Model of ground radio control coverage area

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***Abstract*—In this paper the offered model of coverage area for wireless networks is realized in two stages: calculation of middle radius of coverage area and his further elaboration by geometrical methods along the separate directions with the expressed relief inhomogeneities. Underestimation of this factor can be a reason of absence of receiving signal which leads to interruption of integrity of information, or can be an occasion of propagation of radiowaves beyond of destination area which creates a precondition of leaking or physical interception of information. results allow to promote the level of informative integrity, availability and safety of wireless networks due to a removal of propagation of radiowaves out of setting. They promote reduction of probability of leaking and physical interception of information as well as retain of necessary level of availability and integrity of information**

***Keywords*—- wireless networks, coverage area, model of propagation of radiowaves, base station, terminal, availability of information, integrity of information, interception of information, leaking of information**

I. INTRODUCTION

The development of unmanned aerial vehicles (UAV) with unmanned aerial systems (UAS) and related information technologies requires to ensure the confidentiality, integrity and availability of information. Quality of radiowaves propagation in data exchange systems affect these factors. Currently, the vast majority of telecommunications operators use of varieties Okumura-Hata and COST-231 models, which can determine only the so-called averaged propagation loss values and corresponding averaged radius of zone, and which are correct under the condition, that the coverage area has a circular shape. This occurs due to the fact, that these models take into account only the generic nature of the terrain, antenna height, working frequency, transmitter power and the distance to the observation point, and does not take into account such a phenomena as multi interference and diffraction on obstacles.

However, the real terrain contains a buildings, forests, mountains and other inhomogeneities, which are large in comparison with the wavelength, so the actual area has a significant deviation from the shape of a circle - so-called outbursts and failures. Therefore, the actual distance of stable connection can be several times greater or less than the predicted average value - for example, in the gorges, in the forests, on the dam of the mountains, and others. These factors can lead to a lack of communication with UAV, i.e. to the loss of availability of information, or propagation a data carrier on distance far exceeding the projected values, that can create conditions for the unauthorized interception of data.

These factors may adversely affect the integrity of information and security of wireless networks in the following aspects:

- the actual propagation of data carrier outside of a distance more or less than expected;
- the possibility of leakage of information or lack of it at the point of the reception;
- the creation of unacceptable levels of mutual interference that adversely affect the quality of data;

From these preliminary comments we make conclusions about the necessity for developing such methods of forecasting of coverage area that have a sufficient simplicity and would allow to take into account the inhomogeneities of the real terrain.

II. THE ANALYSIS OF EXISTING RESEARCH

The most common practical application of Okumura-Hata formula, which obtained from the numerical measurement of averaged power losses values in the propagation of radio waves L as an equation with respect to distance radius zone d, is as follows [1]

$$L = 69{,}55 + 26{,}16 \lg f - 13{,}82 \lg h_1 - a(h_2) + \\ + (44{,}9 - 6{,}55 \lg h_1) \lg d - K \qquad (1)$$

where h_1 - height of the antenna control point, m; h_2 - altitude of UAV, m; d - distance between the point of control and UAV, km; f - operating frequency, MHz; $a(h_2)$ - height correction factor which depends on the frequency and is averaged by type of locality, i.e. city, suburb or village [1,2]; K - extra weight coefficient for rural areas and suburbs whose value is given in [2,3]. In practice, using this formula was established [3] that it underestimates the losses at frequencies of 1.5... 2 GHz in a city or dense massif. So, later was offered "Augmented Model Hata" that has eliminated this deficiency. The main value of this model for the averaged propagation losses is

$$L = 46,33 + (44,9 - 6,55 \lg h_1) \lg d + 33,9 \lg f - \\ - a(h_2) - 13,82 \lg h_1 + C \qquad (2)$$

where weight coefficient C = 0 for villages and suburbs, C = 3 for the city or dense massif.

This model takes into account only the type of locality (town, suburb, village), but does not take into account the specific elevation of real obstacles which are hundreds of times more than the operating wave length. But on the real obstacles the radio waves experience of significant diffraction losses with the formation of significant "gaps" in the areas of attainability, and in the cross-sections or streets canyons the repeated reflection with a small difference in path length is the reason of multibeam interference phase to form multiple "emissions" in the range of attainability. Therefore, the most common method of forecasting of attainability by Okumura-Hata model, which does not account for these phenomena, makes it impossible to predict the impact of specific parts of the terrain - mountains, slopes, ravines, clusters of houses, streets, etc. But this averaged prediction of coverage area could cause actual propagation outside the purpose limits or lack of it in the expected point of space with all the effects listed above. In addition, Okumura-Hata model and its modifications as COST-231 model limited the height position of the UAV antenna.

The aim of this work is to improve existing models of forecasting coverage area for networks and data communication through the combined use of propagation model takes into account the geometric parameters of the specific details of the terrain. Such an approach would avoid the propagation phenomena beyond the intended purpose and their absence in the expected points in space by getting actual information about distances of stable connection between a control point and UAV that will build a detailed map of coverage. This in turn helps to avoid possible deterioration of integrity or availability of information leakage in the UAS networks of data exchange.

III. THE BULK OF RESEARCH

For qualited forecasting of coverage area we offer computational procedure which is carried out in two stages. In the first stage, based on the values of the height of the control point antenna and UAV operating frequency, and the ratio between known values of transmitter power and receiver sensitivity on board, the average radius of the range is determined on the base of the Okumura-Hata model given above, according to the value of the average power loss in the propagation path of radio waves. In the second stage it takes into account the peculiarities of the terrain, for example:

- clusters of buildings, structures, slopes, etc., which cause diffraction losses and appropriated "failure" in the coverage area,
- availability of gorges, streets with tall buildings, in which there are cross-sections multibeam interference phenomena with the formation of "emissions" in the coverage area.

Thus, on the second phase of forecasting we offer to make specification of averaged distances values of stable connection in certain area, where there are the details of topography listed above, and which are ignored by the Okumura-Hata model and its modifications. Obviously, the specifying second stage requires such a propagation model which takes into account the diffraction on obstacles and multipath interference in a real location. Therefore, in the second stage we use the Walfisch-Ikegami forecasting model [1,2]. It gives quite accurate results at frequencies from 0.8 to 5 GHz, and at distances from 20 to 10,000 m. This model allows us to analyze separately two cases: propagation through the line of sight and in the "shaded" area out of sight. In conditions of line of sight Walfisch-Ikegami formula for distributing losses L is:

$$L = 42,64 + 26 \lg d + 20 \lg f \qquad (3)$$

where d - distance to the reception point, km; f - operating frequency, MHz.

For the region of space beyond the line of sight with the diffraction phenomenon, propagation losses consist of losses in free space L_{fs} and multiple diffraction losses L_{md}. For these phenomena Walfisch-Ikegami model is:

$$L = \begin{cases} L_{fs}, \text{ if } L_{fs} + L_{md} < 0; \\ L_{fs} + L_{md} + L, \text{ if } L_{fs} + L_{md} > 0, \end{cases} \qquad (4)$$

where L_{fs} - propagation losses in free space, defined by the formula

$$L_{fs} = 32,45 + 20 \lg d + 20 \lg f \qquad (5)$$

L_{md} - multiple diffraction losses, which are determined by the formula

$$L_{md} = -16,9 - 10 \lg n + 10 \lg f + 20 \lg \Delta h + L_O \qquad (6)$$

In the last expression n - the number of points of diffraction, Δh - the value of exceeding line of sight by obstacle, m; L_0 - estimated losses, depending on the angle of diffraction as follows:

$$L_0 = \begin{cases} -10 + 0,354 \lg \varphi, & 0 \le \varphi \le 35° \\ 2,5 + 0,075 \lg (\varphi - 35°), & 35° \le \varphi \le 55° \\ 4,0 - 0,114 \lg (\varphi - 55°), & 55° \le \varphi \le 90° \end{cases} \qquad (7)$$

Obstacles height and distance between them along the direction of propagation are couted by additional factor of multiple losses L_m:

$$L_m = L_{sh} + k_a + k_d \lg d + k_f \lg f - 9 \lg b \qquad (8)$$

where k_a, k_b, k_f - extra weights that take into account losses depended on the distance and frequency for the conditions of the city, suburbs and villages, and which are determined by special nomograms provided in [3]; b - distance between obstacles, m; L_{sh} - attenuation while propagation in the shadows zone:

$$L_{sh} = \begin{cases} -18\lg(1+\Delta h), & \Delta h > 0 \\ 0, & \Delta h \le 0 \end{cases} \quad (9)$$

To account for multibeam interference phenomena in the valley or the street alignment we propose the following procedure. Firstly, it is necessary to determine the presence of sight alignment in the gorge between the control point antenna and UAV. Next, it is need to determine the number of possible points of reflection N, depending on the length of the street (gorge). Tentatively it can be considered $N = 3$, since most of the radio waves reflect from the right and left walls of the gorge and the underlying surface. Thus, the estimated value of the multiplier multibeam interference L_{mi} can take a triple multiplier comparatively with value losses in free space L_{fs}:

$$L_{mi} = 3L_{fs} = 3(32{,}45 + 20\lg d + 20\lg f). \quad (10)$$

The proposed calculations in two-stage forecasting was tested for these parameters: the operating frequency is 1 GHz, ground radio control antenna height is 5m, UAV antenna height above ground level is 50m, obstacles height is 20m, distance between them is 30m, their mutual orientation is consecutive.

The calculations showed that the magnitude of multiple losses increases to 30 dB/decade in the case when control point antenna location is below the obstacle level, and to 18 dB/decade when its location is above the obstacle level. In addition, multibeam interference phenomenon increases the value of multiple losses at least three times if the location of the control point antenna is in the alignment of the gorge. These values are very important, but when we use all kinds of models by Okumura-Hata and COST-231 they are not considered at all.

An examination of the results shows, that the model of coverage area which considers the specific details of relief, unlike the existing models with calculations on the basis of average losses, make it possible to consider:

- the presence of cluster with one or more obstacles, which causes the diffraction losses and forms the "failure" zone within the coverage area;

- such a location of obstacles, that causes the multipath interference with the formation of "emissions" zone within the coverage area.

Thus, the proposed model of calculating of coverage area while designing telecommunications networks for UAS, unlike the existing ones, takes into account diffraction and interference phenomena that cause substantial dependence of stable connection distances on the direction of propagation.

IV. CONCLUSION

The model which is proposed in this paper deals with calculating of coverage area during designing UAS networks for data exchange. It provides accurate determination of the distance of stable connection depending on the direction of propagation that enables to avoid the spread of a data carrier outside the limit of appointment or absence of it in expected point of reception.

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