БЪЛГАРСКА АКАДЕМИЯ НА НАУКИТЕ . BULGARIAN ACADEMY OF SCIENCES

ПРОБЛЕМИ НА ТЕХНИЧЕСКАТА КИБЕРНЕТИКА И РОБОТИКАТА, 46
PROBLEMS OF ENGINEERING CYBERNETICS AND ROBOTICS, 46

София . 1997 . Sofia

An Improved Statistical Model of Communication Channel in the Cellular Radiotelephone Networks

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Introduction

A comparatively simple model of communication UHF channel is described in [1]. The multi-storey housing development and vertical displacement of the buildings are not taken into account. These are the basic model disadvantages. In this paper an attempt for their elimination is made. For this reason the bulk density of the development is entered and thus the approximation of the model is close to the experimental data, obtained in [2, 6].

Formulation of the problem

A plane model of the rejection of single building is shown in Fig. 1, [1]: *A*, *B* and *C* are the points where the radiative and receiver antenna and reflective area are arranged respectively. The sum of the distances $r_1 + r_2 = r$, covered by the ray in any position of *C* on the ellipse is a constant value. Therefore, evrey reflector, positioned on its tangent will generate a ray with a delay $\tau = r/c$, where *c* is free space light velocity.

In this way the approximate value of the big semi-axis of the ellipse is

(1) $$2a \approx (\sin^2(\theta) + \lambda / r)^{-1} \sqrt{\lambda r [1 - (r_0 / r)^2 + (\lambda / r)]},$$

where λ is a wave length.

From this expression it follows that for distances about 10km, covered by the ray (this distance corresponds to cell radius 5km), the big semi-axis of the ellipse will vary from about 10m to 55m. This does not exceed the dimensions of the building walls.

Mathematical model

The reflectors, positioned on the ellipse, generate rays, directed to the point of receiving only if they are suitably oriented. When the orientation is correct, the reflected ray falls on the point of receiving only when thre is no obstacle. The probability of this event can be determinde taking into account the multi-storey development and vertical displacement of the buildings. It is assumed that the development is parallelpiped and D^2 is the basis and H is the height. The single buildings in this development have the same form and d^2 and h are the basis and height, respectively. Accordingly, the relative bulk density of the development is:

(2) $$\zeta = \frac{d^2 \ h}{D^2 \ H} = \sqrt{\xi \eta},$$

where n is a coeffcicient for the multi-storey development and vertical displacement.

Since the positioning of development and of each building is a stochastic event with respect to the reflective ray, the probability to neet an obstacle is:

(3) $$D_{av} = \frac{d \ h}{D \ H} = \sqrt{\xi \eta} = \sqrt{\zeta \eta}\,.$$

Therefore, the probability for free transition is

(4) $$P_{tr1} = 1 - \frac{d \ h}{D \ H} = 1 - \sqrt{\zeta \eta}.$$

Taking into account the number of developments, passed by the ray – $[(r - r_0)/D]$, the total probability for transition is:

(5) $$P_{tr} = (1 - \sqrt{\zeta \eta}\,)^{(r - r_0)/D}.$$

The rays, reflected by the buildings, positioned on one ellipse and reaching the receiver are summing up. The investigations show that in a mulipath channel the most important is the non-coherent summation parctically. Let m be the designation of the number of reflectors, positioned on the ellipse. In fact this is the ratio between the length of the ellipse nad the length of the development, multiplied by a factor $H/2a$. Then the number k of the summing rays in the point of receiving is stochastic quantity, distributed binomially $p(k) = C_m^k p_n^k (1 - p_n)^{m-k}$, where $p_n = p_{or} p_{tr}$ is the probability of non-coherent summing up; p_{or} is the probability of correct orientation of the reflector,

(6) $$p_{or} = \frac{1}{2\pi} \sqrt{\frac{\lambda}{r}} \ \sqrt{1 - \left(\frac{r_0}{r}\right)^2 + \frac{\lambda}{r}}\ .$$

The total power in the receiving point is

(7) $$P_{2\Sigma} = kP_2 = kP_1(\gamma^2\lambda^2)/(4\pi r)^2,$$

where P_1 is radiated power.

The average value of power in the receiving point can be obtained averaging (7) by all possible values of k:

(8) $$P_{2\Sigma} = P_2(r) = kP_1(\gamma^2\lambda^2)/(4\pi r)^2 = p_n m P_1(\gamma^2\lambda^2)/(4\pi r)^2,$$

where γ is the reflection factor.

Taking into consideration the substitution of p_n and assuming that $r>>r_0$, and that the ellipse is transformed into a circle (i.e., $m=\pi r H/2aD$), (8) is modified,

(9) $$P_2(r) = P_1(\gamma^2\lambda^2)/(4\pi r)^2 H \frac{\sqrt{\lambda} r}{4aD} \sqrt{1-\left(\frac{r_0}{r}\right)^2} + \lambda / r\,(1-\sqrt{\zeta\eta})^{(r-r_0)/D}.$$

If (9) is divided by the radiated power P, taking into account $r=\tau c$, it is obtained that the average transmission coefficient of the channel $K_p(\tau)$, is

(10) $$K_p(\tau,\xi,\eta,H.\ D) = \gamma^2 \left(\frac{\lambda^2}{4\pi}\right) \frac{H}{4aD} \sqrt{1-\left(\frac{r_0}{r}\right)^2} + \lambda / \tau c\,(1-\sqrt{\zeta\eta})^{(r-r_0)c/D}$$

The dependence of K_p on τ is shown in Fig. 2 and Fig. 3 for $\lambda = 0.33$m and $\gamma = 1$. It can be seen that taking into consideration multi-storey housing development and vertical displacement of the buildings, the passibility of the multipath channel becomes better as can be expected.

This effect is most significant when the delay of the reflected rays is greater than 5 for the example, shown in Fig. 2.

Fig. 3

Conclusions

At the end, taking into consideration the analytical and graphical dependencies above mentioned, it can be concluded that the model proposed is as simple as the model considered in [1], but more adequate fo the radio waves propagation in the range useful for cellular radiotelephone networks.

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Улучшенная статистическая модель коммуникационного канала в сотовых радиотелефонных сетях

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Предлагается относительно простая модель многолучевого распространения радиоволн в частотном диапазоне сотовых радиотелефонных систем и сетей. Отчитывается этажность зданий и особености рельефа путем введения плотности застройки. Таким образом результаты, полученные моделированием, очень близки к экспериментальным.