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PECULIARITIES OF THE RADIO SIGNALS AND HINDRANCES IN THE NAVIGATION SYSTEM OF THE REMOTE-PILOTED VEHICLES

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Abstract. *The article dwells upon the peculiarities of radio signals concerning the use of remote-piloted vehicles. It is highlighted that it is important take into consideration the fractal analysis of remote-piloted vehicles based on diverse fractal dimensions. The significance of remote-piloted vehicle control system investigation based on radio signals is presented. Also it is highlighted that there are many hindrances during the remote-piloted vehicle flight and it is important to take them into consideration and develop methods in order to omit them. Also the vital role of remote-piloted vehicles in different spheres of life, for example, in environment research is depicted..*

Keywords: radio signals, fractal analysis, remote-piloted vehicle, fractal dimension

CHARAKTER SYGNAŁÓW RADIOWYCH I UTRUDNIEŃ W SYSTEMACH NAWIGACJI W BEZZAŁOGOWYCH STATKACH POWIETRZNYCH

Streszczenie. *W artykule został poruszony temat cech sygnałów radiowych w przypadku ich zastosowania w bezzałogowych statkach powietrznych. W pracy podkreśla się istotność bazowania na fraktalnych wymiarach podczas analizy fraktalnej bezzałogowych statków powietrznych. Podkreślono znaczenie sygnałów radiowych w systemach sterowania. Przedstawiono istnienie wielu utrudnień podczas lotów bezzałogowych statków powietrznych oraz wskazano na konieczność uwzględniania i opracowania metod uniknięcia tych utrudnień. Podkreślono również istotną rolę bezzałogowych statków powietrznych w różnych sferach życia, na przykład w badaniach środowiska.*

Słowa kluczowe: sygnały radiowe, analiza fraktalna, bezzałogowy statek powietrzny, wymiary fraktalne

Introduction

Nowadays, remote-piloted vehicles are widely used in different spheres of life, particularly in the area research. They have a lot of advantages: high economic efficiency; low altitude of aerial photoshooting; aerial photoshooting exactness.

But also here are some hindrances at any height, in particular, if take into account low-level remote-piloted vehicles. Then the flight is complicated due to the high turbulence of the atmosphere and the inability to track the change in the altitude, as on small unmanned aerials, the device for measuring the relative altitude is used for landing or absent altogether. Therefore, it is necessary to increase the height of the automatic flight and thus reduce the efficiency of the accomplishment of the tasks [1, 6].

However, using ultrasonic ultrasound, which is small, consumes little energy and inexpensive, and vertical load data can stabilize the relative altitude of the flight. To increase the range of measurements, a satellite navigation system signal and a barometric altimeter are used [1, 7].

The remote-piloted vehicle may lose contact with the control panel as a result of the operation of a small interference jammer of the corresponding power. The GPS spoofer intercepts the drone without destroying it, with the help of the false signal of the Global Positioning System, namely by silencing the positioning signal and flashing a signal. In the result, the user of the spoof can send a drone to where he wants [2].

The main component of the spoofer is the GPS simulator. This device is used to test navigation systems. The GPS signal simulator is low-power and operates within a radius of ten meters. Therefore, the second component of the spoofer are amplifiers that increase the power of the wrong GPS signal tens of times.
Also remote-piloted vehicles during flight are under the influence of a variety of factors [6, 7]:

- weather (temperature, wind direction, humidity);
- the level of radio barriers;
- region relief;
- atmospheric pressure.

So, it is extremely important to improve the control and localization of remote-piloted vehicles by improving metrological measurements and the reduction of the metrology errors.

Also it is not simple to recognize remote-piloted vehicles with the help of infrared means due to low-powered and almost noiseless engines. An experimental study of reflected signals from moving objects shows that different complexity of motion leads to different forms of the signal, that is, the analyzed signal has fluctuations due to change in frequency, phase and amplitude of the reflected signal.

Recently, fractal time series analysis has been used to in order to analyze signals having a complex form have been used fractal method of time series analysis. The nature of the fluctuations of the reflected signal is determined by the nature of the motion of the object. The degree of fluctuations can be described with the help of the characteristic coefficient, so called fractal dimension [9, 10].

1. Remote-piloted vehicle control and navigation systems

It is necessary to make the further researches by analyzing the existing problems regarding the control of remote-piloted vehicles. Also, it is important to develop metrology supply mathematical model and to improve metrology supply indices measurement of remote-piloted vehicles control based on the practical realization.

The main remote-piloted vehicle equipment consists of: angular velocity sensor; accelerometer; magnetometer; altimeter; inspection device, GPS tracker etc.

Especially, GPS tracker it is a receiving and transmitting device designed for remote monitoring of the location of a mobile object. The GPS tracker is located on the object under observation (monitoring) and determines the location of the object using the GPS receiver, location data is transmitted to the GPS monitoring system, or directly to the user's computer.

The tracker provides the ability constantly to observe the movement of the object everywhere, where there is coverage of GSM networks. Most modern trackers have the ability to store traffic data in the event of a temporary lack of a GSM network and transmit the march-rout record after the connection is restored.

The main device in the GPS-monitoring system is the GLONASS / GPS / GSM-terminal, which performs functions of determining the coordinates with the help of a satellite receiver, collecting information from on-board equipment and additional sensors, transmitting information by channels of GSM communications, control of on-board equipment for commands received from the operator [2–4].

The collected information is then transmitted to the processing server in the form of a binary AVL package containing the "snapshot" of the data received by the terminal – time, coordinates, values of internal and external parameters. The user then receives information from the server using the client software clock, or, in some cases, directly through the browser, using the WEB-system interface [2, 3].

The navigation system of remote-piloted vehicle is depicted in the Fig. 1 [5, 8].

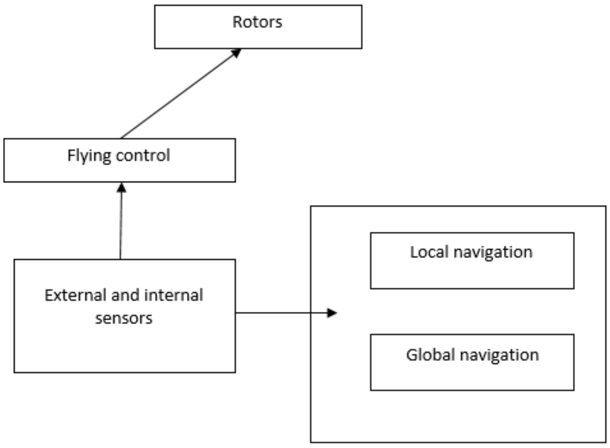

Fig. 1. Navigation system of remote piloted vehicle

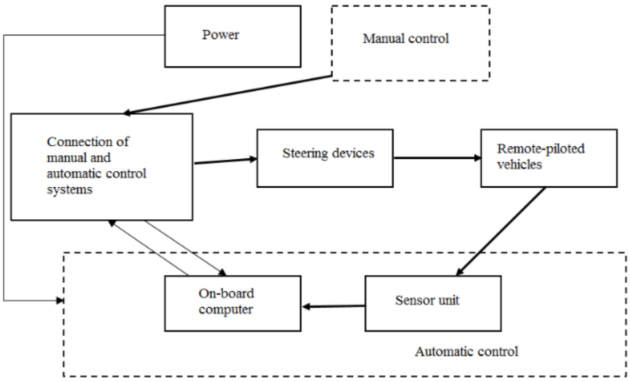

Fig. 2. Control system structure of remote-piloted vehicle

Self-positioning and modeling of environment relative to the local coordinate system is under control of local navigation. 3D information is formed based on a set of flat images, forming 3D map of the studied surface. Block "Global navigation" presents the positioning of the remote-piloted vehicle by using the constructed 3D model of the external environment.

This technique allows to solve the problem of positioning in the condition of absence of GNSS signals. Local positioning system takes into consideration the onboard sensors indices, external sensors and position change data from the camera, which after processing by the filter solve the problem of orientation in space of dense urban development [6].

The high speed of errors accumulation in inertial systems of positioning is caused by error of measurements of the used integrated accelerometers and the need to calculate the integral, leads to the multiplication of errors and does not allow to obtain positioning accuracy comparable with the accuracy of GNSS.

The positioning of remote-piloted vehicle is made on the basis of the analysis of the location of ground objects and pre-designed models of environment. The block "Flying task and control" is responsible for the collection and processing of the 2D images obtained through the onboard camera, and solves such important tasks:

- adjustment of coordinates of an inertial positioning system;
- stabilization with respect to a predetermined position;
- safe landing of remote-piloted vehicle.

There are various types of remote-piloted vehicles control system:

1) manual control when remote-piloted vehicle is under the control of a pilot;
2) automated control when the control is made based on the telemetric data;
3) automatic control when the control is made based on the system chosen parameters.
4) It is presented in the Fig. 2 [6].

Figure 2 depicts the overall structure of the control system for drone. In particular, the sensor unit contains an inertial module, a tri-axial magnetometer, a receiver of satellite navigation signals, receivers of static and dynamic pressure, an ultrasound altimeter.

In order to use remote-piloted vehicles in appropriate way it is also important to understand the control system structure. It is presented in Fig. 3 [6, 7].

Such scheme demonstrates that the control system of remote piloted vehicles consists of radio signal receiver and transmitter, terrestrial control and remote piloted vehicle operator. Also, such control is based on the engines controllers.

Nowadays radio signals fill all frequency ranges and it is extremely important to protect the signal from accidental and non-accidental interferences. One of the most effective method is fractal analysis based on fractal dimensions. That is why it is necessary to investigate it taking into consideration different conditions of remote-piloted vehicles.

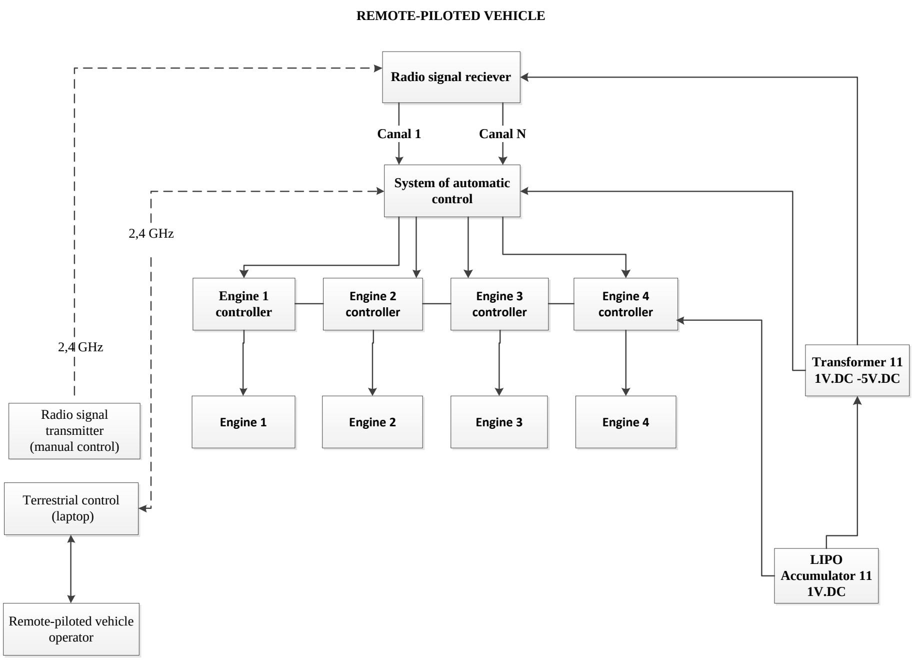

Fig. 3. Control system of remote-piloted vehicles

2. Fractal analysis in the process of remote-piloted recognition

To solve the problem of analyzing background signals, it is expedient to calculate the fractal dimension and to estimate the complexity of the reflected signals. Thus, the difference in the values of the fractal dimensions of the signals from the output of the headphones during background and remote-piloted vehicle sounding can be used as a sign of remote-piloted vehicle recognition [9, 10].

Fractal dimension it is a positive non-integer number that displays, to some extention, the complexity of the signal form. A large degree of filling of the plane corresponds to a large value of the fractal dimension. Fractal dimension is close to 1 (practically coincides with the topological dimension of the line) in case of smooth signals and for the cut-off signals it is close to 2 (practically coincides with the topological the dimension of the whole area).

The calculation of the fractal dimension of the initial time series allows to analyze the complexity form of the reflected signals. The forms of the reflected signals from moving objects have different complexity. So the value of the fractal dimension, which characterizes this complexity, also depends on the type of the moving object, which can be used when recognizing them.

It is expedient to analyze signal during the move of remote-piloted vehicle. It is revealed that the signal structure is not homogeneous as in the case of remote-piloted vehicle hanging.

The values of the fractal dimension signals obtained during the hanging of the remote-piloted vehicle and during its move in the direction to and from the radar are practically the same. It is impossible to determine the type of remote-piloted vehicle move by the size of the fractal dimension. This is because the modulation of the signal is mainly due to the rotation of the screws, and not because of the flight speed of the remote-piloted vehicle, which during the experiments was not high [9, 10].

Thus, the difference in the nature of the remote-piloted vehicle move (entrainment or movement in the direction to and from the radar) can be determined by the extent and periodicity of the appearance of the smallest fractal dimensions.

In the modern conditions, remote piloted vehicles are widely popular in different spheres. It helps to solve various tasks of the territory observation. Remote-piloted vehicles have a lot of advantages.

They are mobile, effective, convenient and cheap means of exploration in the form of photos, videos. However, it is difficult to recognize them by the means of radiolocation due to theirs relatively small dimensions and materials that weakly reflect electromagnetic waves.

3. GPS-spoofing and hindrances concerning remote-piloted vehicles

The use of the Global Positioning System (GPS) is very popular nowadays, especially concerning the use of remote-piloted vehicle. GPS it is a set of radio electronic means that allows to determine the position and speed of the object on the Earth's surface or in the atmosphere. The position of the object is calculated by using a GPS receiver that receives and processes the signals of the satellites of the global positioning system.

However, the phenomenon of GPS spoofing, attack that tries to cheat the GPS receiver by transmitting a more powerful signal than received from GPS satellites is widespread today. As a result, the location is incorrectly determined.

The GPS systems work by measuring the time taken for the signal to reach from the satellite to the receiver. So the simulating signal must be designed with allowable time delay [3, 4].

The spoofing system operates in such a way that the GPS signal generator transmits the simulation of the signal of several satellites through the antenna at the GPS frequency. In case that the level of the simulating signal is slightly higher than the signal level of real satellites, the GPS receiver will perceive the simulated signal and calculate the position on its basis.

A separate problem is the creation of a field of spoofing in the conditions of urban development, where the reflection of the signal interferes with the buildings, as well as radios, the configuration of which for a real signal coming from satellites, and signal interference is very different [2, 3].

There are different methods to detect GPS spoofing. For example, the allocation of an erroneous signal may be based on the direction of the source. It is possible to determine the direction by comparing the phase of the signal on several antennas.

Consequently, the main problem of using remote-piloted vehicles is the accuracy of long-range data management and data transmission. The most important task is to carry out research where it is difficult to obtain information using other methods and means. To do this, it is necessary in the future to consider in detail the specialties of the management of different types of drone.

The work of the radar station occurs under the conditions of various types of interference, which cause a decrease in the efficiency of the functioning. The degree of reduction of the efficiency is directly related to the change in the characteristics of the radar image under the influence of various obstacles.

The degree of interference is significantly dependent on the nature of the interaction of noise and signal. On this basis, the hindrances are divided into two types: multiplicative and additive. The effect of multiplicative interferences leads to parasitic amplitude and phase modulation of a useful signal. Aditive obstacles create a masking noise, against which there are useful signals. By its nature, the noise is divided into regular (deterministic) and random (statistical), the methods of filtering which are different.

For the effective operation of the radar system installed on the remote-piloted vehicle, it is crucially important accurately to determine the flight parameters of the remote-piloted vehicle, since, due to the relatively low mass and speed of the flight, they essentially change under the influence of turbulence of the atmosphere, vibration of the engines, errors of on-board equipment [2–4].

The main hindrances causing errors in determining the parameters of the remote-piloted vehicle flight are the following: the trajectory instability of the remote-piloted vehicle, elastic variations of the structure, errors in the control system and the errors of inertial meters.

In the formation of the radio image in the radar station the control of both real and synthesized directional diagrams of the antenna are important. The laws of management are determined by the given type of survey of the earth's surface. In this case, the scanning of the synthesized directional diagrams is carried out using appropriate supporting functions.

However, regardless of the type of inspection, the character and parameters of control signals are determined either by a priori data on the flight mode, or by the a posteriori values of the parameters of the remote-piloted vehicle movement. If the type of trajectory of the phase center of the antenna for which the reference function (reference trajectory) is calculated is fixed and known then the reference function can be pre-introduced into the memory of the processing system.

With an arbitrary reference trajectory, when it varies from one correction interval to another, the reference function is calculated for each interval separately during the flight based on the determination of the parameters of the remote-piloted vehicle movement.

As a fixed trajectory of the remote-piloted vehicle flight is usually used a straight line trajectory. In the simplest case of side examination with uniform rectilinear flight for the formation of the radio image, in principle, it is only necessary to measure the velocity of the remote-piloted vehicle.

However, really, no flying machine can fly quite evenly and straightforwardly. And first of all, this statement relates to the remote-piloted vehicle. The fact is that during the remote-piloted vehicle flight in the atmosphere there is a continuous change in the direction and speed of wind, pressure and air density, etc., in connection with which there are random deviations of the remote-piloted vehicle flight mode from the given.

The remote-piloted vehicle control system, on the one hand, does not always have time to react to all these changes and maintain a given flight mode, on the other hand, it introduces accidental elements in the remote-piloted vehicle movement itself. The most typical example in this regard is the piloting errors on the part of the remote-piloted vehicle operator.

Any random deviations from the given flight mode are called trajectory instabilities. Trajectory instabilities include deviation of the remote-piloted vehicle from the program flight trajectory, its angular oscillations, random modifications of the module and direction of the velocity vector.

Trajectory instability is the reaction of the remote-piloted vehicle as a solid body to the influence of the turbulent atmosphere and noise of the control system. At the same time, it should be borne in mind that the design of the remote-piloted vehicle is flexible.

Elastic shifts of the remote-piloted vehicle design elements under the influence of aerodynamic forces during a flight in a turbulent atmosphere are called elastic structural variations. In real-life conditions, trajectory instabilities and elastic structural variations operate on the radar station simultaneously and cause random deviations of the trajectory of the phase center of the antenna from the reference, which is illustrated in the Fig. 4 [3, 4].

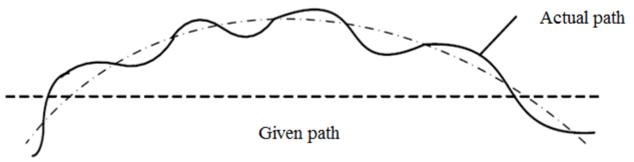

Fig. 4. Lines of given and actual path

In the figure, the dashed line shows the line of the given path, the dash-dotted line - the deviation from it through the trajectory instabilities, and the solid line is the actual path, taking into account the trajectory instabilities and the elastic structural variations. Random deviations from the given flight mode are inherent to all aircraft.

In the conditions of flight through the trajectory instability and elastic structural variations, the fuselage of the carrier is bent, which leads to errors in the definition of the module and the angular orientation of the vector.

In order to compensate trajectory instabilities and elastic oscillations of the structure affecting the synthesis of apertures, a modern system of compensation is provided in modern radar station, which is created using inertial meters.

4. Conclusions

Nowadays information society develops very fast. New scientific prospects become visible and acceptable. One of the perspectives is the use of remote-piloted vehicles in different spheres of life. It is really justified. Many countries use remote-piloted vehicles for different purposes concerning aerial photoshooting and terrestrial researches. It is the effective mean of reconnaissance. Modern remote-piloted vehicles use new technologies, cameras, radars, infrared detector and others.

So, there is a need for new methods of intelligence in areas where information is difficult to obtain using other methods. It is important to provide protection against unauthorized encroachments on location information. It is necessary to create new means of electronic combat on the basis of the phase-frequency theory of the measurement and transformation of radio signals.

Modern countermeasures are often energy-poor, with a low radius of signals and high value. That is why it is necessary to develop mobile systems of electronic warfare against modern types of radio communications by measuring and generating radio signals, with radio control channels and shooting video information.

It is necessary to improve the accuracy of metrological measurements, obtaining research indicators through the analysis and improvement of control systems for drone taking into consideration radio handrances.

The difference in the values of the fractal dimensions of the signals from the output of the headphones during sounding of the background and the remote-piloted vehicle can be used as a sign of the remote-piloted vehicle recognition.

The fractal dimensions of the signals during the remote-piloted vehicle hanging and its movement at a low speed practically are the same and it is impossible to determine the type of remote-piloted vehicle movement based on the size of fractal dimension.

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