INTERFERENCE IN DIRECT SPREAD SEQUENCE MOBILE COMMUNICATION SYSTEM

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Abstract: *In this paper reverse link in the direct spread sequence code mobile communication system has been discussed. First part of the paper deals with interference conditions in the uplink transmission. Interference conditions calculations are based on statistic method by using the average emission power of mobile station in a cell. Also comparison of results obtained by Ramjee Prasad, using calculation of multiple cell interference reduction factors, has been performed. The end of the paper deals with interference conditions in down link transmission.*

Keywords: *Mobile Communications, Spread Spectrum, Interference*

1. INTRODUCTION

A direct spread spectrum mobile communication system is based on the code sharing among the users. All users within a cell group share the same orthogonal codes group. Multimedia applications, dedicated to mobile communication systems of third generation including video telephony or videoconferencing, require higher transmission rate and signal to noise ratio.

In a cellular system, each base station not only receives information from the mobiles in the home cell (intracell interference) but also from terminal located in adjacent cells. Also, each mobile station in observed cell receives information from base station in the home cell as well as from base stations located in adjacent cells.

This paper deals with the interference influence, among users of CDMA system in the reverse and forward link.

2. AVERAGE MOBILE STATION BROADCASTING POWER

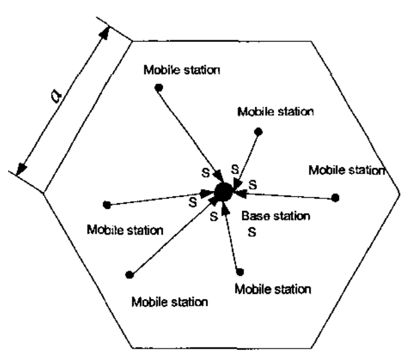


Fig. 1. Cell presentation of CDMA mobile communication system for reverse link

Within one cell of code spread mobile communication system the broadcasting power control system of mobile users has been established. The broadcasting power control system works on the following principle; all signals that arrive to the base station, from different mobile users, have the same power S. The power broadcasted by the mobile station S_{mob} is larger than power S, that base station receives, for the amount of propagation loss L, that can be expressed using expression (1)

$$S_{mob} = S \cdot L \tag{1}$$

where: S_{mob} - mobile station emission power, S - power that base station receives from a mobile station, L - propagation loss. Propagation loss is determined by the propagation low that can generally be expressed as in the equation (2);

$$L = \alpha \cdot d^{\gamma} \tag{2}$$

where: α - coefficient which is complex function of several factors like: working frequency, mobile and base station height, population density and etc, d - distance between base and mobile station and γ - attenuation propagation coefficient. The mobile station emission power can be written as (3);

$$S_{mob} = S \cdot \alpha \cdot d^{\gamma} \tag{3}$$

The mobile stations are equally distributed on the cell. All users within one cell occupy equal partial surface of the cell P_j.

$$P_1 = P_2 = P_3 = \dots\dots = P_j = \dots\dots = P_i \tag{4}$$

Partial surfaces of each mobile station are concentric circles. The radius of the first circle r_1 is function of the first surface P_1. The radius of the second circle r_2 is function of the sum of the first and second surface $P_1 + P_2$. The surfaces of each mobile station are concentric circles. Let suppose that mobile stations are situated on the line that splits the partial surface into two equal parts. Mobile station has radius determined by equation (5).

$$r_{mob(j)} = r_{(2j-1)} = \sqrt{\frac{P_{hexagon}}{2 \cdot i \cdot \pi}} = a \cdot \sqrt{\frac{3\sqrt{3}}{4 \cdot \pi}} \cdot \sqrt{\frac{2j-1}{i}} \tag{5}$$

Mobile station emission of the "j" mobile station is given by (6).

$$S_{mob}(j) = S \cdot \alpha \cdot a^{\gamma} \cdot \left(\sqrt{\frac{3\sqrt{3}}{4 \cdot \pi}} \cdot \sqrt{\frac{2j-1}{i}} \right)^{\gamma} \tag{6}$$

The average mobile station emission is given by (7).

$$S_{mob}(average) = S \cdot \alpha \cdot a^{\gamma} \cdot \left(\sqrt{\frac{3\sqrt{3}}{4 \cdot \pi}} \right)^{\gamma} \cdot \frac{1}{i} \cdot \sum_{j=1}^{i} \left(\sqrt{\frac{2j-1}{i}} \right)^{\gamma} \tag{7}$$

2. INTERFERENCE POWER ON THE BASE STATION OBSERVED CELL IN THE UPLINK

The assumption is that within every cell of multi cell system there are «i» active users, where i is the largest number of active users that can be present in the system cell due to interference conditions. Total interference power that receives base station of the observed cell consists of interference power that is received from the active mobile stations within a cell and the total interference power of all surrounding cells. Interference power that base station receives from the active mobile stations from the observed cell is *(i-1)S*. Interference power of all surrounding cell is denoted as S_{pis}. Total interference power in observed cell can be described using following expression (8)[3] as

$$S_{\text{int}} = S(i-1) + S_{pis} \tag{8}$$

2.1. Radiated interference power of a distant cell for reverse link

Let in a distant cell there are *i* active users. Let all active users broadcast the average power, described by the expression (7), and they are equally distributed on the distant cell. To simplify calculation the following approximation is taken – let suppose that the position of all active mobile users are located within a cell centre, and they broadcast their average emission power. If all this assumptions are taken into consideration emitted interference power from a distant cell, produced by *i* mobile stations, is given by the equation (9).

$$S_{ois} = i \cdot S \cdot \alpha \cdot a^{\gamma} \left(\sqrt{\frac{3\sqrt{3}}{4\pi}} \right)^{\gamma} \frac{(\sqrt{2})^{\gamma}}{2} \frac{1}{i} \cdot \sum_{j=1}^{i} \left(\sqrt{\frac{2j-1}{i}} \right)^{\gamma} \tag{9}$$

2.2. Received interference power in the observed cell from a distant cell for reverse uplink

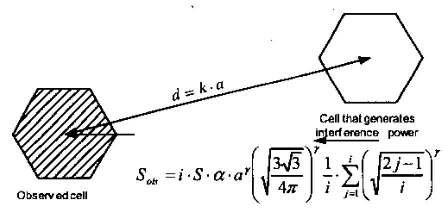


Fig. 2. Received interference power in the observed cell from a distant cell for reverse uplink

Figure 2. shows distant cell that with interference power effects the observed cell. Broadcasted interference power S_{ois}, which on the route to receiving base cell passes route *d*. Route *d* can be expressed as the product of the hexagon side *a* and linear coefficient *k*. Broadcasted interference power from the jamming cell to observed cell, attenuates along the route according to propagation low, defined by the equation (2). Total received interference power from distant cell in the observed cell is given by the equation (10).

$$S_{pis} = i \cdot S \cdot \left(\frac{1}{k} \sqrt{\frac{3\sqrt{3}}{4\pi}} \right)^{\gamma} \frac{(\sqrt{2})^{\gamma}}{2} \frac{1}{i} \cdot \sum_{j=1}^{i} \left(\sqrt{\frac{2j-1}{i}} \right)^{\gamma} \tag{10}$$

2.3. Total interference power in reverse uplink from the surrounding cells circles

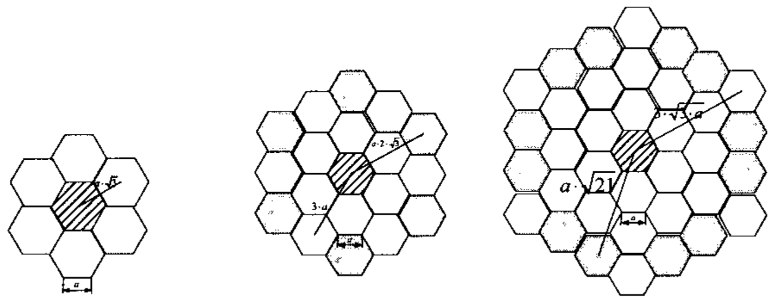


Fig. 3. First, second and third circle of surrounding cells

The assumption is that every cell has i active users, where i is maximum number of active users that can work within a system cell due to interference conditions.

Total interference power that arrives into observed cell from three circles of surrounding cell shows equation (11).

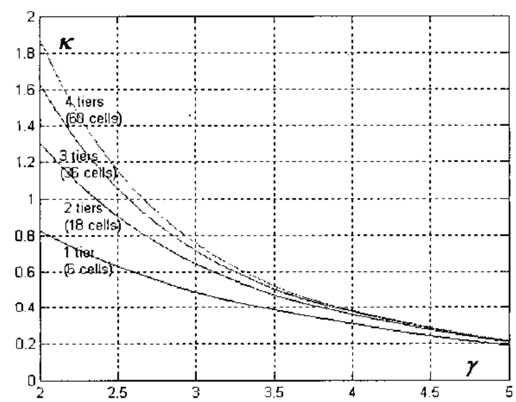


Fig. 4. Coefficient κ changes in the function of propagation factor changes γ for one, two, three and four interference circles

$$S_{pis}\Big|_3 = \cdot i \cdot S \cdot 6 \cdot \left(\sqrt{\frac{\sqrt{3}}{4\pi}}\right)^{\gamma} \frac{\left(\sqrt{2}\right)^{\gamma}}{2} \frac{1}{i} \cdot \sum_{j=1}^{i} \left(\sqrt{\frac{2j-1}{i}}\right)^{\gamma} \left[1 + \frac{1}{\left(\sqrt{3}\right)^{\gamma}} + \frac{1}{(2)^{\gamma}} + \frac{1}{(3)^{\gamma}} + \frac{2}{\left(\sqrt{7}\right)^{\gamma}}\right] \tag{11}$$

Introducing parameter κ, defined by the equation (12) into equation (11), a new equation (13) is given by

$$\kappa = 6 \cdot \left(\sqrt{\frac{\sqrt{3}}{4\pi}}\right)^{\gamma} \frac{\left(\sqrt{2}\right)^{\gamma}}{2} \frac{1}{i} \cdot \sum_{j=1}^{i} \left(\sqrt{\frac{2j-1}{i}}\right)^{\gamma} \left[1 + \frac{1}{\left(\sqrt{3}\right)^{\gamma}} + \frac{1}{(2)^{\gamma}} + \frac{1}{(3)^{\gamma}} + \frac{2}{\left(\sqrt{7}\right)^{\gamma}}\right] \tag{12}$$

$$S_{pis}\Big|_3 = \cdot i \cdot S \cdot \kappa \tag{13}$$

Let consider changes of the coefficient κ as the function of $\kappa = f(\gamma)$.

From the figure 4. can be noted that enlargement of observed interference circles, from one to two, three or four, the curve that describes coefficient κ changes in the function of $\kappa = f(\gamma)$ changes slightly comparing to the previous curve. Coefficient κ describes interference influence that changes significantly when changing attenuation coefficient γ when changing number of surrounding cells.

2.4. Multiple cell interference reduction factor Fm as a function of the path-loss exponent γ calculated of the Ramjee Prasad

In the book "Universal Wireless Personal Communications" by author Ramjee Prasad (Artech House – 1998) pp. 350-353, author describes the same problem using different approach. To calculate interference from terminals in a distant cell Ramjee Prasad uses following equation (14).

$$P_{RB}(d) = \frac{2NS_p}{\pi R^2} \int_0^R r^{\gamma-1} dr \int_0^\pi \frac{d\theta}{(d^2 + r^2 + 2rd\cos\theta)^{\gamma/2}} \tag{14}$$

where: N - is the number of users per cell (in our case we use i), S_p is the power received in the case of perfect power control (in our case we use S), R is the radius of the cell, d is the distance between two base stations. Ramje Prasad computes the total received interference from surrounding cells in the system. The interference correction factor due to multiple cell interference *Fm* is defined as the ratio of the interference power received from the outer cells (*Im*) and the interference power generated by users in the home cell (*Ih*). *Fm* correction factor in the book of the Ramjee Prasad is the similar as our correction factor κ, *Fm* is written as:

$$F_m = \frac{I_m}{I_h} \quad \text{and} \quad F_m = \frac{i}{i-1}\kappa \tag{15}$$

Correction factor *Fm* is computed using equation (14) and (15), for one, two, three and more surroundings circles of cells. Correction factor κ is computed using equation (12) for one, two and four surroundings circles of cells.

Correction factor *Fm* and correction factor κ is the same factors for large number of users *i*. Table 2.1 shows values of the correction factor *Fm* and κ . As it can be seen from the table 2.1 a very good coincidence between our results, that are obtained using statistical method, and results of Ramjee Prasad method, obtained by using partial integration, is achieved.

Table 2.1 Interference Correction Factors Fm and κ

Ramjee Prasad method		Interference Correction Factor Fm			
Number of tiers		γ=2	γ=3	γ=4	γ=5
1	*Fm*	0,904	0,417	0,284	0,191
2	*Fm*	1,365	0,579	0,312	0,199
3	*Fm*	1,669	0,625	0,319	0,200
Winton Afric method		Interference Correction Factor κ			
1	κ	0.8283	0.4897	0.3037	0.1930
2	κ	1.3115	0.6447	0.3564	0.2114
3	κ	1.6402	0.7155	0.3725	0.2152

3. INTERFERENCE POWER ON THE MOBILE STATION IN THE DOWNLINK

Total broadcasting power of the base station in the observed cell depends on the number of active users in cell, spatial distribution of the users in the observed cell and the power control system.

We assume that the each cell has i active users, and they are uniformly distributed in the each cell with appropriate users density. In this paper the case of the system without power control in downlink is discussed. In the system without power control in the forward link base station power emission for each i users in the cell is on the same level. Desired power signal level on the j mobile station is given by equation (16). j is a number between 1 and i, where r_j describes distance between mobile and base station in observed cell, r_j is given by equation (5).

$$S_{MP(desired)} = S \cdot \left(\frac{a}{r_j}\right)^{\gamma} = S \cdot \left(\frac{a}{a\sqrt{\frac{3\sqrt{3}}{4 \cdot \pi}}\sqrt{\frac{(2j-1)}{i}}}\right)^{\gamma} = S \cdot \left(\frac{1}{\sqrt{\frac{3\sqrt{3}}{4 \cdot \pi}}\sqrt{\frac{(2j-1)}{i}}}\right)^{\gamma} \tag{16}$$

Signal to total interference noise ratio on the mobile station j is given by equation (17)

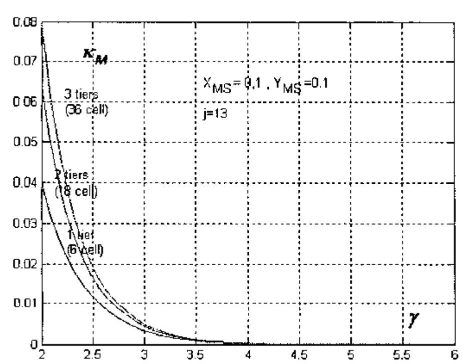
$$\frac{S_{MP(desired)}}{N} = \frac{S}{(i-1) \cdot S + i \cdot S \cdot \left(\sqrt{\frac{3\sqrt{3}}{4 \cdot \pi}}\right)^{\gamma} \left(\sqrt{\frac{(2j-1)}{i}}\right)^{\gamma} \cdot \left[\sum_{m=1}^{6} \frac{1}{k_{1m}{}^{\gamma}} + \sum_{m=1}^{12} \frac{1}{k_{2m}{}^{\gamma}} + \sum_{m=1}^{18} \frac{1}{k_{3m}{}^{\gamma}}\right]} \tag{17}$$

where k_{xy} is the linear distance coefficient which describes distance between mobile and surrounding base stations It is given by equation $d_{xy} = a \cdot k_{xy}$.

Multiple mobile station interference reduction factor κ_M for downlink direction is given by equation (18).

$$\kappa_M = \left(\sqrt{\frac{3\sqrt{3}}{4 \cdot \pi}}\right)^{\gamma} \left(\sqrt{\frac{(2j-1)}{i}}\right)^{\gamma} \cdot \left[\sum_{m=1}^{6} \frac{1}{k_{1m}{}^{\gamma}} + \sum_{m=1}^{12} \frac{1}{k_{2m}{}^{\gamma}} + \sum_{m=1}^{18} \frac{1}{k_{3m}{}^{\gamma}}\right] \tag{18}$$

Multiple mobile station interference reduction factor κ_M depends of the mobile station position in the observed cell, as is shown on figure 6.



a) b)

Fig. 5. Coefficient κ_M changes as the function of propagation factor changes γ for one, two, three interference circles and depend of the position of the mobile station

Interference reduction factor κ_M is defined as the ratio of the interference power received from the other cells (other base stations) and interference power generated from the users in the home cell.

4. CONCLUSION

In this article calculations of the multiple interference reduction factor have been described using two different approaches. Results for the uplink are very similar as results obtained by Ramjee Prasad method. Using identical method as in uplink we achieved the calculations for multiple interference reduction factor in the downlink.

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