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METHOD OF MULTIPATH EFFECT ELIMINATION IN MOBILE COMMUNICATIONS

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This article describes the multipath nature of radio waves propagation in space during transmission from the base station to the receiver and the effect on signal information forwarding. It also presents how to combat interference using OFDM technology.

Метод боротьби з багатопроменевістю в мобільному зв'язку

У даній статті описується багатопроменевий характер поширення радіохвиль у просторі при передачі від базової станції до приймача і його вплив на передачу сигналу. Описується спосіб боротьби з впливом інтерференції за допомогою технології OFDM.

The propagation of radio waves in free space, as a rule, depends on several factors, regardless of what radio communication is used for. Among the main factors, there are losses in free space, including receiver noise, additive interference, as well as multiplicative interference, the cause of which is the multipath nature of the propagation of electromagnetic waves that creates interference, i.e. superposition of waves in the receiver.

Apart from direct waves, the mobile receiver will receive some waves reflected from the surface of the Earth or other nearby objects (trees, stationary structures, etc.). Reflected waves with a random phase and amplitude are similar to the main wave, so they can cause some negative changes in the level of the main received signal. The longer the time delay of the reflected ray, the more interference appearance. Contrariwise, a delay significantly shorter than the signal duration is least manifested in reception quality.

Since it is difficult to influence the time delay, we can mitigate the effect of multiplicative noise by adaptively choosing the symbol duration of the transmitted signal, which is comparable (longer) with the time delay.

Thus, it is necessary to solve two problems:

- determine the method of adaptive change in the duration of the transmitted characters;
- estimate the delay time of the reflected rays.

As part of the first task, we note that in UMTS and LTE technologies, Orthogonal Frequency Division Multiplexing (OFDM) is used to transmit down-link streams. From the base station to the terminal, many narrow 180 kHz frequency bands are used for data transmission, instead of expanding one signal over the entire 5 MHz bandwidth, i.e. it uses a large number of narrow subcarriers for data transmission.

In order to solve the problem of the negative effects of multipath fading, OFDM technology is used to split a high-speed stream for one subscriber into a group of low-speed streams with orthogonal frequency division multiplexing. In each slow stream, the symbol durations will increase compared with the original stream by a number of times equal to the number of OFDM subcarriers. By controlling the number of subcarriers, we can control the duration of the transmitted characters.

To solve the second problem, let us look at the deterministic model of the VHF radio channel.

In [2], a mathematical model was proposed that gives a spatial description of the region of reflected rays formation by describing Cassini ovals.

A Cassini oval is a quartic plane curve defined as the set (or locus) of points in the plane such as the product of the distances to two fixed points (focus) is constant and equal to the square of a certain number a, i.e. $a^2 = R_1R_2$.

Assuming that h_1, h_2 are the antenna heights, h_0 is the minimum effective antenna height, P_1 is the transmitter power, G_1 is the antenna gain, η_1 is the efficiency of the energy transmission system from the transmitter to the transmitting antenna, ω_{in} - receiver input resistance, U_{in} is the sensitivity of the receiver, it is possible to determine the region where the energy of the reflected signal exceeds the sensitivity of the receiver.

$$R_1R_2 = \sqrt{(h_1^2 + h_0^2)(h_2^2 + h_0^2)\sqrt{P_1G_1\eta_1b_1\eta_2\omega_{\text{вх}}/U_{\text{вх}}}} \quad (1)$$

Parameter b_1 – is the height of the obstacle located at a distance R_1 from the emitting station (radius of the first Fresnel zone), which can be determined by the dependence: $b_1 = \sqrt{(\lambda R/3)r(1-r)}$ (2), where R is the distance from the transmitting to the receiving antenna; r is the ratio of the distances to the obstacle and from the transmitting to the receiving antenna.

The parameter a depends on the characteristics of the communication system and soil characteristics included into the parameter h_0. Marking half the distance between correspondents $R / 2 = c$, all cases of Cassini ovals can be reduced to the main ones: $a \geq c\sqrt{2}$; $c < a < c\sqrt{2}$; $a = c$; $0 < a < c$.

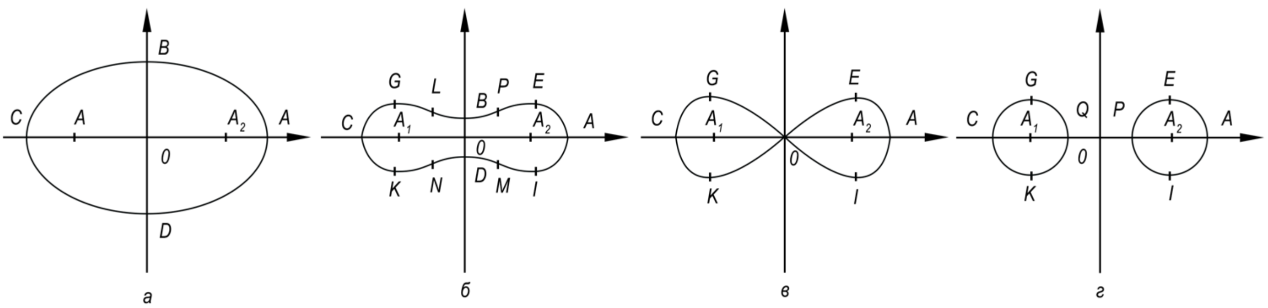

Fig. 1. Forms of zones formation of reflected rays.

In the first case, the Cassini oval is actually an oval with foci at the locations of the receiving and transmitting stations (Fig. 2a). For c < a < c√2; the oval is more compressed in the middle of the route (Fig. 2b). In the third case, where a = c - the reflection zone is a lemniscate (Fig. 2c). When a < c, the oval turns into circles around the locations of the antennas (Fig. 2d).

If we substitute the standard parameter values used in LTE into formula (1), we obtain certain parameter values a and c.

In the microwave range, signal transmission from the base station (point A) to the receiver (point A_1), which are located at a distance R, is illustrated in Fig. 3.

Suppose that the main signal passes from point A to point A_1, but at the same time another signal arrives at the receiver, reflected from the nearest surface. The voltage of the reflected signal exceeds the sensitivity of the receiver. Line A_1-C determines the radius of the reflection zone.

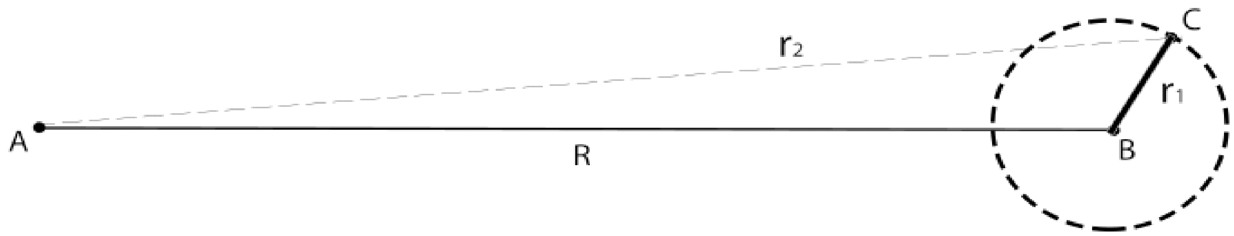

Fig. 2. Signal transmission from the base station to the receiver.

Using the initial parameters of the radio line, it is possible to calculate the diameter of the circle for the case of Fig. 2, d: $d = \sqrt{c^2 + a^2} - \sqrt{c^2 - a^2}$ (3)
and signal response delay: $\Delta t = \frac{d}{C}$ (4), where C is the speed of light.

The calculation of the response delay of the signal will give us the opportunity to compare this value with the duration of one character. Thus, a copy of the reflected previous signal (response) will not come superimposed on the adjacent signal. For this, it is necessary to increase the symbol duration by the time delay of its response by increasing the number of OFDM subcarriers in order to get rid of inter symbol interference.

Thus, OFDM technology will allow decomposing a high-speed data stream into a large number of substreams and transmitting each substream at a separate frequency, while increasing the length of the symbol. Obtaining spatial characteristics in a particular channel, it is possible to select such a number of subcarriers at which it is possible to minimize the influence of the multipath factor.

References

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