PROBLEMS OF CONTROL OF MINI UNMANNED AERIAL VEHICLE (MINIUAV)

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Abstract

It was introduced suggestions and results concerning some of control miniUAV problems in this article. They were formulated on base of theoretical and experimental investigations. Now the own construction miniature system avionics is being investigated. This system is designed to stabilisation of miniUAV and to control of navigation with GPS signal. Now system is used also as flight control recorder. The avionics control system which lets for very good and saved navigation miniUAV should be created. More over this system should use GPS signal and miniature sensors.

Especially, a block function diagram of a miniature avionics unit – miniBSP MSOP.= 3 accelerometers, 3 rate gyroscopes, static pressure sensor, dynamic pressure sensor, control path in the autopilot channel of pitch and roll during the Start and Steady Flight stage, Control path in the draught control channel during Start and Steady Flight stage, general scheme of a ground-based flight control to pilot miniBSP unmanned aircrafts, visualization of the ground-based flight control station operation, airframe for testing during flight, positions of equipment items in the miniBSP airframe are presented in the paper.

Keywords: *UAV, technical object, engineering, miniature avionics system*

1. Introduction

For some recent years scientists of the Air Force Institute of Technology have been researching the design of miniature avionics systems designed to control and pilot a miniBSP drone [1-2, 5]. A working team of the Division of Aircrafts and Helicopters of this Institute was among the first such teams who worked out and tested an observation unit, the miniBSP - „HOBBIT". During the study this team of researchers have verified and expanded the knowledge on the autopilot structure, the possibility of conducting autonomous flights, the functionality of a ground-base flight control station and the possible reconnaissance from different heights. Basing on gained experience the researchers made a proposal of their own more advanced solution designed to control flights of a small miniBSP, a solution based on a PC104 controller. The initial assumptions and the architecture of the presented system are presented in work [1] as well as in other works.

2. Structure of a PC104 controller based miniature avionics system

The structure of a PC104 controller based miniature avionics system to pilot a miniBSP is shown in Fig. 1. This structure is selected according to goals and the destination of this class of drones, according to missions to be performed, according to a mission range etc.

A MSA unit comprises the following elements:

- CPU – a PC104 (PCM-3347F) computer controller with an A/C converter card (PCM-3718) and with a CompactFlash data saving memory,
- miniature space orientation system (MSOP) to measure the angular velocity (three rate gyroscopes), to measure the acceleration (3 accelerometers), the altitude (static pressure sensor) and the air velocity (dynamic pressure sensor),
- PWM-controller to control electric servo-mechanisms,
- GPS (5Hz) satellite navigation system receiver,
- RC-receiver with a PWM signal converter converting PWM signals to digital form,
- ground based flight control – a portable laptop with a radio-modem to transfer/exchange data on board of the miniBSP-drone.

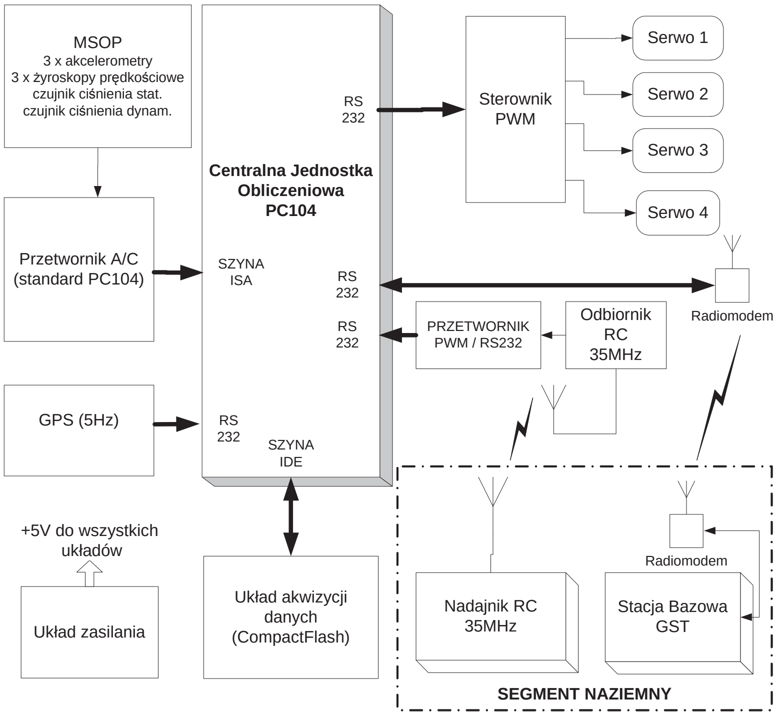

Fig. 1. Block function diagram of a miniature avionics unit – miniBSP MSOP.= 3 accelerometers, 3 rate gyroscopes, static pressure sensor, dynamic pressure sensor; przetwornik A/C = A/C converter; +5V do...= +5V to all systems; układ zasilania = supply system; Centr. Jedn. Obl. = CPU; szyna = bus; układ akwizycji danych = data acquisition system; sterownik = controller; przetwornik = converter; odbiornik = receiver; nadajnik = transmitter; stacja bazowa = ground based flight control; segment naziemny = ground based segment

The carried out research shows that the key element for the construction of an avionics unit for the miniBSP drone is to properly select the CPU. At the initial research stage the avionics system must be very versatile, as its configuration requires often changes. As it turned out a solution based on the PC104 controller is one of greatest assets of the project under development. The PC104 controller as a CPU was selected due to its: low price and market availability, easy programming (PC-compatible), substantial processing and computing capacity and versatility (relatively easy to reconfigure) of the designed system.

During the project realization, after a number of laboratory and flight-testing some changes to the original design were made. Some of these are the following:

- the CPU (PC104) was replaced with a 4-port RS232 one, with which an internal clock can be programmed,
- connection of a radio-modem link to transfer data between a miniBSP and the GPS,
- connection of the RC receiver via the PWM signal converter and the PC104 controller,
- replacement of the standard 1Hz GPS system with a GPS with a 5Hz data beaming,

- the number of data saved in a recorder was increased by servomechanism position data (data required for the object identification).

The MSA functional scheme compared to designs presented in earlier works [5] shows some significant modifications. However, it should be pointed out, that the decision, which was made then on selecting the PC104 controller, the DOS 6.2 operational system, the C programming language and the general structure based on program and hardware operation cycle interruptions (which enabled execution and controlling of individual tasks „concurrently" – within a „quasi-real time") made it possible to quickly implement all necessary changes to the design.

One of the PC104 controller functions (when operating as a BSP autopilot) is to count the individual servomechanism control signals according to adopted control/piloting rules.

The MSA system was tested not only on crafts classic control surfaces but as well with crafts with a flying wing. The control systems operated at a control function division as follows:
- longitudinal movement,
- transverse movement,
- control by draught.

The control signals to position elevons are mixed as late as in the servocontroller system. Due to the adopted method, by which a track change is recalculated to a proper change in the roll (Fig. 2), no flight course path is distinguished.

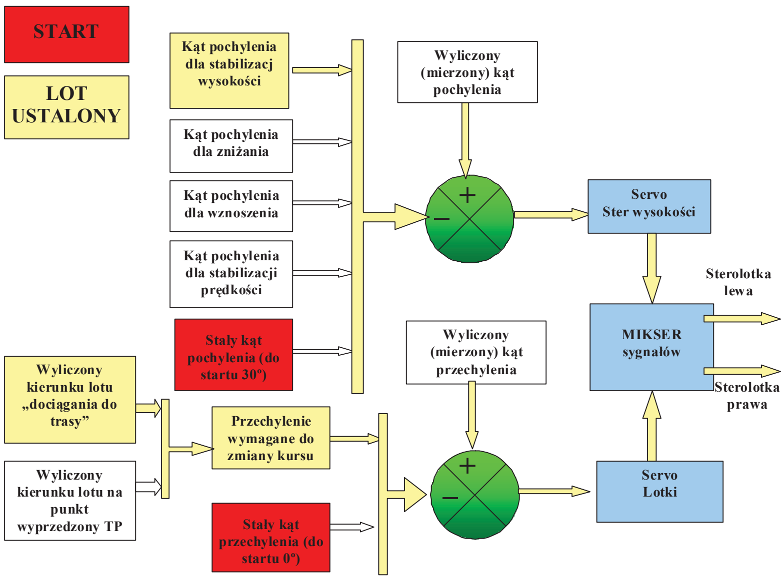

Fig. 2. Control path in the autopilot channel of pitch and roll during the Start and Steady Flight stage; lot ustalony = steady flight; wyliczony kierunek lotu dociągania do trasy = computed flight direction to approach the track; wyliczony kier. lotu na punkt wyprzedzo(a)ny TP = computed flight direction to a next successive flight course point - TP; kąt pochylenia dla stab. wysokości = pitch angle for altitude stabilization; kąt pochyl. dla zniżania = pitch angle for descent; kąt pochyl. dla wznoszenia = pitch angle for ascent; stały kąt pochyl. = constant pitch angle (for a 30deg. start); przechylenie wymag...= roll required for the course change; stały kąt pochyl. = constant pitch angle (for a 0 deg. start); wyliczony (mierzony) kąt pochyl. = computed (measured) pitch angle; wyliczony (mierzny) kat przechyl. = computed (measured) roll angle; servo ster wysokości = servo – elevator; MIKSER sygnałów – signal MIXER; serwo lotki = servo – ailerons; sterolotka lewa = left elevon; sterolotka prawa = right elevon

3. Ground-based flight control

A ground-based flight control serves for:
- Visualization of the air situation,
- BSP flight parameters control (velocity, altitude, engine status, temperature etc.),
- Transmission of flight parameter change orders (velocity, altitude),

- Transmission of single control commands (e.g. emergency landing).

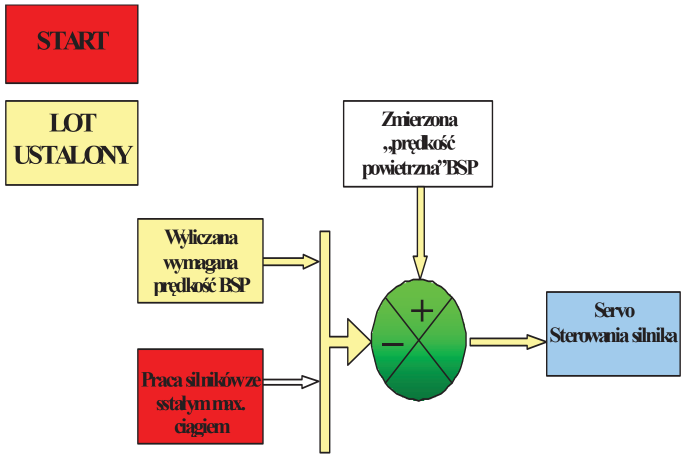

Fig. 3. Control path in the draught control channel during Start and Steady Flight stage; Lot ustalony = steady flight; wyliczana wymagana prędkość...= computed required BSP velocity; praca silnika ze stałym ciągiem = engine operation at steady draught; zmierzona prędkość powietrza = measured air velocity; servo ster. silnikiem = engine control servo

A two-direction radio-modem operating at a 19,200 bit/sec transmission rate sends signals between a BSP and a „Ground Based Flight Control Station". This modem is linked with the computer via a serial RS232 port.

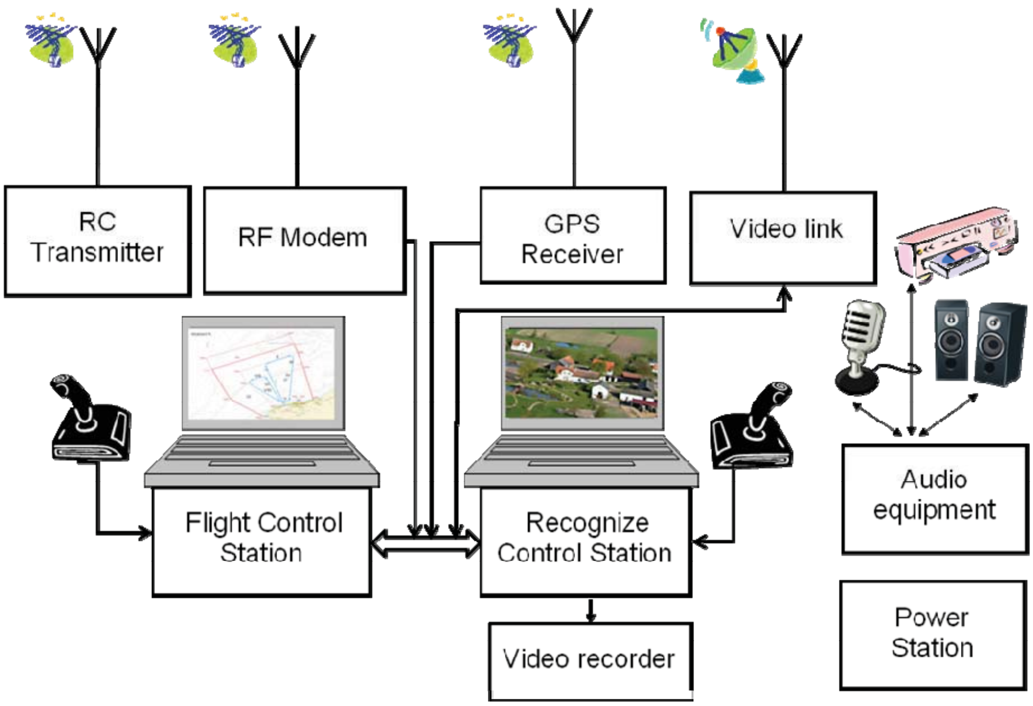

Fig. 4. General scheme of a ground-based flight control to pilot miniBSP unmanned aircrafts

4. Integration of the avionics system with an airframe

Under the autopilot-testing program some 30 flights with the NIETOPERZ-VR3 airframe designed and made by MSc Jarosław Hajduk were conducted. This is a flying wing airframe driven by an electric motor and launched from a rubber launcher. Main geometric parameters of this airframe are shown in Fig. 6. Positions of individual elements of are shown in Fig. 7.

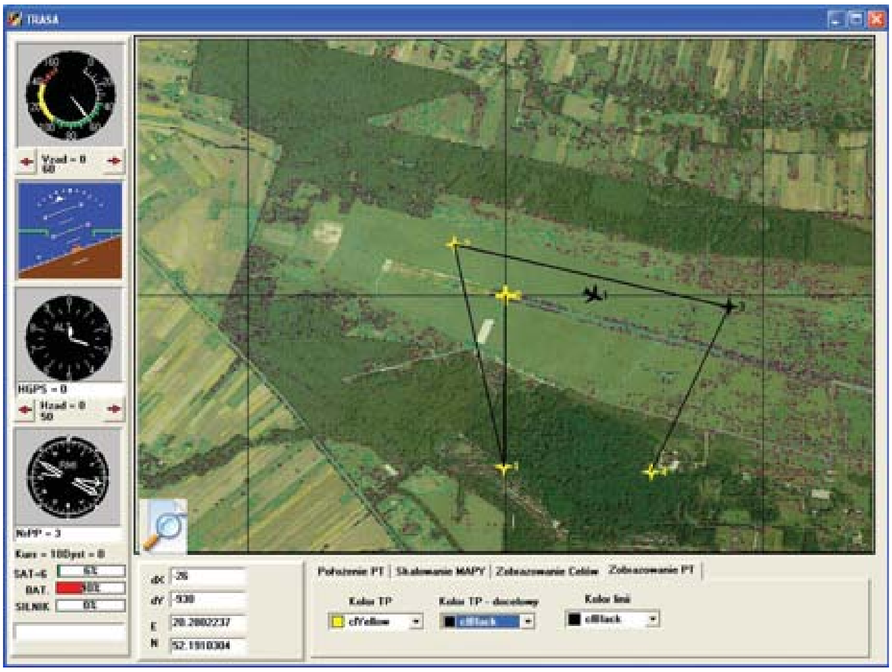

Fig. 5. Visualization of the ground-based flight control station operation

The duration of test flights was normally some 10 minutes. Also twelve long distance flights within a closed air space at the Wicko Morskie testing ground were carried out. The longest flight was approximately 40 minutes, from it a 17 km flight beyond the shoreline, and the total covered distance was 40 km. During each flight individual flight stages were tested, however, excluding the take-off and landing section. The most frequent tests covered:

- BSP navigation at a steady velocity to a set target,
- BSP navigation at a steady velocity along a set line connecting two points,
- BSP behavior during a change in the set velocity (the BSP NIETOPERZ behaviour was tested within a velocity range of 50-120 km/h),
- BSP behavior during the climb (the BSP NIETOPERZ behaviour was tested between 50-300 m above aerodrome level),
- BSP behavior during the descent (the BSP NIETOPERZ behaviour was tested between 300-100 m above aerodrome level),
- BSP behavior during a change of the target during flight (testing of the correctness of the autopilot navigation procedures and the correctness of transmitted radio-modem telegrams).

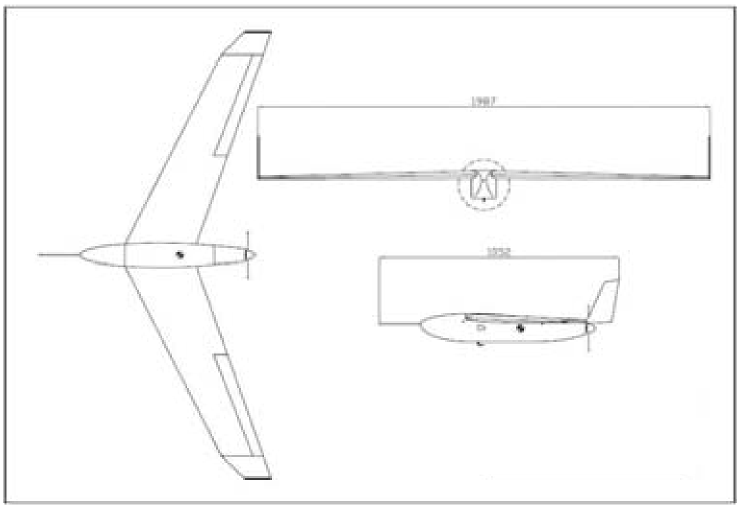

Fig. 6. Airframe for testing during flight

Fig. 7. Positions of equipment items in the miniBSP airframe

5. Comments on and problems of the avionics and control system for a flight control of a miniBSP

Attention should be drawn to a number of problems ensuing from designing and making of an avionics system to control the flight of a miniBSP and to limitations of this kind of solution in practical experience. Conclusions and observations on limitations of reconnaissance systems with miniBSPs are often skipped or passed over or belittled by authors. The authors of this paper present their evaluation basing on gained experience and results during flights. They are also fully aware that the progressing technology of construction and electronics will result in a steady and fast improvement in this field.

Basing on gained information from researching and tests one can formulate conclusions as follows:

- since the on-board data acquisition system is the main source of data to be analyzed after a flight, it should be further developed – visual evaluation and observers' perceptions are often not adequately reflecting actually occurring events,
- the miniBSP control and piloting with the GPS and simple control rules (without the optimum control option) do not allow to achieve the expected accuracy of reaching a set position in space,
- taking still shots and movie shots with an on-board camera without image stabilization is possible only at good weather,
- with common modem links transmission of HD pictures to a ground station is not possible,
- screening and elimination of interferences between devices is absolutely necessary.

Test flights are evaluated mainly on the basis of data saved in the on-board data acquisition system – the recorder. These data are analyzed and evaluated after completion of a flight. Thanks to gathered data (digital recording of input and output signals) the controlled object can be identified, control rules selected, measurement errors analyzed, etc.

Navigating miniBSPs with the aid of the GPS ensures a proper quality and accuracy of controlling. With the help of a GPS with a 5Hz data transmission information update takes only 0,2 sec. At miniBSP flight velocity reaching up to 40m/sec it causes position determination errors of an 8m order. In addition GPS system errors and non-zero errors of regulators cause the accuracy of a target run onto a set space point not above 20÷40m. This parameter can be bettered by improving the control rules. However, it calls for numerous flight tests and an exact knowledge of the dynamics of a controlled object. Therefore, at present priority was given to the identification researching. First results of these tests will be soon published.

An underestimated side effect during a miniBSP flight (a light craft of a small moment of inertia) is its susceptibility to all disturbances (wind gusts, vibration and structural deformation, engine vibrations etc.). During such flight substantial space position angle changes of a miniBSP occur and in addition they occur at high velocities. In authors' opinion this is the main reason for bad quality fuzzy photographs. Nowadays it would be impractical to use cameras of a definition above 3Mpixel. A simplest analysis of an image proves that even with such a definition a saved picture dose not contain adequate number of information items on a photographed object. Due to a continuous movement of a platform even large focal length lens most often decrease the picture quality.

Researches show that transmission of miniBSP flight data over common modem links is absolutely sufficient. A data transmission rate of 19200 bauds ensures without any problem such a quantity of transmitted data that the position of a miniBSP can be followed at an only insignificant delay, to observe a BSP flight parameters, or to change its flight trajectory during the mission time etc. Links of this kind, however, do not prove worthy for image transmission especially that of HD images. Additionally, what makes the problem even worse, is that during a transmission only some pictures are of a sufficient quality and contain interesting information. So far it is not possible to preselect pictures on board of a miniBSP prior to sending them.

A large number of radio devices, sensors, converters with a PC104 controller, which are packed within a cramped space at small distances between them, cause substantial interference problems. For the project under discussion one simplest solution was used, where the engine supply systems are galvanically separated (current consumption up to 30A) from execution servos supply (four servomechanisms consuming 1.5 A each) and remaining electronic devices and items.

6. Conclusions

The presented comments on the integration of an airframe with an avionics system, piloting problems and the results of test flights show how important for the project are experience and data gathered during test flights. First stages of study were carried out with model class of airframes at distances, where observations were possible within humans eye reach. The goals of these tests among other things were:

- perfecting the measurement signal filtration algorithm,
- perfecting of calculation algorithms to determine the angles of pitch, roll and yaw (Φ, Θ, Ψ) of a miniBSP, where measurement results were highly uncertain,
- evaluation of the piloting rules correctness,
- evaluation of the accuracy of determining X, Y, Z coordinates from GPS receivers,
- evaluation of the accuracy of X, Y, Z coordinates from inertia measuring modules during short duration flights (when GPS signals fade),
- testing the range and reliability of the radio- modem operation,
- definitive determination of „data telegrams" and testing data exchange between a miniBSP and a ground station,
- testing the reliability of supply systems.

At present flights along a preset route within a radius of 15-17 km away from the ground-based flight control are conducted.

The ultimate project goal is a design of a specially designed airframe with integrated execution mechanisms, cabling, central supply, radio-modem aerials and a radio communication.