Unmanned Aerial Vehicles Using Pseudo-Conical Scanning

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ABSTRACT: *In this work, we have created a model for targeting unmanned aerial vehicles that have vertical landing using a mobile landing site. It has required dimensions based on changes in pseudo-conical scanning. It is used for changes to for applying the radar targets.*

Keywords: Automatic Landing of UAV, Pseudo-conical Scanning, Radio-navigation and Radiolocation

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1. Introduction

The landing of unmanned aerial vehicles (UAVs), and in particular those of a lower category, is carried out under the supervision of a qualified operator. The landing site is usually commensurate with the dimensions of the UAVs and GPS accuracy of the GPS for civilian purposes is not sufficient to target it directly. This is done using a differential GPS, the cost of which is significant [1]. All this complicates their expected massive application for various services in the future. For these reasons scientists and engineers are working to automate this process by using civil GPS data. The following are generally accepted:

• Image processing and recognition of the landing site combined with light signals [2];

• Applying the radiolocation principle of pseudo conical scanning to accompany objectives [3];

• Applying the principles of lidar optic systems [4].

The solution to automatic landing problems also leads to the next step - landing on a moving landing site. Such landing can be on a vessel, a car and with a lot of reserves and conventions on a train, because over it there is a power supply line, and there are obstacles (trees, poles). At a landing site on a car moving on a relatively straight section at approximately uniform and low speed there would be no problems as long as there were no big trees above the road, the crowns of which are over it. At a landing site on a vessel, a single problem can occur if there is a strong water turbulence that requires much more serious software to compensate for it. Therefore, this article proposes a system of landing on a vessel floating in calm waters (lakes, dams, floating rivers and a relatively calm sea).

A solution for automatic landing on a moving vehicle is available in [5], assuming that the UAV has taken off from a landing site that is mounted on a car, has completed a task or mission and is back to the same landing site. It is proposed to use a landing site that is recognizable by a video camera whose image is processed by the droning equipment. There is no mention of what happens if there are crowns of trees above the road, what is the influence of the unevenness of the road, the change of direction of movement.

Video-image processing is a perspective area of development but with some drawbacks to this application. Image quality is dependent on weather conditions, and software is much more complex. If it is also applied to mobile landing sites, the problems are much more due to the dynamics of the incoming image. In this case, it is good to look for an alternative solution.

2. Formulation of the Task and Schematic Solution

The most appropriate solution for a method and an automatic landing system on a mobile area is the use of the radiolocation principle to accompany targets with conical or pseudo-conical scanning.

This is not the same situation like in the case of radar accompanying targets. Here the object of accompaniment is “own” and not “alien”. For this reason, the principle of radiolocation, which works with reflected signals from the monitored “foreign object”, disappears. This makes it possible to significantly simplify the automatic landing system, all the more so that the whole process can be digitized. Here, the scanning area is stationary upwards above the landing site. The UAV moves and searches for this area on its assigned GPS coordinates, aiming to position itself above it, level the speed of the vehicle, and then turn on the automatic landing system just above the landing.

With this set-up, signal processing software and hardware implementation are made much easier and more economical.

In Figure 1. shows the functional scheme of the system and the setting of the individual stages of the landing.

On board of the UAV is an on-board unit (O-BU), which consists of an on-board control-command module (OBCCM), which includes all flight control and control components [6].

Control components are controllers, GPS receivers, altimeters, gyroscopes, barometers, electric motor drivers and others. It is also connected to the Wireless Interface for Remote Communication 1 (RCWI) with the Mobile Station of the landing site (MSLS). Additionally, an information microcontroller (IMC) is installed. The information microcontroller receives information from a microwave receiver (MR), and through a nearby communication interface 1 (NCI) (Wi-Fi, RF or other), it is possible to connect to another.

The pilot-in-command of the UAV guides the flights through the mobile station at the landing site which is located on the mobile object. He is accessing the system via a personal computer (C). The computer (C) connects to the UAV via a Wireless Interface for Remote Communication 2 (RCWI) (GSM, RF or other) and continuously transmits information about its movement and position. The directional microcontroller (DMC) manages the positioning and landing processes. Through a nearby communication interface 2 (NCI) can be established a close communication with the UAV, and by the gyroscope (G) the change in the direction of motion of the mobile object is monitored, via the modulator (M) transmitting data to the microwave transmitter (MWT), the signals from which are emitted by the antenna with Electronic Pseudo-Conical Scanning (AEPCS). The antenna is controlled by the Directional Microcontroller (DMC). After landing, the system also includes electromechanical or electro-magnetic grip (EMG) for the UAV to stay stationary on the landing site (LS).

The landing process consists of three stages: positioning over the pseudo-conical scanning area, signal processing, and positioning of the UAV at the center of pseudo-conical scanning, downhill and landing on the landing site [9].

The landing method on a mobile object is realized by a series of operations, whose interrelationship is also presented in the form of algorithms (Figure 1).

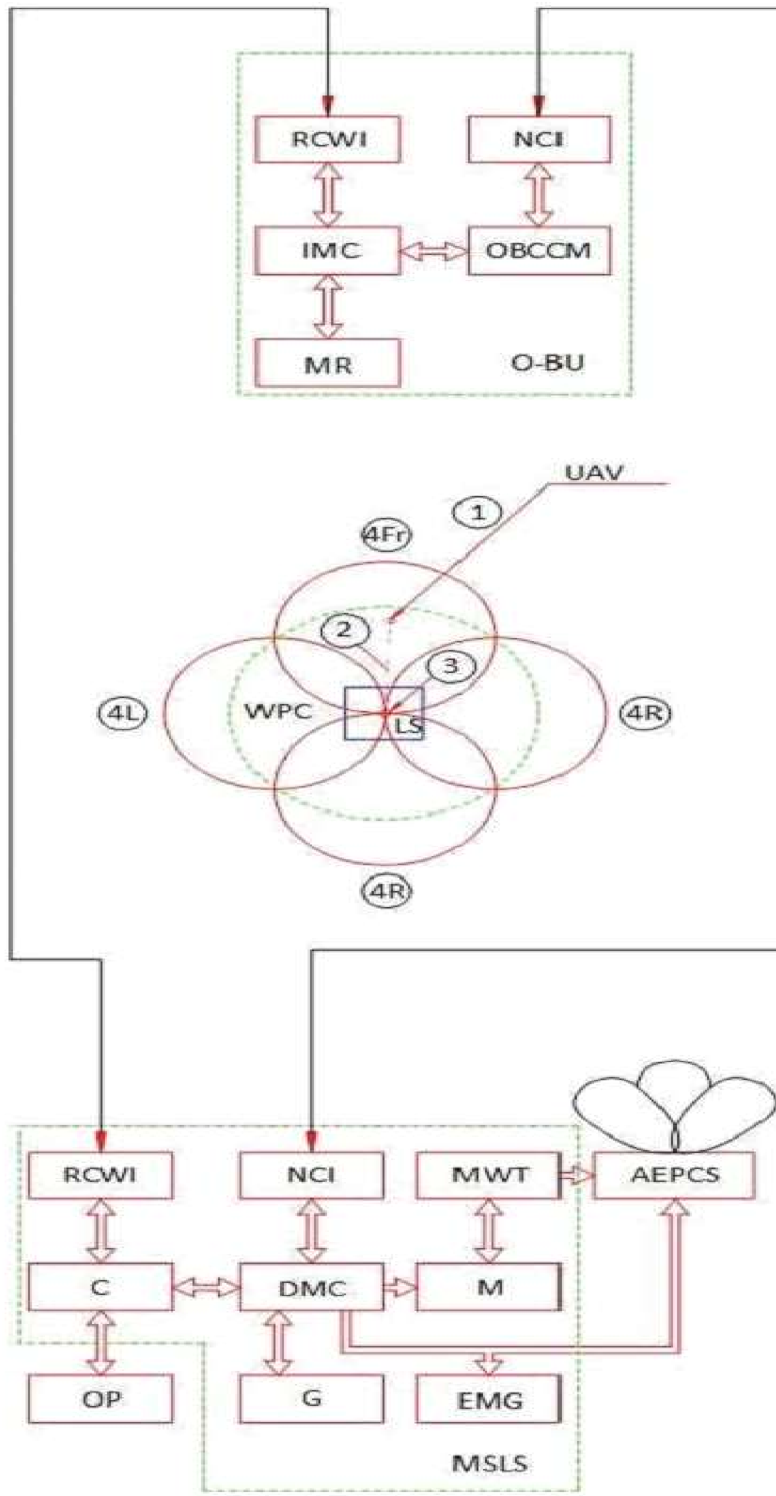

Figure 1. Figure example

3. A Condition For Successful Positioning of the UAV Over the Landing Site

Figure 2. shows a schematic diagram of the positioning of the UAS over the pseudo-conical scanning antenna. In order not to complicate the figure, only two beams ("left-right") facing each other are pointed upwards. The other two beams ("back and forth") are in the perpendicular plane of these two. The geographic directions are not used here because the object is mobile but the antenna is fixed to it and to the direction of movement as well, which facilitates the movement of the drones that move in the same direction and at the same speed.

The center axis for the entire setting 0Z is in a perpendicular upward direction and pseudo-conical scanning is performed against it. The angle of deflection depends on the accuracy of the GPS module used in the drones. Trough the given maximum permissible errors for civilian purposes of GPS and Galileo in the three coordinates (ΔX = 2-4 m, ΔY = 4 m and ΔZ= 8m) [7, 8], the UAV can be expected to be a part of the air space, formed by a cylinder with a radius of 8 m and a height of 16 m. This area can be called a "wrong positioning cylinder" [3]. To prevent a collision between the drones and the site it is good to have the base of this zone (cylinder) a few meters above it (for example, ΔZ = 8m). This determines the system's maximum operating height H=3, ΔZ = 24 m and the coordinate Z for positioning of the drones before landing should be 16m above the landing site. Depending on it, the UAV must fall somewhere in the space inside the wrong positioning cylinder. This cylinder must be into the scanning cone to ensure the successful capture and landing. The cone is formed by the 0M rays.

With this configuration, it is necessary to determine at what angle the four beams pointing up should be dissolved. Figure 2 shows the angle of light dissolution α and the angle of the tip of the inverted cone β, formed by the lower base of the wrong positioning cylinder and the center of the landing site . It can be seen that:

$$\frac{\Delta X}{\Delta Z} = tg\,\frac{\alpha}{2} \quad or \quad \alpha = 2\, arctg\,\frac{\Delta X}{\Delta Z} \tag{1}$$

After taking into account the errors of GPS and Galileo:

$$\alpha = 2\, arctg\,\frac{4}{8} \tag{2}$$

angle β must be less than 60° and angle $\alpha = 60^{\circ}$

An additional condition is to reliably accept the signals of the rays in the upper base of the wrong positioning cylinder, which depends on the sensitivity of the microwave receiver (MWT). The level of all signals is increased in the landing process and centering direction. The angle of dissolution of the rays α is better to be larger than the angle β, but unlike the analog conical scan, even if the UAV is from the outside of the beam, it will still orient itself, where it is to fly because it receives coded digital targeting, which is not affected by its position relative to the axis of the beam.

4. Additional Remarks

The algorithms to perform the individual stages are autonomous and run sequentially, each ending with an emergency signal to the landing site if problems arise. In this case, its movement must be stopped to ensure a safe landing and, if necessary, stopping the movement of the object and moving to manual control.

5. Conclusion

The article provides a system for automatically targeting unmanned aerial vehicles with a vertical landing on a mobile site, based on a pseudo-scanning modification used to accompany targets with radar. By pointing up the four rays of pseudo-scanning, a gripping and guiding zone for the unmanned aircraft is formed. It is positioned over GPS coordinates above this area, and landing accuracy is achieved as a result of its pseudo-conical direction by processing the signals emitted from the center of the site.

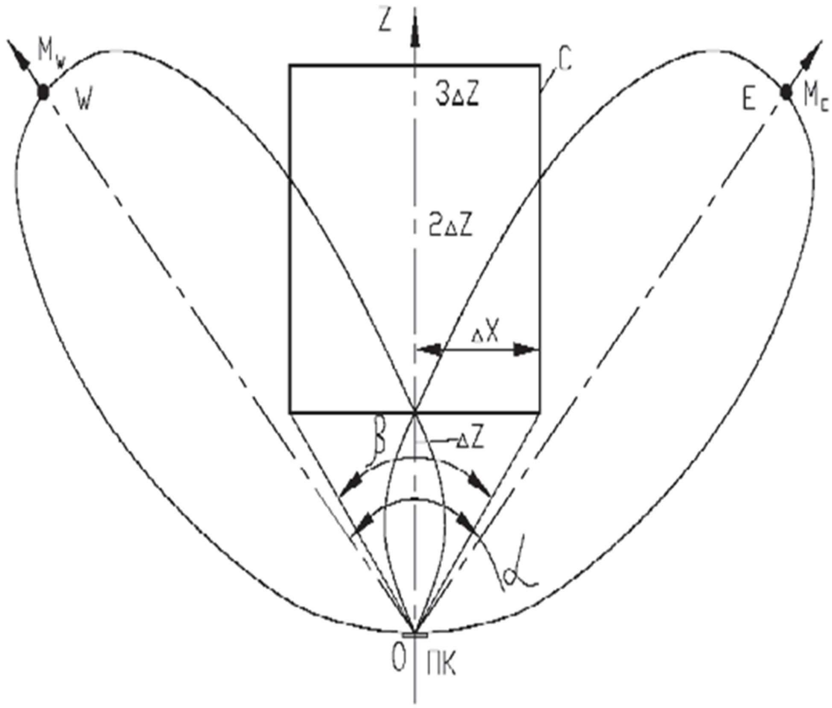

Figure 2. Diffusion angle α and tip angle of the inverted cone β of the pseudo-conical scanning setup

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