Propagation Of Millimeter Radio Waves On Microcellular Communication Links

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***Abstract-* Studying the theoretical and experimental data which are obtained from using millimeter wave MMW, in microcellular links shows that it is impossible to neglect the value of power , reflected from a spreading surface and from local subjects. And with the growth of reflection area, the received signal can be increased to some decibels as it is described in this scientific work.**

Keywords-* *propagation, microcellular, link, reflection, frequency.

Introduction

When using millimeter wave (MMW) systems in microcellular telecommunication networks the level of received signal is determined by the sum of signals, reflected from spreading surface and coming on direct optically visible path. In the known techniques of designing of microcellular communication systems the influence of reflected signals on characteristics of these systems is not taken in consideration yet. However experiments show, that reflected signals being mixed with a signal of a direct ray, increase the level of received power and can't be neglected. For definition of influence area of reflection on the level of received MMW signals on microcellular paths, the theoretical and experimental researches at the Vladimir State University were fulfilled. The present article is directed for the discussion of the obtained results.

When the site of waves reflection (a1 + a2 in Fig.1) has passive micro-transmitters with sizes, which are commensurable with a wavelength of MMW signals and are chaotically oriented concerning of propagation direction of a radio wave, it is possible to suppose [1-3], that the result of reflection will be a superposition of a great number of separate rays with random amplitudes and random phases. Thus as a result of reception of reflected and direct signals the resulting input signal of the receiver will be defined as the sum of powers of determined signal and great amount of random signals. A received signal is a sum of direct component and random components.

Model of a Millimeter-wave Microcellular Channel

The scheme of link for which the model of MMW propagation is developed is shown in Fig.1.

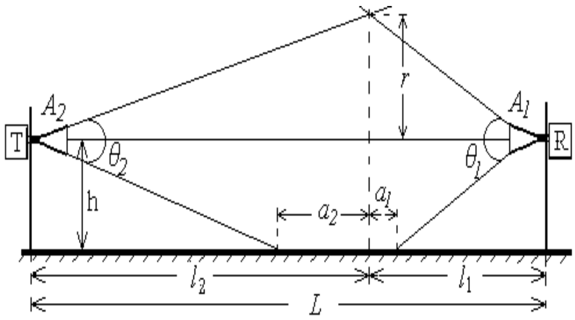

Fig. 1. The scheme of a site of microcellular MMW transmission link network.

Let's consider a geometrical model of the process of reflections, for which we believe, that the energy of a signal is radiated [4-5] and is received by the system inside space angles limited by the radiation patterns of antennas A1 and A2, as shown in Fig. 1.

The plane of reflection of signals from a spreading surface represents the section of a geometrical shape is formed from two circle cones, having in general different apex angles. Let's suppose, that the overall radiation pattern of a micro spot of reflection has omnidirectional character. The top view of the reflection area of the signals on the path shown in Fig. 1, is represented in Fig.2.

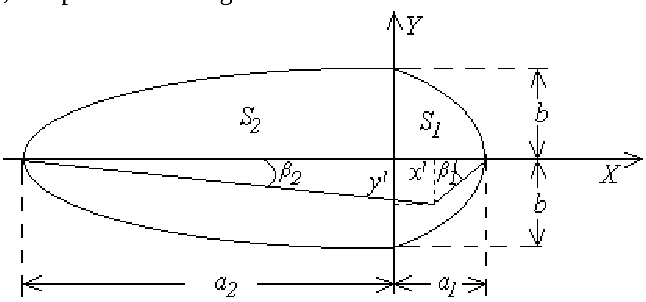

Fig.2. A platform of reflections from a spreading surface.

If it is supposed that average power of signals reflected by different reflectors is identical, then the overall power of the reflected signal from all areas (S2 +S1 (Fig. 2) is proportional to the area of the areas that are participating in the signals reflection.

From geometrical relations it is possible to define:
Parameters of segments of a parabola:

$$b = \sqrt{r^2 - h^2}; \quad a_1 = l_1 - hctg\frac{\theta_1}{2}; \quad a_2 = l_2 - hctg\frac{\theta_2}{2}$$

And area under segments:

$$S_1 = \frac{4}{3} ba_1; \qquad S_2 = \frac{4}{3} ba_2.$$

The common area of signals reflection from a spreading surface will be defined as

$$S = \frac{4}{3}[L - h(ctg\frac{\theta_1}{2} + ctg\frac{\theta_2}{2})]\sqrt{\left(\frac{Ltg\frac{\theta_1}{2}tg\frac{\theta_2}{2}}{tg\frac{\theta_1}{2} + tg\frac{\theta_2}{2}}\right)^2 - h^2} \quad . \qquad (1)$$

For the accepted model, when $h \le r$ the power proportional to the value $k\sqrt{r^2 - h^2}$, is added to the fixed power of a received signal coming by a direct optically visible way, , where k - some coefficient that is determined by the properties of elementary reflecting spots of a spreading surface.

The offered model can be specified if to take in consideration that there is no uniformity in radiation patterns inside the angles θ_1 and θ_2. In this case each reflecting element of the area *S* brings into the common received power its own part distinct from others.

Let's select a reflecting element with coordinates x^1, y^1 and designate the radiated power along an axis of antennas as P_{01} . And the power radiated by the antenna in the direction on the selected reflecting element with angle β in horizontal plane from an axis of antennas and making the angle α downwards in vertical plane, is designated as $P_{u1}(\alpha_1, \beta_1)$. Similarly for the second antenna we shall designate $P_{u2}(\alpha_2, \beta_2)$. Relative values of powers we shall designate as $q_1 = \frac{P_{u1}(\alpha_1, \beta_1)}{P_{01}}$ and $q_2 = \frac{P2(\alpha_{2,}\beta2\}}{P_{01}}$

.

For such model the power of a reflected signal will be proportional to the integral of the product $q_1 q_2$, which is taken across the area *S*. The boundaries of the area are defined by the curves: for area *S*1: $x^1 = \alpha^1 - y_1^2$, and for area S2: $x^1 = y_1^2 - \alpha_2$.

The appropriate integral will look like:

$$Y = \int_{-b}^{b}\left[\int_{0}^{a_1 - y_1^2} q_1 q_2 dx^1\right] dy_1 + \int_{-b}^{b}\left[\int_{y_1^2 - a_2}^{0} q_1 q_2 dx^1\right] dy_1 . \qquad (2)$$

The radiation patterns of circle antennas are precisely described by the functions proportional to this value:

$$\frac{sin(\frac{2\pi\alpha}{\theta})\, sin(\frac{2\pi\beta}{\theta})}{(\frac{2\pi\alpha}{\theta})(\frac{2\pi\beta}{\theta})}$$

Then the integrand function in expression (2) will be determined as:

$$q_1 q_2 = \left[\frac{\sin\frac{2\pi\alpha_1}{\theta_1}\sin\frac{2\pi\beta_1}{\theta_1}\sin\frac{2\pi\alpha_2}{\theta_2}\sin\frac{2\pi\beta_2}{\theta_2}}{16\pi^4\alpha_1\alpha_2\beta_1\beta_2/\theta_1^2\theta_2^2}\right]^2$$

Here angels $\alpha_1, \alpha_2, \beta_1, \beta_2$ are defined by the formulas:

$$\alpha_1 = arctg\frac{h}{a_1 - x^1}; \qquad \alpha_2 = arctg\frac{h}{a_2 + x^1};$$

$$\beta_1 = arctg\frac{y_1}{a_1 - x^1}; \qquad \beta_2 = arctg\frac{y_1}{a_2 + x^1}.$$

The received power of reflected signal is proportional to the integral (2), and the whole power of the received signal P_S is the sum of direct power P_d , passed by the optically visible way, and the reflected power P_{ref} from a spreading surface and local subjects on a path of link.

Experimental Researches and Discussion

In Fig. 3 the graphic of power P_S which is calculated considering the reflected component (2) for different values of antenna raising heights *h* where the results of experimental measurements of the power of received signal are represented. The experiments were carried out on the microcellular path by extent $L = 43m$, with the frequency 28056 MHz, transmitted power 1мВт and the following angles of antenna radiation patterns $\theta_1 = 3{,}0^0$, $\theta_2 = 8{,}0^0$.

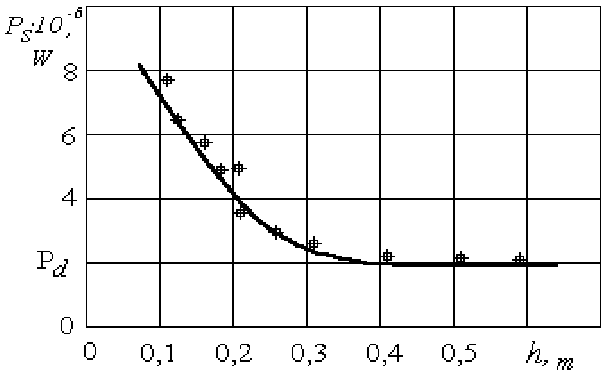

Fig3. Dependence relationship between received power and antennas increasing heights values above the spreading surface.

Obtained theoretical and the experimental data show, that in microcellular with MMW link it is impossible to neglect the value of power P_{ref}, reflected from a spreading surface and from local subjects [6]. And with the growth of the area of reflection of the received signal can be increased to some decibels [7].

It is possible to explain the large slope of dependence of received power on the increase of antennas height by the fact that simultaneously with the growth of the reflection area the angles of incidences and wave reflections are diminished.

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