Autonomous Distance Finding Microwave System for Middle Range Remotely Piloted Vehicle

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Abstract – **The paper describes developed and realized autonomous system for remotely piloted vehicle (RPV) distance finding related to ground control station (GCS). The system is integrated in microwave telemetry and telecommand communication subsystems, both having RPV and GCS located parts. Secondary radar principle for distance measurement and monopulse principle for azimuth angle measurement are successfully applied and field proven.**

Keywords – **Remotely piloted vehicle (RPV), secondary radar, autonomous distance finding, microwave link, Barker code**

I Introduction

Remotely piloted vehicles are improved significantly concerning possibilities of payload (mission equipment), construction and performance, trying to fulfil increased customers demands in recent years [1]. Middle range RPV (50 to 100 km range) are the most frequently used. Field of their application is really very wide, from government (military intelligence, border surveillance, counter drug and smuggling, traffic control, etc) to commercial (surveying, hard terrain surveillance, ecological control: radiation, crops diseases, waters – sea, coast, lakes, rivers and floods, forests and wild life, different kinds of pollution etc). The absence of risk for human lives and health besides lower exploitation expenses compared to missions with human crew is important in making decision to use RPV for certain tasks. One of the most demanding tasks is determining position of RPV, both in commercial and government oriented applications. It’s not only to run the RPV and secure it’s safe return to base, but to get the most possible precise information of spatial distribution of objects and actions of concern at the field. Choice of method of position determining of RPV depends of possibilities of using specific technologies, aim of RPV’s use, radius of action and of course of available financial resources.

II Methods of position finding

There are two groups of methods of position finding: global and autonomous [2]. Global methods cover complete Earth including atmosphere, while autonomous systems are not dependent from any equipment outside of RPV system.

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There are two kinds of global systems: satellite based and Earth based. Satellite based systems, which are nowadays dominant and consist of objects equipped with appropriate receivers that can receive signals in every place on Earth and in airspace from satellite based microwave transmitters and determine object’s position. Now exist USA owned Global Positioning System - GPS and Russian GLONASS, while European Union is in process of making it’s own system GALILEO, but it is not finished yet. Earth based systems like Loran-C and Omega which are older and which are based on network of radio low frequency transmitters distributed on Earth’s surface with known characteristics. Satellite systems, first of all GPS got widespread usage, lowering costs for users who only have to buy appropriate receiver which price dramatically drops, even for professional applications.

Autonomous position determining systems could be for instance: inertial (giroscope), terrain recognition, Doppler radar based, compass based, and of course, based on primary or secondary radar as a part of RPV system.

Every method has advantages and drawbacks as it is usual in engineering practice, forcing designer to make tradeoffs, depending of purpose, conditions of exploitation and price. It happens often that two or even more methods are combined in the same RPV system. They are used simultaneously or one at the time, following the decision of the commander of mission, based on estimation of conditions of use.

For example, for covered missions success of mission depends significantly of radio silence of RPV, because radar cross section of middle range RPV is usually small and it is hard to detect it by surveillance radar, especially in low level flight. At the same time, it’s hard to track RPV’s position by friendly surveillance radar from the same reason. Concerning secondary radar activity it has serious disadvantage because of its radio emissions that discover it’s position. Advantage over primary radar is a fact it needs significantly reduced emitted power of RF signal for the same range. As it is well known, inertial system integrates position error during the flight which can lead to significant errors if the flight is not of short duration, so periodical corrections of position data are compulsory, as is the case with terrain following systems.

Space based systems don’t need bilateral communication, so only receiver is needed on RPV, providing radio silence. Existing space based systems are from time to time unreliable (even GPS). Sometimes they have intentionally inserted error by system owner, known to selected users only. Difficulties in GPS satellites functioning happen occasionally and than one uses corrupted position data while not been aware of that.

III Communication system of middle range RPV

In purpose to understand the role of position determining system of middle range RPV first of all the whole RPV system is described. It consists of two main parts: aerial – one or several remotely piloted vehicle (in this case one), and ground part – usually one ground control station (GCS) with supporting equipment.

Fundamental role of communication subsystem (Fig. 1) in RPV system is to connect two distant parts of the system (airborne and ground) every time it is needed, so they can obtain correct information at right time.

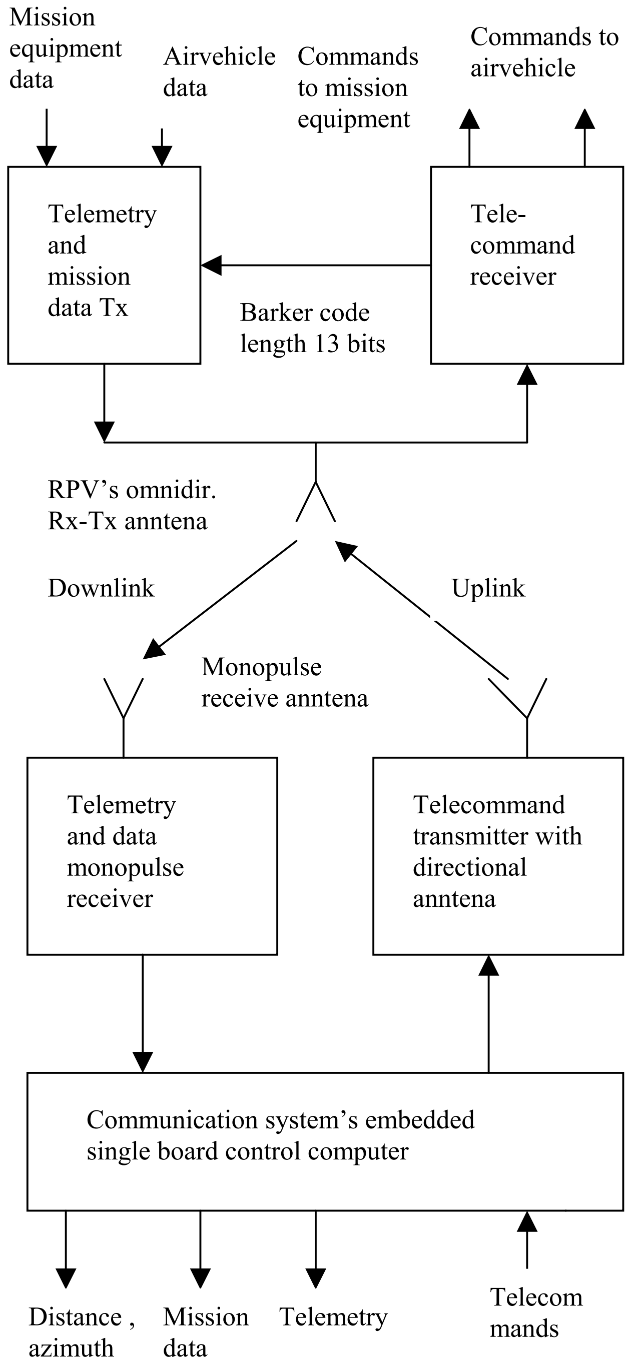

Fig. 1. Communication subsystem of RPV system

The other role of communication subsystem in RPV system under concern, of the same significance for proper functioning of the RPV system and tightly coupled with the first one, is in completely autonomous determining position of the RPV with GCS position as the referent position.

Airborne part of middle range RPV system consists of aerial vehicle itself (aircraft including motor group with fuel supplying equipment and flight command equipment with autopilot, actuators and flight and airvehicle parameters sensors) and payload (including communication system and mission equipment – first of all different kinds of TV or other cameras, but there is large choice of various sensors depending of mission's objective).

Ground part of middle range RPV system usually consists of shelter placed on the appropriate vehicle - truck or terrain vehicle) with all equipment necessary for functioning. Often GCS is realized in form of modular functional blocks that allow making necessary configuration in non dedicated vehicle or even in the open space. GCS consists of at least one working place (bay), but usually for middle range RPV two or three places exist: pilot of RPV, mission equipment operator and in some cases commander. Bays have monitoring equipment and command tables, usually computer supported. Also there are telecommand transmitter, telemetry receiving system, antenna system, and of course system of supply of energy. Usually there are communication equipment to superior operating center and RPV's launch and maintenance equipment. It's obvious that RPV system is very complex and demands highly skilled and trained operators and analysts to obtain maximum useful information from data gathered during the mission.

Communication subsystem's part on RPV (Fig. 1) consists of telecommand receiver and telemetry transmitter including omnidirectional antenna and interfaces to other RPV subsystems. Part of communication subsystem in GCS consists of telecommand transmitter with it's antenna, telemetry receiver with it's separate antenna system and interfaces to other GCS subsystems. Configurations and way of use of those two parts depend of aims of RPV system.

Telecommand transmitter together with it's transmitting antenna and communications supporting embeded single board computer (SBC) in GCS, and telecommand receiver with interfaces in the RPV together with RPV's antenna make communication channel named uplink. Telemetry transmitter with interfaces in the RPV, RPV's antenna and telemetry antenna, receiver and supporting embeded computer in GCS make downlink. Downlink is complex: its purpose is to transmit mission equipment signals (in our case digital TV signal) and telemetry signals to user in GCS, both as little corrupted by noise and interference as possible.

IV Realization of autonomous position finding

Role of the communication subsystem of RPV, both uplink and downlinkhe in the process of RPV's position determining is of key importance, because autonomous system for RPV's position determining is chosen. The choice is made primarily having in mind RPV's purpose and range of operation. Finding of RPV's position consists of three main activities:

1) measurement of distance between GCS and RPV,
2) measurement of azimuth of RPV referenced to GCS

3) measurement of RPV’s height above sea level.

After completing all the three measurements, position of RPV related to GCS is completely defined in space (all three dimensions) and knowing GCS absolute geodetic position RPV absolute position can be calculated.

Concerning maximal operating distance of RPV, conditions of exploitation (e.g. limited energy resources of airvehicle and as a consequence limited transmitted power of telemetry signal) and use of omnidirectional antenna at RPV and available components, highly directional monopulse telemetry antenna and receiver system are chosen [3].

Telemetry receiving antenna has monopulse characteristic in azimuth plane only. Barometric altimeter in RPV gives RPV’s height above sea level, which together with slant distance and known GCS height above sea level gives elevation angle and horizontal distance by trigonometric computing in GCS. Antenna system is mounted on appropriate two axes (azimuth and elevation) antenna positioning system to obtain angular position of RPV and thus realize continuous tracking of RPV along it’s trajectory during the flight. It is prerequisite condition for GCS-RPV communication at long distances [4], [5].

V Realization of distance measurement

Distance determining in this system will be described more detailed in this paper, because description of the whole position determining system (which is very complex) will take much more space than available. Distance measuring procedure between GCS and RPV is based on implementation of secondary radar principle of active response [6]. Secondary radar has two distinct parts: interrogator and transponder, as it is presented at Fig. 2. Interrogator sends signal (named “question”) and when transponder’s receiver detects it correctly, sends it’s own signal (called “answer”) back to the interrogator. When interrogator’s receiver detects this signal correctly, it concludes the communication round was successful, and the data obtained from previous stages of communication (received from transponder or generated in interrogator) are good and may be used in next stages of processing.

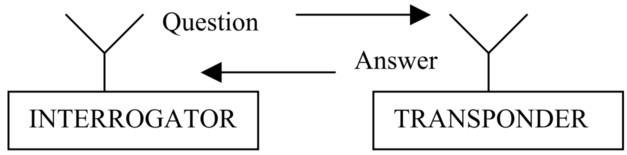

Fig. 2. Secondary radar block diagram

Measuring the time needed to make one successful round and subtracting from it time necessary for signal processing in interrogator and transponder, two way signal propagation time from GCS to RPV and back is obtained. This procedure is possible because applied signal processing algorithm has constant time, and even more it can be measured exactly. By this procedure one way propagation time is obtained and distance can be easily calculated, i.e. it is also known.

In case we are dealing with, interrogator is incorporated in ground part of communication system (Fig. 3), and transponder is incorporated in airborne part of RPV’s communication system (Fig. 4), so we get strait line distance from GCS to RPV (known as “slant range”).

Telecomand and telemetry signals are digital and uplink and downlink communication are realized by periodical messages with defined format - packets of bytes and with fixed period. Several types of modulation are implemented experimentally for microwave data transmitting

Communication starts by sending telecommand message under control of embeded single board computer, and after successfully transmitting telecommand message, Barker code of 13 bits length (1 1 1 1 1 0 0 1 1 0 1 0 1) is periodically sent several times under control of SBC. Each time at the same moment when the code is sent, hardware time measurement is started with the same bit interval as the code has. This well known code is chosen because of good auto-correlative properties – single correlation peak (having maximal possible value equal to the length of the sequence - 13) and lowest sidelobes (maximal value 1), giving robustness to noise and interference. The second reason for choice is it’s simplicity. It is important to stress that the Barker code bit interval is much smaller than telecommand and telemetry bit interval. Resolution of distance is directly proportional to Barker code bit interval.

Immediately after receiving of every telecommand message, telemetry message of RPV is sent as response. In RPV’s communication subsystem the received Barker code is regenerated and retransmitted to GCS as transponder’s answer to secondary radar interrogator’s question.

In telemetry receiver telemetry message is separated from Barker code and Barker code is led to hardware realized correlator. When correlation peak is detected (correlation above adjustable treshold) timer is stopped and its state is read by SBC. Afterwards timer is reset and prepared for new cycle of time (distance) measurement. After each group of time measurements is finished, SBC calculates arithmetic average of time (i.e. distance) and sends it to GCS computer, so it can be used for further operation of the RPV system.

VI Conclusion

The paper presents the original method of remotely piloted vehicle (RPV) autonomous position finding. Realized and successfully field test proven microwave position determining system of middle range RPV is described, as well as it’s coupling with other systems of RPV system. The stress is given to applied secondary radar principle based distance measuring method, which is described in detail.

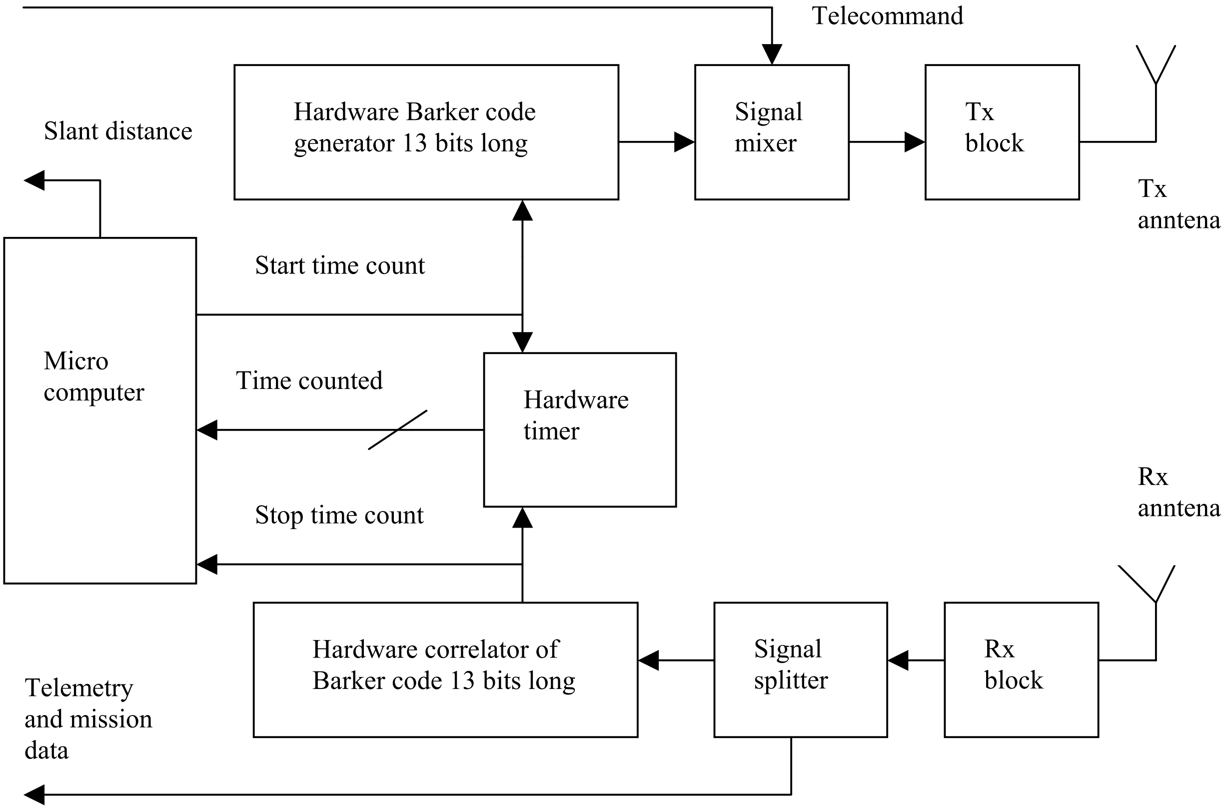

Fig. 2. Interrogator - ground station part of distance measuring system

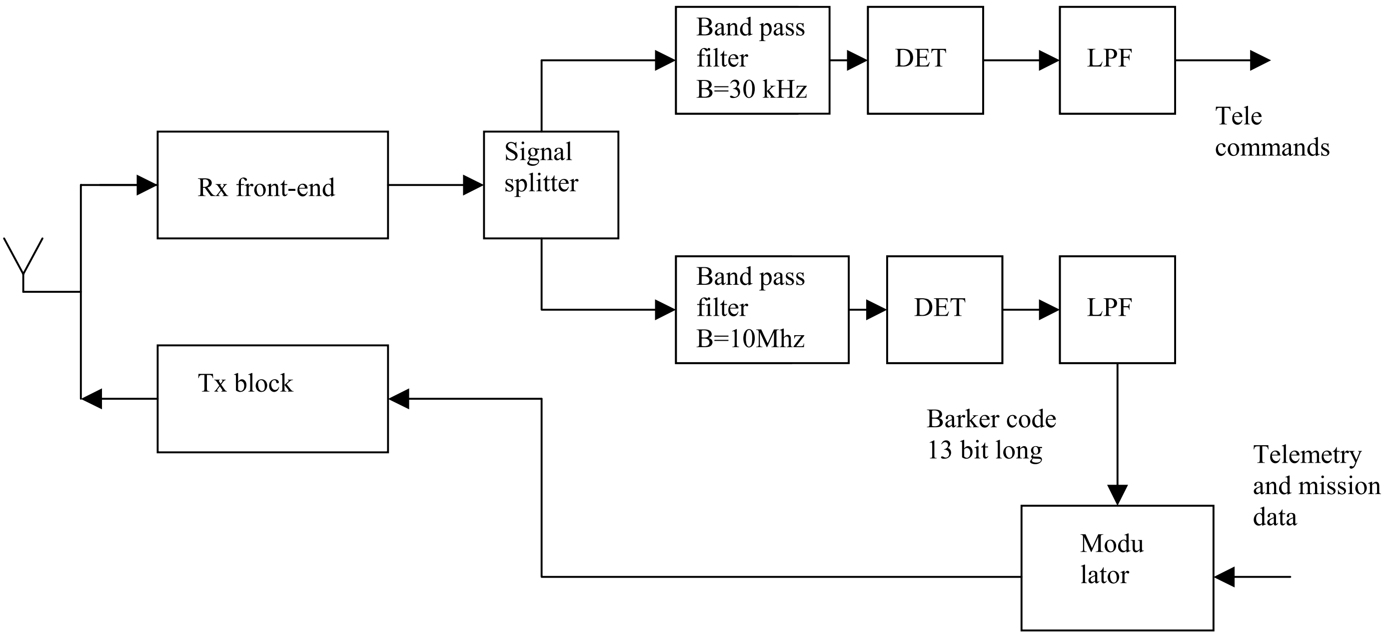

Fig. 3. Transponder - airborne part of the autonomous distance measuring system of RPV

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