jim Hendrix started "The Deturbulator Project" [5]. During this project improved measurement system was used for measurements, while mechanical pressure measurement instruments were changed into electronic instruments. Using small pipes the measured parameter (pressure) from measurement point located on the wing to on-board sensors is being transferred.

While performing wing aerodynamic characteristic measurement the resolution was taken to improve J. Hendrix used system for designing the measurement information system (MIS), and to use wireless technologies to automatically collect measurement data. Furthermore, to increase a number of measurement points working at the same time is very purposeful too.

This project presents MIS will used for low speed (up to 300 km/h) aircraft wing aerodynamic characteristic measurements. In the second part of the article MIS conception, structural scheme and wireless technology selection are described. MIS equipment and data transferring protocol are presented in the third part.

2 Measurement information system

Measurement information system (MIS) consists of three main components (Figure 1): wireless sensor (WS) unit, wireless sensor network coordinator (WSNC) and data collecting and processing device (DCPD), i.e. a portable computer.

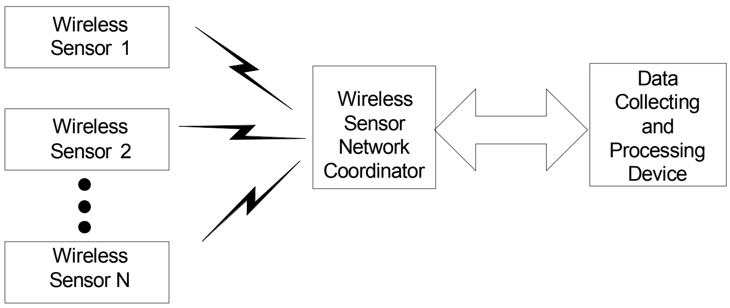

Figure 1: MIS structural scheme

The first MIS component will be equipped on the particular wing parts that will be analysed. WSNC and DCPD will be in the cockpit so that to ensure communication with all WS arranged on the wings (Figure 2)

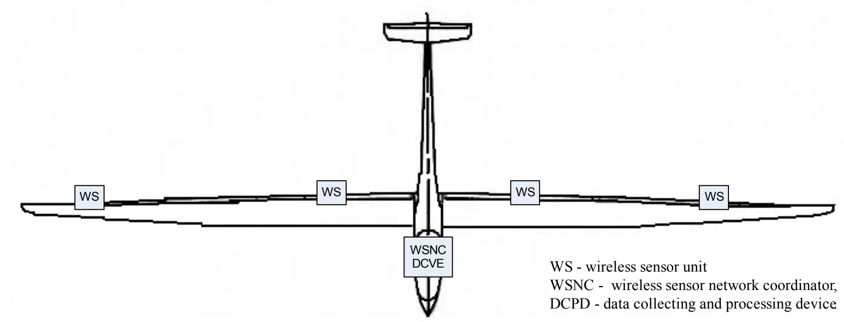

Figure 2: Arrangement of MIS components into an aircraft

A comparison of communication technologies and MIS design stages are presented below.

2.1 Communication technology selection

Different communication technologies are applied for wireless sensor network design:
The selection of communication technology is based on several factors. The first factor is a frequency range and necessary amount of energy used for keeping communication. The other factors causing technology selection are data transferring speed, protocol features, a number of controlled devices, communication module selection, and programme provision.
The following technological solutions - IEEE 802.15.1 (Bluetooth) [9], IEEE 802.15.4 (ZigBee) [10] and IEEE 802.11 (WLAN) [11] technologies (Table 1) at present widely used on the market were analysed for the MIS that is being designed. The technologies work in wireless communication industrial, scientific and medical (ISM) frequency band.

Table 1: Wireless technology review

Name	Range	Network topologies	Bit Stream (kbps)	Power	Band (MHz)	Module Dimensions (mm)	Target Battery life	Additional comments
Bluetooth	1-100 m	Ad-hoc, Point to point, star	24000	100 mW	2400	31x16x2,2	Days-months	Up to 7 Devices
WLAN	300 m	Mesh, ad-hoc, star	11000	100 mW	2400	10x10x1	Days	
ZigBee	Up to 400 m	Mesh, ad-hoc, star	250	30 mW	2400, 868, 915	28x18x2	6 months – 2 years	Up to 16 devices

Reviewing the above mentioned technologies, the ZigBee technology was chosen that enables to create high capacity wireless networks. The technology requires low energy consumption, sufficient data transferring speed (250 kbps) and not complicated data transferring protocol [10].

2.2 ZigBee General Characteristics and possibilities

ZigBee is a new communication standard for wireless personal area networks. It is optimized by low price, low energy need. Its data transferring speed (2,4 GHz 16 channels) reaches up to 250 kbps automation for data collecting and control systems. The ZigBee is targeted at direct sequence spread spectrum DSSS mixed mesh, stars and pear-to-pear topology networks that are linked by modulation. Nominal connection distance is about 10 m, but under direct visibility conditions the distance reaches 100 m and more. The ZigBee uses IEEE address of 64 bites and short address of 16 bites used for local addressing. The addresses enable to connect thousands of end devices into one network.

3 System description

Wing aerodynamic characteristics measurement system (WACMS) using wireless ZigBee technology is being designed. Figure 1 illustrates the system structural scheme using a star network topology. Every sensor with network coordinator can communicate directly or through other wireless sensor communication nodes that are in the network. Every system node will be described in the following chapter.

3.1 Wireless sensor conception and realisation

Functional scheme of the wireless sensor communication node consisting of sensor, interface and energy source is presented in Figure 3.

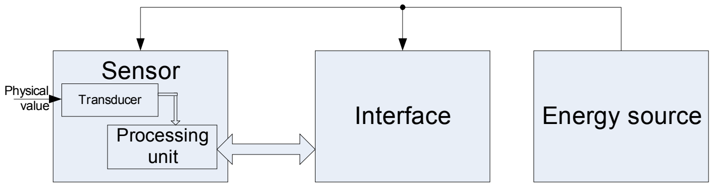

Figure 3: Functional scheme of the wireless sensor communication node

3.1.1 Sensor

WSCN sensor unit can be comprised of one or more sensors (temperature, pressure, etc) performing physical parameter changes with appropriate electric signal and signal processing unit that process signals (analogue figure transducer, DSP and other) taken from sensor.
We have chosen Integrated Silicon Pressure Sensor On-Chip Signal Conditioned, Temperature Compensated and Calibrated, dual of Ports Differential Pressure Sensor with piezoresistive transducer MPXV5004DP produced by *Freescale semiconductor* for our designed system [8]. These are the main sensor characteristics: supply voltage – 4,75 ÷ 5,25 V, pressure limits – 0÷3,92 kPa, sensitivity – 1 V/kPa.

3.1.2 Measurement data collection

Analogue signal is formed by a sensor. As a result output voltage is proportionate to pressure. To collect and transfer measurement results a flash of 64 KB memory and 8 bites, 1 KB EEPROM, CPU speed (MIPS) – 10, and ADC transducer of 10 channels and 10 bites, a *Microchip* microcontroller PIC18F2620 were used. Microcontroller will be used as an analogue-digital converter. Also the ZigBee protocol stack will be recorded to the microcontroller. Wireless sensor module will only transfer measured pressure value corresponding to voltage value.

3.1.3 Communication and wireless sensor module

Figure 4 shows structural scheme of the transmitter MRF24J40MA proposed by *Microship* ensures the ZigBee data transferring standard and is used for organizing wireless sensor network.

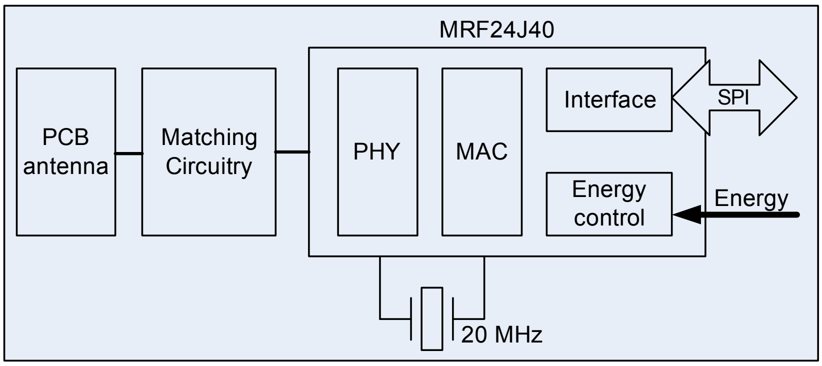

Figure 4: MRF24J40MA transmitter structural scheme [1]

As we can see from Figure 4, MRF24J40MA transmitter is composed of the controller MRF24J40 realizing ZigBee protocol standard, Serial Peripheral Interface (SPI), communication matching circuits and printed circuit board (PCB) antenna. BJRM structural scheme (Figure 5) is made by taking into account provided recommendations of MRF24J40MA module connection to microcontroller.

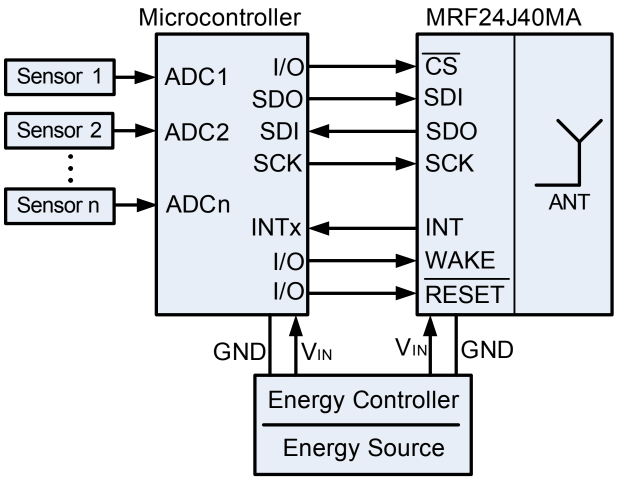

Figure 5: Structural scheme of wireless sensor communication node

WSM consists of sensors that may be connected to microprocessor, the ZigBee transmitter module and energy source.

3.1.4 WSN Coordinator and Data Visualisation

The network coordinator is being designed for WSN network control, measurement data collecting and transferring used for data processing device. The same ZigBee MRF24J40MA transmitter and PIC18F2620 microcontroller are used for WSN coordinator as it is given in Figure 6.

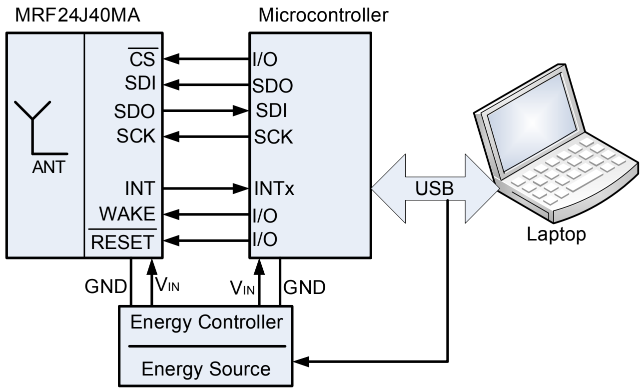

Figure 6: Wireless sensor network structural scheme

The USB interface was used for interface with a computer. While energy consumption of the coordinator that is being designed is very low (maximal usable current is about 50mA), the USB port is used as a power source.

3.2 Network topology and configuration

Star network configuration scheme was chosen for this project. Simple data transferring protocol was designed for network control and measurement data collection (
Figure 7). In the addressed WSN configuration a coordinator is an actuator and a wireless sensor is a controlled device that must wait for commands of the coordinator.

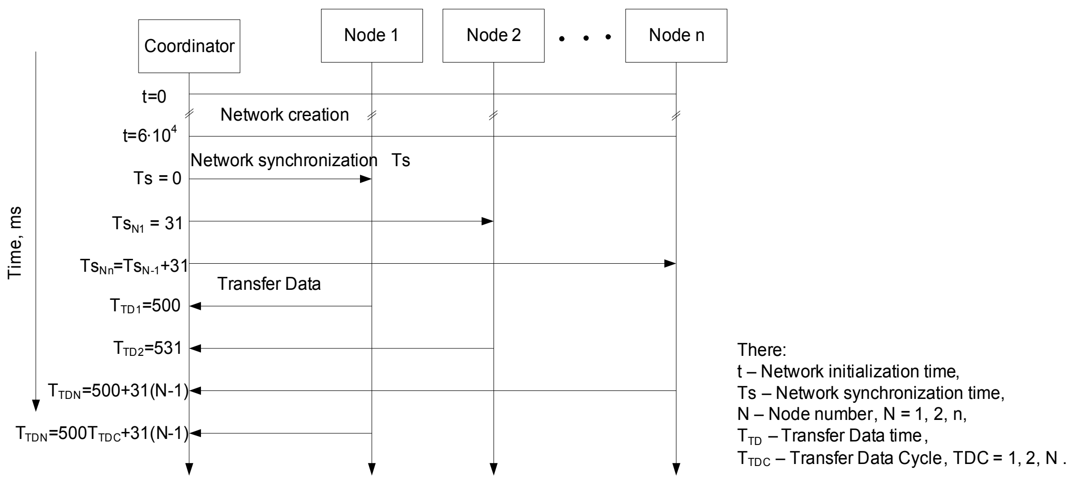

Figure 7: Network organization and data transfer time diagram

The organization of the network control consists of three steps: network creation, network synchronization and data transferring. Below every step is presented in detail.

1 step: when a coordinator starts a network is created (it takes about 50ms). Later in a period of 60 seconds wireless sensors that are being connected to the network are registered.
2 step: a coordinator synchronizes wireless sensors. Each sensor of the network coordinator receives synchronization signals every 31 ms. Also, after each sensor receives the synchronization pulse, every sensor starts calculating time intervals of 500 ms.
3 step: the coordinator waits for information provided by wireless sensors (in case of all 16 sensors are connected to the network, the coordinator receives the information in every 31 ms.)
Exception: in case when a new wireless sensors connects to the network in the process of data receiving, or a present sensor has already been restarted, the coordinator sends „STOP" command and starts a procedure of step 2. As a result, data collecting is being continued.
Stages of the wireless sensor are very similar. However, there are some differences: a network search is performed in indefinite period of time, and a time interval between connection and synchronization is not defined.
When synchronization time is known, every sensor sends measurement data for the coordinator every 500 ms. A sensor performs measurements between package sending. While data packages are being sent every 500 ms, the rest of the time a sensor uses stand-by mode. To increase a measurement precision, three measurement procedures are performed between data transferring procedures, and the arithmetical average of the measurements is transferred to the coordinator. This solution has allowed increasing a precision of the measurement results.

4 Conclusions

The wireless sensor network was considered one of huge influence high-technology produces in the 21st century. ZigBee is short distance wireless technology standard in view of application in sensor network, process control and so on, is the low power, low data rate, near distance and low cost wireless communication.
This paper presents a measurement information system (MIS) of the aircraft wing aerodynamic characteristics project based on wireless technologies. After analysis of wireless technologies for the MIS realization IEEE 802.15.4 ZigBee allowing having 16 end devices (wireless sensors) in one network was chosen. This wireless technology works in ISM frequency band.
For this project the star network topology scheme was chosen. The network control and the data control transferring protocol were designed as well. During experiments obtained network synchronization ant data transfer cycles times.

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