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Investigation of using quadcopter as a means of acoustic and optic surveillance

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Abstract. The main problem in performing optic and acoustic surveillance is the distance. Using quadcopters for gaining access to optic and acoustic information allows coming closer to the places of storing, processing and transmitting of information, suggesting that the interception of this information might be unauthorized. The object of surveillance can be located in the places traditionally inaccessible for normal surveillance – on (restricted areas) closed grounds or on a high floor. The objective of this article is theoretical and practical investigation of using civil unmanned aircrafts to perform surveillance. The basic task of acoustic surveillance is to determine the possibility of receiving and recording the signal of appropriate quality in spite of the noises of the quadcopter itself on the basis of the methods of calculation of discrete word intelligibility index developed by N. B. Pokrovsky. The basic task of optic surveillance is to determine the distance of text recognition on the monitor display or paper using traditional cameras installed on quadcopters. The special task is to choose the parameters of a quadcopter, which can be used for the objectives, to determine its possible characteristics of noise, weight, energy and size. In conclusion, the authors determined critical conditions of quadcopter use in acoustic and optic surveillance for understanding the range of necessary preventive measures against technical leak of information.

1. Introduction

The objective of the research is the determination of possibilities of using quadcopters for performing acoustic and optic surveillance at short distances and heights, up to 100 m. The research can be of interest for security services of different organizations, which have leakage risk of confidential information via optic and acoustic channels.

The problems of using unmanned aerial vehicles have been already described in sources, but they mainly concern their use by military forces or strategic intelligence departments of different countries of the world [1]. However widely spread, rather cheap and efficient civil versions of quadcopters, gave birth to new opportunities for getting direct channels of information leak by ordinary citizens, interested in unauthorized interception of confidential information [2].

Traditional preventive measures against the emergence of leakage channels often turn out useless against usual mass-produced quadcopters available to any individual. The previous security measures required the refinement of basic methods and tactics of information protection means.

2. Acoustic information channel

The main difficulty in obtaining the acoustic information using a quadcopter is its own noise. The noise of the propellers, which reaches 70 dB on the volume scale for a quadcopter under load, is a significant hindrance even at short distances from the object of surveillance. The noise level of the quadcopter in the frequency spectrum is represented in figure 1.

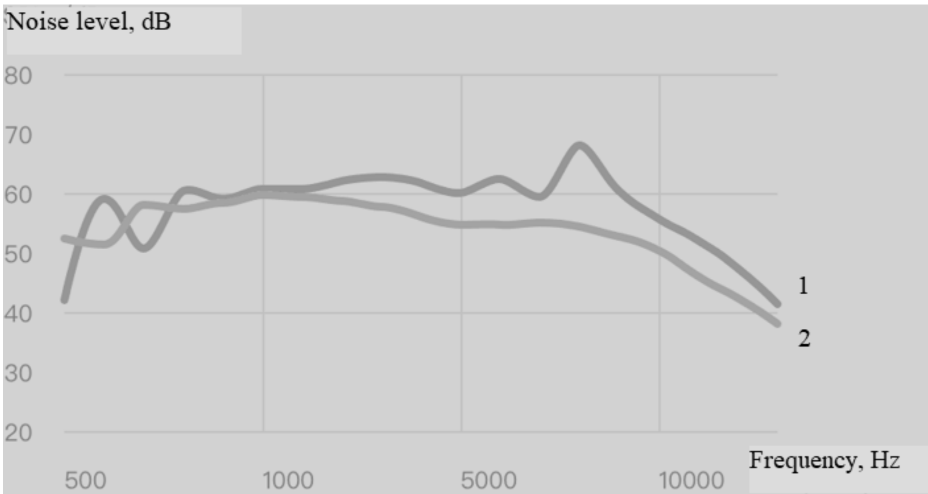

Figure 1. Graphs of quadcopter noise level in two experiments. The first line is Mavic Pro, the second line is Mavic Pro Platinum.

Let us estimate noise factor impact using calculation of discrete word intelligibility method of Pokrovsky by using ordinary point microphone [3]. We will conduct the calculations for the spectrum of five octave bands: 250, 500, 1000, 2000 и 4000 Hz, where 90 % of spoken information produced by human voice is concentrated. Discrete word intelligibility index is determined by the following formula:

$$\begin{cases} W = 1{,}54R^{0{,}25}(1-\exp(-11R)), \text{if } R < 0{,}15 \\ W = 1-\exp\left(-\dfrac{11R}{1+0{,}7R}\right), \text{if } R \geq 0{,}15, \end{cases} \quad (1)$$

where R – integrative articulation index. R is calculated by formula:

$$R = \sum_{i=1}^{5} r_i, \quad (2)$$

where r_i- octave articulation index.

Value of r_i is calculated by formula:

$$r_i = k_i \left| z - \frac{0{,}78 + 5{,}46\exp\left|-4{,}3*10^{-3}\left(27{,}3 - |E_i - A_i|\right)^2\right|}{1 + 10^{0{,}1|E_i - A_i|}} \right|, \quad (3)$$

where z=0, if $E_i \leq A_i$; 1, if $E_i \leq A_i$; k_i – weight coefficient of band.

Value of E_i is calculated by formula:

$$E_i = L_{Si} - L_{No}, \quad (4)$$

where E_i – octave difference signal-noise; L_{Si}– signal level; L_{No}– noise level; Ai – numerical value of formant spectrum parameter of speech signal in octave frequency band, dB, in the place of possible location of sound receivers. These values are represented in table 1 [3].

Table1. Values of parameters A_i и k_i.

Geometric average of octave band frequency, Hz	Weight band coefficient, k_i	Parametrer value, A_i
250	0.03	18
500	0.12	14
1000	0.20	9
2000	0.30	6
4000	0.26	5

The value of valid acoustic signal can be 60 dB, which will approximately correspond to the volume of normal human speech at a distance of about 10 m. The calculation shows the value of word intellegibility index about 40%, which is appropriate value, but not entirely efficient for qualitative survey [9]. Approximate values of sound signal quality are presented in figure 2.

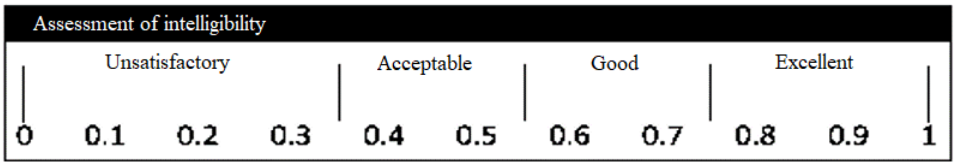

Figure 2. Word intelligibility assessment.

To intensify the level of useful signal it is necessary to use directional microphones, which suppress close side noises and intensify the signal going along axial direction. The directed action coefficient of tube type microphone can be calculated on formula:

$$G = \frac{4L}{\lambda}, \tag{5}$$

where λ sound wave length, L – tube length of directed microphone.

It will show the degree of increased signal level of microphone output when a non-directional microphone is replaced by directional one.

For example, when we use lightweight autonomous directional microphone “Yukon” (0,130 kg) [10], on a quadcopter, we will get directivity coefficient on 2000 Hz frequency equal to 3.56, which will allow to intensify useful signal and to suppress noise and to increase intellegibility index up to excellent values.

3. Optic information channel

Portable video cameras are widely used on quadcopters [4]. However, almost all of them are designed to shoot general views, big objects and vast spaces. It implies rather wide view angle and correspondingly short focal length [5].

For optic surveillance purposes a quadcopter should have a camera capable of recognizing text on the monitor screen, visible through the window, or paper document in the room. Taking into account distances (not more than 15-20 m), a camera should have normal or narrow view field and comparatively long focal lenth.

The condition for recognition of symbol, letter or number is their reflection by at least 4 matrix elements of the camera horizontally and vertically, figure 3 [6].

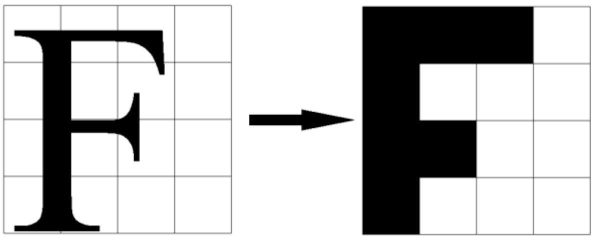

Figure 3. Symbol recognition.

Let us examine equivalent optic scheme of the camera in figure 4.

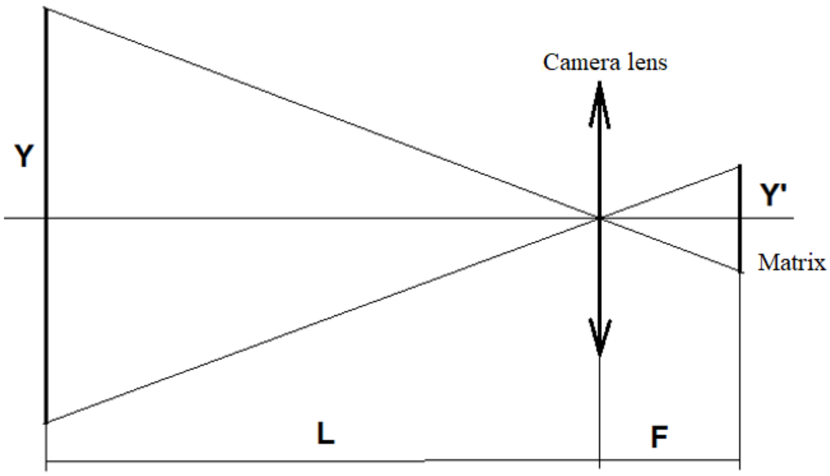

Figure 4. Equivalent scheme of the camera.

Y – it is the size of the symbol to be recognized. In most cases the size of the symbol or letter on the monitor screen does not exceed 3 mm. The same size can be taken for the symbol on the paper.

L – shooting distance. When using quadcopter for surveillance of rooms it is possible to lead it up to the very window or 3-5 m away from the window stealthily. Taking into account the size of the room itself, we will get optimal distance of 15 m.

F – focal length of camera objective.

The size *Y’* is four discrete elements of matrix resolution, which the symbol image should be projected onto.

Our task is to determine the appropriate camera resolution and to choose necessary objective, which are able to recognize the text on the monitor screen or paper document, if they are visible through the window of the room.

Focal length should be chosen in advance from the objective catalogue. For these purposes will be quite suitable an objective with 25 mm focal length [7].

From figure 4 we can find the size *Y’* if we follow the conditions mentioned above:

$$Y' = \frac{Y * F}{L} = \frac{(3*25)}{15000} = 0,005\ mm \qquad (6)$$

This is the size of four resolution elements. Then the size of one matrix element will be 0.00125 mm.

When using most wide-spread matrix of 1/3 inch format, the length of the sides will be 4.52 by 3.39 mm. thus, the number of matrix resolution elements in horizontal direction will be 4.52 / 0.00125 = 3600, in vertical direction 3.39 / 0.00125 = 2700. The total number of matrix resolution elements is 10 Mn. pixels.

Naturally, with such a resolution we are speaking only about photo shooting. To provide the necessary resolution for video shooting, at least 50-mm focal length objective is required.

To perform surveillance based on presented calculations it is possible to use the quadcopter F450, which represents DIY set [8].

The GPS module enables the quadcopter to get back to base location, to hold the height in windy weather with the accuracy of 2.5 m horizontally 0.8 m vertically.

The frame of F450 is made of ultra-strong plastic armed with glass fibre. It consists of 4 beams with 45-sm diagonal. The mass of the frame is 282 g. As a power drive unit, one can use the engines 2312E, propellers 9450 and propeller control units 420 Lite.

Relevant question is reducing the noise level. To reduce the noise, one should increase the size of the propellers, and reduce their speed, while the weight of the propeller should remain quite low.

The parameter of rotation number (kV) is also important. With high value of kV, the engine has less number of winding loops [9]. Thus, the less kV value is, the more the spin-producing moment is. In accordance with the spin-producing moment value, the propellers are chosen. The lower the kV parameter value is, the bigger propellers can be used. In our case the most appropriate variant is the 11-inch propellers with the pitch of 4,7.

4. Conclusion

This article considered theoretical aspects of using quadcopters with acoustic and optic surveillance means. The obtained calculation results allow making a conclusion about the necessary measures against the organization of any information leakage channels by any wrongdoer. The obvious protection means is continuous monitoring of building front face or area perimeter at a distance not less than 15 metres from possible sources of acoustic or visual information, and also the use of simplest means of acoustic and optic screening and preventing direct visibility of information sources within the known limits.

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