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DETERMINATION OF UNMANNED AERIAL VEHICLE STABLE CONNECTION DISTANCE UNDER THE INFLUENCE OF WOODLAND

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Abstrakt. *Data are given about the necessity to use double obstacles method with the specific attenuation inside the woodland. Attempts are made to conduct analysis of Unmanned Aerial Vehicle Stable connection distance determination inside the woodland. It allows to take into account the peculiarities of woodland influence in the stable connection distance forecast.*

Keywords: connection, reach, modeling, prediction, radiowave.

Introduction. There are many radio – electronic means of flight control, video surveillance, communication system etc. on boards of UAV (Unmanned Aerial Vehicle). All radio complex functioning is performed by the ground – based electronic equipment of the external crew, date collection and processing system. Also there is a steady connection with all channels of communication system, especially on stages of low –altitudes flights and maneuvers before landing.

During the low – altitudes flights (less than 300 m) between the control tower (external crew) and board the obstracle in the form of woodland can be encountered. Thus, it’s important to take into account the influence of woodland during the forecast of distance of stable connection determination with UAV.

Review of methods. For a terrestrial radio path where one terminal is located within woodland or similar extensive vegetation, the additional loss due to vegetation can be characterized on the basis of two parameters:

– the specific attenuation rate (dB/m) due primarily to scattering of energy out of the radio path, as would be measured over a very short path;

– the maximum total additional attenuation due to vegetation in a radio path (dB) as limited by the effect of other mechanisms including surface-wave propagation over the top of the vegetation medium and forward scatter within it.

In fig. 1 the transmitter is outside the woodland and the receiver is a certain distance, d, within it. The excess attenuation, A_{ev}, due to the presence of the vegetation is given by:

$$A_{ev} = A_m\left[1 - \exp(-d\gamma / A_m)\right],$$

where d – length of path within woodland (m); γ – specific attenuation for very short vegetative paths (dB/m); A_m – maximum attenuation for one terminal within a specific type and depth of vegetation (dB). It is important to note that excess attenuation, A_{ev}, is defined as excess to all other mechanisms, not just free space loss. Thus if the radio path geometry in fig. 1 were such that full Fresnel clearance from the terrain did not exist, then A_{ev} would be the attenuation in excess of both free-space and diffraction loss. Similarly, if the frequency were high enough to make gaseous absorption significant, A_{ev} would be in excess of gaseous absorption.

It may also be noted that A_m is equivalent to the clutter loss often quoted for a terminal obstructed by some form of ground cover or clutter.

Decision of problem. The value of specific attenuation due to vegetation, γ dB/m, depends on the species and density of the vegetation. Nomogram values are given in Recommendation [2] as a function of frequency. At frequencies below 1 GHz vertically polarized signals to experience higher attenuation than horizontally, this being thought due to scattering from tree-trunks. It is stressed that attenuation due to vegetation varies widely due to the irregular nature of the medium and the wide range of species, densities, and water content obtained in practice. The values shown in homogram 2 should be viewed as only typical. At frequencies of the order of 1 GHz the specific attenuation through trees in leaf appears to be about 20 % greater (dB/m) than for leafless trees. There can also be variations of attenuation due to the movement of foliage, such as due to wind.

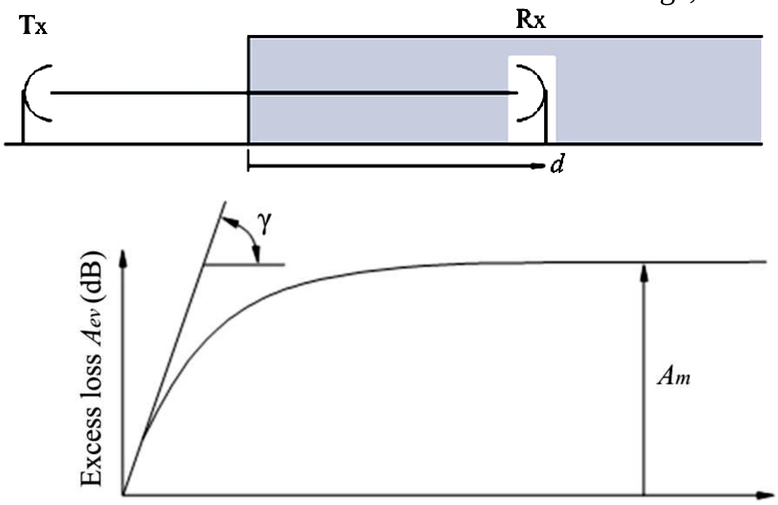

Fig. 1. Representative radio path in woodland

The maximum attenuation, A_m as limited by scattering from the surface wave, depends on the species and density of the vegetation, plus the antenna pattern of the terminal within the vegetation and the vertical distance between the antenna and the top of the vegetation.

A frequency dependence of A_m (dB) of the form:

$$A_m = A_1 f^{\alpha},$$

where f – operating frequency (MHz); α – ratio of the forward scattered power to the total scattered power, numerical value is given in [1].

The diffraction consideration of the edge of woodland is described next. The definition of diffraction loss must be reviewed with the single knite – edge obstacles. In this extremely idealized case (fig. 2, *a* and *b*), all the geometrical parameters are combined together in a single dimensionless parameter normally denoted by ν which may assume a variety of equivalent forms according to the geometrical parameters selected:

$$\nu = h\sqrt{\frac{2}{\lambda}\left(\frac{1}{d_1} + \frac{1}{d_2}\right)}, \qquad \nu = \theta\sqrt{\frac{2}{\lambda\left(\frac{1}{d_1} + \frac{1}{d_2}\right)}},$$

$$\nu = \sqrt{\frac{2h\theta}{\lambda}}, \qquad \nu = \sqrt{\frac{2d}{\lambda} \cdot \alpha_1 \alpha_2}.$$

where h – height of the top of the obstacle above the straight line joining the two ends of the path; d_1 i d_2 – distances of the two ends of the path from the top of the obstacle; d – length of the path; θ – angle of diffraction (rad); α_1 i α_2 – angles in radians between the top of the obstacle and one end.

Nomogram values loss $J(\nu)$ (dB) as a function of ν is given in [2]. $J(\nu)$ is given by:

$$J(\nu) = -20 \log \left(\frac{\sqrt{[1 - C(\nu) - S(\nu)]^2 + [C(\nu) - S(\nu)]^2}}{2} \right),$$

where $C(\nu)$ and $S(\nu)$ are the real and imaginary parts respectively of the complex Frenel integral $F(\nu)$.

For ν greater than – 0,78 an approximate value can be obtained from the expression:

$$J(\nu) = 6{,}9 + 20 \log \left(\sqrt{(\nu - 0{,}1)^2 + 1} + \nu - 0{,}1 \right).$$

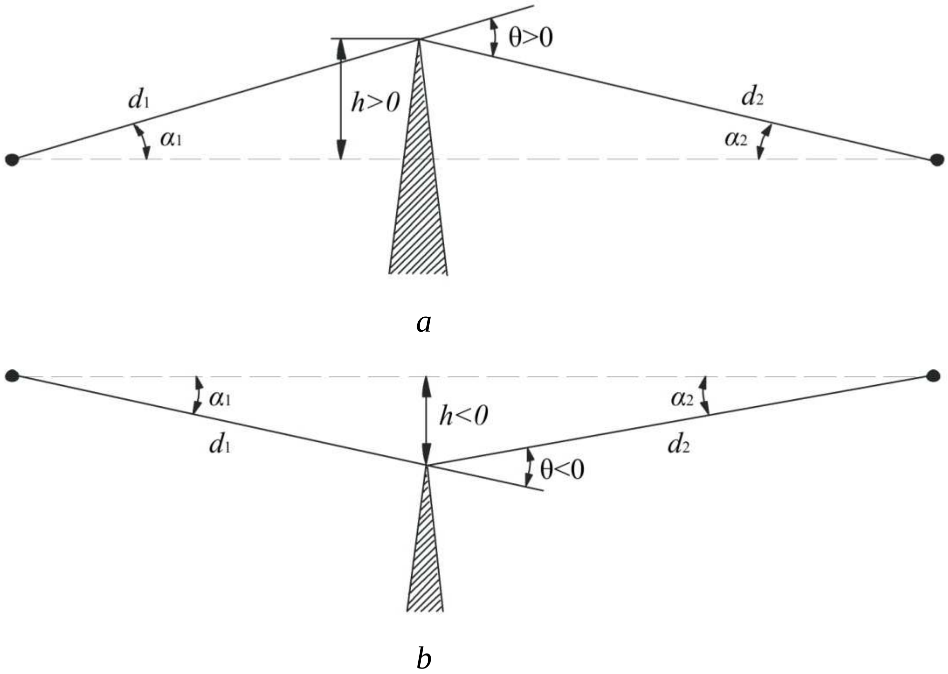

Fig. 2. Geometrical elements profile of the path

Let's observe the loss of diffraction on the edge of double obstacles in the form of woodland front and rear edges. This method consists of applying single knife-edge diffraction theory successively to the two obstacles, with the top of the first obstacle acting as a source for diffraction over the second obstacle (fig. 3).

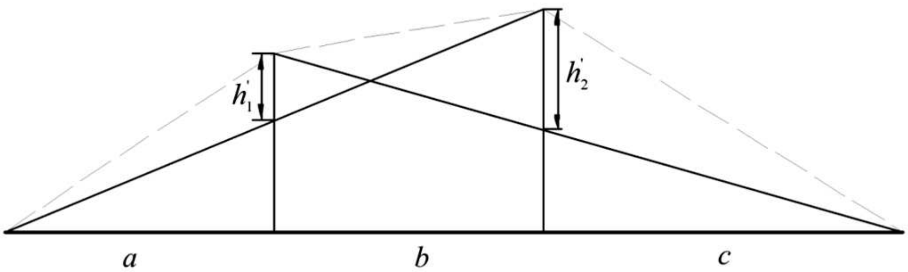

Fig. 3. Demonstration of the method for double isolated edges

The first diffraction path, defined by the distances a and b and the height h'_1 gives a loss L_1 (dB). The second diffraction path, defined by the distances b and c and the height h'_2 gives a loss L_2 (dB). L_1 and L_2 are calculated using formulae of [2]. A correction term L_c (dB) must be added to take into account the separation b between the edges. L_c may be estimated by the following formula

$$L_c = 10 \log \left[\frac{(a+b)\,(b+c)}{b\,(a+b+c)} \right],$$

This formula is valid when each of L_1 and L_2 exceeds approximately 15 dB. Then the total diffraction loss is defined as:

$$L = L_1 + L_2 + L_c \,.$$

The above method is particularly useful when the both edges give similar losses. It’s typical for the majority of European woodland when they are bordered with grasslands and fields.

Conclusion. To increase forecasts accuracy of radio waves propagation and distance of stable connection determination with the UAV during the low – altitude flights, it’s necessary to consider the effects of diffraction and diffusion on the woodland edges. It’s important to note that the most important stage of flight is gaining the altitude by the UAV after taking – off and maneuvering before UAV landing on the airfield.

To perform UAV flights, normative documentation gives the airfield or aerodrome sertification. The attention is given to the radio – electronic UAV average range. However, the usage of average range values is considered to be unacceptable, because the real distance values of stable UAV connection in all ranges and all azimuth values will differ from the average one. Thus, it’s necessary to pay attention to all features of terrain, especially woodland, for accurate forecast of stable connection distances.

References

1. *Recommendation* of the International Telecommunication Union ITU R.833 (02/2007) “Attenuation in vegetation”.
2. *Recommendation* of the International Telecommunication Union ITU R.526-12 (02/2012) “Radio wave propagation by diffraction”.

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Визначення відстані стійкого зв’язку з безпілотним літальним апаратом в умовах впливу лісного масиву

Проведено аналіз моделей визначення відстаней стійкого зв’язку в умовах лісного середовища. Виявлено доцільність використання методу подвійних перешкод разом з урахуванням погонного ослаблення всередині лісного масиву. Це дозволить більш точно враховувати особливості впливу лісних масивів при прогнозуванні відстаней стійкого зв’язку.

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Определение расстояния устойчивой вязи с беспилотным летательным аппаратом в условиях влияния лесного массива

Проведен анализ моделей определения расстояний устойчивой связи в условиях лесного массива. Показана целесообразность применения метода двойных препятствий совместно с учетом погонного ослабления внутри лесного массива. Это позволит более точно учитывать особенности влияния лесных массивов при прогнозировании расстояний устойчивой связи.