PERFORMANCE OF TIME DIVISION DUPLEX CDMA MOBILE COMMUNICATION

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Abstract

In this paper an analytical expression for the signal-noise ratio in the output of the user's receiver, worked in cellular mobile system with Pre-Rake diversity combination is determined. On this basis the bit error rate (BER) depending on the input signal to noise ratio (SNR) on the technical peculiarity and on the number of the users in the cell is derived.

1. INTRODUCTION

In the systems with time division duplex code division multiple access the up and down links are time slots on the same carrier. They have the same channel impulse response during a short period of time. Instead of building a rake receiver in the portable unit the base station can pre-rake the signal before transmission in the down ink using the channel impulse response estimated from the up link. When the pre-rake signal is convolved with the channel impulse, the function of rake receiver is automatically performed. The mobile or portable unit uses a conventional, one tap, matched filter (MF) and still achieves the diversity gain of a multiple tap rake receiver [8]. Therefore the parameters of the environment and the system has influence on the SNR, but from there on the BER. In the almost all of known works [1, 5, 8] determined the SNR approximately, the parameters for the systems realization did not used. The purpose of this paper is to determine the dependence between BER in the receivers with pre-rake diversity combination in dependence from the type on pseudo noise (PN) code, the number of channel paths in the impulse response of the channel of user and number of the users in cell. For determination of this problem first will be determined SNR in the output of the receivers for information signals with binary phase shift keying modulation (BPSK) and quadrature phase shift keying modulation (QPSK) in the PN carrier frequency.

2. MULTIPATH CHANNEL MODEL

The environments for propagation is determined through the multipath channel model [8], in who the up link channels are assumed to be statistically independent for all users. Also with the utilization of up link power control we assume that all channels are statistically identical, even if the portable mobile units (MU) are at different distances from the base station (BS). The K-user's channel impulse response is:

$$h_k(t) = \sum_{l=0}^{L-1} \beta_{k,l} \delta(t - lT_c) \exp(j\gamma_{k,l}), \tag{1}$$

where L is the number of channel paths, the path gains $\beta_{k,l}$ are independent identically distributed (i.i.d.) Raleigh random variables for all K and l, the angles $\gamma_{k,l}$ are i.i.d. uniformly distributed in [0, 2π], δ(t) – the complex envelope of the transmitted signal and T_c is the PN code chip duration. Without loss of generality we can take the normalization

$$E[\beta^2_{\kappa,1}] = 1 \tag{2}$$

In a time division duplex (TDD) system under slow fading conditions, which are typical for portable communication systems, we assume that $h_k(t)$ does not change during two successive up and down time slots. In particular when a slot is received at the BS through $h_k(t)$, it estimates $h_k(t)$ for use in its own rake receiver. We assume that $h_k(t)$ will not have changed when the BS transmits the following time slot to the MU of user K.

3. TDD CDMA with Pre-Rake System

In a multipath-fading channel a conventional rake receiver is often used. A rake receiver consist of a matched filter followed by a number of rake fingers, each synchronized to one of the channel paths. Using maximal ratio combining [1] each rake finger multiplies the received signal with the complex conjugate of the path gain of its path and all outputs are then added. Hence, the receiver in both BS and MU's must be equipped with sufficient rake fingers and the corresponding channel estimation.

In TDD CDMA systems we can utilize the fact that for a period of time the channel impulse response is the same for the up and down links. Hence, only the BS needs to estimate it. As shown in figure 1, to pre-rake the down link signal of a certain user, the

BS multiplies this signal by the time inverted, complex conjugate, of the up link channel impulse response of that user [8].

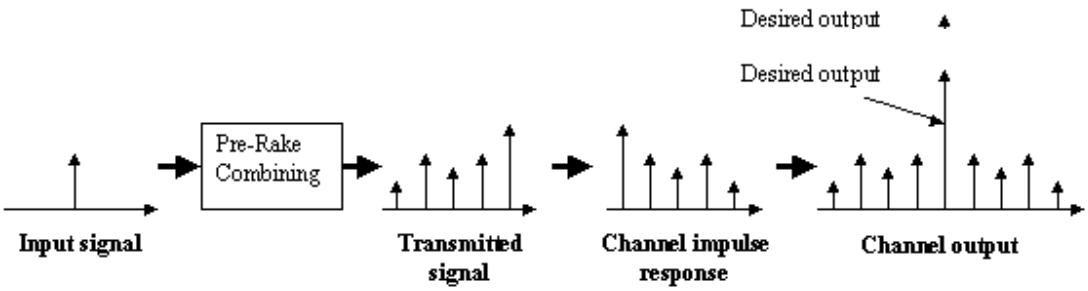

Figure 1. The Pre-Rake combination process.

In a pre-rake system, the down link transmitted signal will be [8]:

$$s_k(t) = \sqrt{\frac{2P_c}{U_k}} \sum_{l=0}^{L-1} \beta_{k,L-l-1} b_k(t - lT_c) a_k(t - lT_c) \exp\left(j\omega_0(t - lT_c) - j\gamma_{k,L-l-1}\right) \quad (3)$$

where P_c is the transmitted power, f_0 is the carrier frequency ($\omega_0 = 2\pi f_0$), $b_k(t)$ is the data stream for user k consisting of a train of i. i. d. data bits with duration T_d which take the values ±1 with equal probability, $a_k(t)$ is the PN code of user k with ±1 chips of duration T_c and code length $B=T_d/T_c$ (i. e., one code period per bit). The variable U_K is a normalizing factor that keeps the instantaneous transmitted power constant regardless of the number of paths. U_k is given by:

$$U_k = \sum_{n=0}^{L-1} \beta_{k,n}^2 \quad (4)$$

Note that the up-link channel impulse response is independent for all users. The received signal by user k is Eq. 3 convolved with the channel impulse response of user k. This produces a strong peak at the output of the channel, equivalent to the conventional rake receiver's combining. Therefore, the receiver of the MU does not need to estimate the channel impulse response and can only use one rake finger tuning to this peak. The pre-rake concept is shown graphically in Fig. 1 for δ(t) transmitted signal. A more detailed description of the BS and MU block diagrams can be found in [9].

4. PERFORMANCE ANALISIS

In systems whit direct sequence spread spectrum (DS-SS) signals the basis of signal is determined from the product as [1]:

$$B = FT >> 1, \tag{5}$$

where F – width of the frequency spectrum and T is the duration of DS-SS signals.

The BER for this systems depend from SNR of the output of MF in the receiver [1]:

$$\gamma = B.\left(\frac{P_C}{P_{CM}}\right)_{INPUT},$$

(6)

where P_{CM} is the power of jamming at the input receiver;

P_C is the power of the signal at the input receiver.

The equality (6) is equitable for broad circle of jamming including narrow-band pulsed structured and other [1, 3, 4, 11].

The sum of DS-SS signal and the additive white Gaussian noise (AWGN) – n(t), can by written as [2]:

$$u(t) = \sqrt{P_c}\, d(t)\left[I(t)\cos\omega_0 t + Q(t)\sin\omega_0 t\right] + \sqrt{P_{CM}}\, n(t), \tag{7}$$

where d(t)=±1 – BPSK мodulation of data sequence, I(t) and Q(t)=±1 – pseudo noise carrier sequence (inphase and quadrature) and n(t) are process with zero mean and single mean-square value, so P_c and $P_{см}$ characterized the power of DS-SS signal and AWGN. Shall consider, that I(t) and Q(t) are independents accidentals binary sequences. The spectrum of jamming has limited frequency band F_{CM} around the frequency carrier f_0 and has accurate synchronization of frequency carrier, on the data symbols and PN codes. Noise is stationary and Gaussian whit rectangular spectrum:

$$n(t) = n_c(t)\cos\omega_0 t - n_s(t)\sin\omega_0 t. \tag{8}$$

where

$n_c(t)$ – inphase part;

$n_s(t)$ – quadrature part.

In the case of DS-SS system with BPSK and QPSK modulation of data sequences in the PN carrier frequency sequences the receiver output SNR (without pre-rake diversity combination) is [2]:

$$\left(\frac{S}{N}\right)_{\text{output}} = 2F_{CM}T_d\left[\frac{\frac{\pi}{2}}{Si(\pi F_{CM}T_c)+\frac{1}{\pi F_{CM}T_c}\left[\cos(\pi F_{CM}T_c)-1\right]+\frac{1}{\pi F_{CM}T_d}\left(\frac{\sin\pi F_{CM}T_c}{\pi F_{CM}T_c}-1\right)}\right]\left(\frac{P_C}{P_{CM}}\right)_{input} \quad (9)$$

for $T_d \geq T_c$,

where T_d is the duration of a single bit, T_c is the duration of a single chip of m - sequence (maximal length) and $Si(x)=\int_0^x(\sin\lambda)/\lambda d\lambda$ - integral sine. For majority military and commercial systems $T_d>8T_c$ [2]. The formula (9) can be used, when $T_c \geq T_d$ as to change places indexes **d** and **c** in square brackets [2].

In the case with pre-rake diversity combination for this system must be used the ratio $\left(\frac{P_C}{P_{CM}}\right)_{INPUT}$ in the equation (9). For the purpose will be used the dependence [8]

$$\gamma_K = \left[\frac{L}{\bar{\gamma}_b U_K}+\frac{4\chi}{BU_K^2}-\frac{2\mu}{B^2U_K^2}+\frac{(K-1)(L-1+W)}{BL}\right]^{-1}, \quad (10)$$

where L is the number of channel paths in the impulse response of the channel, K – number of the users in the cell, B – the basis of signal (for DS-SS signal whit PSK modulation $B=\frac{T_d}{T_c}$), $\bar{\gamma}_b = P_C T_d L / N_{CM}$ is the average received signal to noise ratio, N_{CM} – power spectral density of the jamming in frequency band of DS-SS signal, $\chi=\sum_{j=0}^{L-2}\sum_{m=j+1}^{L-1}\beta_{1,j}^2\beta_{1,m}^2$ and $\mu=\sum_{j=0}^{L-2}\sum_{m=j+1}^{L-1}(m-j)\beta_{1,j}^2\beta_{1,m}^2$.

The variable W, defined the sort of PN sequence, where W=0 for orthogonal codes such as the Walsh-Hadmard and W=1 otherwise. The variable $\beta_{k,l}$ is Raleigh random distribute for all users and path.

From equality (6):

$$\left(\frac{P_C}{P_{CM}}\right)_{INPUT\ P-R} = \frac{1}{B}\gamma_K = \left[\frac{BL}{\bar{\gamma}_b U_K} + \frac{4\chi}{U_K^2} - \frac{2\mu}{BU_K^2} + \frac{(K-1)(L-1+W)}{L}\right]^{-1}. \quad (11)$$

In this case we replace (11) in (9) for W=0 - m-sequences (maximal length) given by the analytical dependence for K^{-th} user whit pre-rake diversity combination:

$$\left(\frac{S}{N}\right)_{K\ \text{output}} =$$

$$= 2F_{CM}T_d \times \left[\frac{\frac{\pi}{2}}{Si(\pi F_{CM}T_c) + \frac{1}{\pi F_{CM}T_c}\left[\cos(\pi F_{CM}T_c) - 1\right] + \frac{1}{\pi F_{CM}T_d}\left(\frac{\sin \pi F_{CM}T_c}{\pi F_{CM}T_c} - 1\right)}\right] \times$$

$$\times \left[\frac{BL}{\bar{\gamma}_b U_K} + \frac{4\chi}{U_K^2} - \frac{2\mu}{BU_K^2} + \frac{(K-1)(L-1+W)}{L}\right]^{-1} \quad (12)$$

The bit error rate can compute by using results from [11]:

$$P_b = Q\left(\sqrt{\left(\frac{S}{N}\right)_{output}}\right), \quad (13)$$

where $Q(X) = \frac{1}{\sqrt{2\pi}}\int_X^{\infty} \exp\left(-\frac{y^2}{2}\right)dy$, and SNR determined from (12), is given by.;

$$P_b = \frac{1}{\sqrt{2\pi}}\int^{\infty} \sqrt{2F_{CM}T_d \times \left[\frac{\frac{\pi}{2}}{Si(\pi F_{CM}T_c) + \frac{1}{\pi F_{CM}T_c}\left[\cos(\pi F_{CM}T_c) - 1\right] + \frac{1}{\pi F_{CM}T_d}\left(\frac{\sin \pi F_{CM}T_c}{\pi F_{CM}T_c} - 1\right)}\right] \times \left[\frac{BL}{\bar{\gamma}_b U_K} + \frac{4\chi}{U_K^2} - \frac{2\mu}{BU_K^2} + \frac{(K-1)(L-1+W)}{L}\right]^{-1}} \exp\left(-\frac{y^2}{2}\right)dy \quad (14)$$

The probability density functions of χ and μ are very difficult to obtain. The final probability of error P_b is evaluated from Eq. (14) using Monte-Carlo integration [12]. At each iteration L Rayleigh r. v.'s are computer generated; U_K, χ and μ are evalu-

ated. For each value, Eq. (14) is averaged over a sufficiently large number of iterations [8].

5. NUMERICAL RESULTS AND DISCUSSION

A TDD CDMA system with following parameters: 20 users in cell (K=20), PN sequence with length 63 and 127 (m-sequence) and binary date rate 16 kbit/s and 64 kbit/s is considered. Fig. 2 shows the probability of error in dependence from the received average SNR- γ_B for: PN sequence with length 63 and 127. The curves 2 and 4 on fig. 2 – triple paths impulse response of channel (L=3). The curves 1 and 3 on fig. 2 – quadruple impulse response of channel (L=4). The results are shown on fig. 2 for binary date rate:

- 16 kbit/s – the curves 1 and 2;
- 64 kbit/s – the curves 3 and 4.

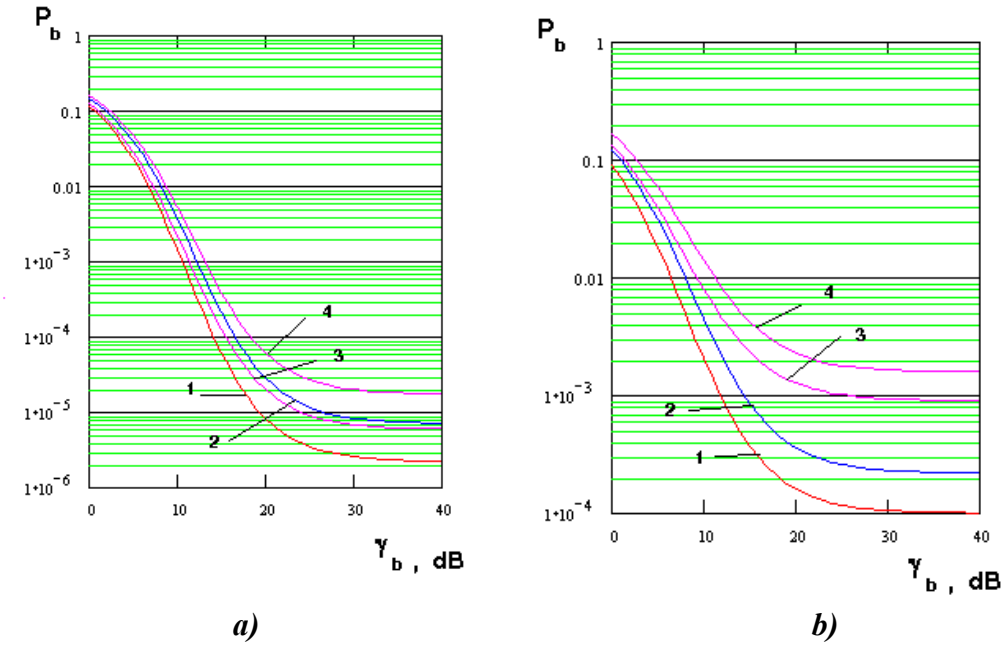

Figure 2. Bit error rate in terms of:
a) signal to noise ratio for PN sequence with length 127
b) signal to noise ratio for PN sequence with length 63

Figure 3 shows the probability of error in dependence from the users' number in the cell for this received average SNR– $\gamma_{в}$=15 dB – PN sequence with length 63 and binary date rate:

- 16 kbit/s – Fig. 3 – a);
- 64 kbit/s – Fig. 3 – b).

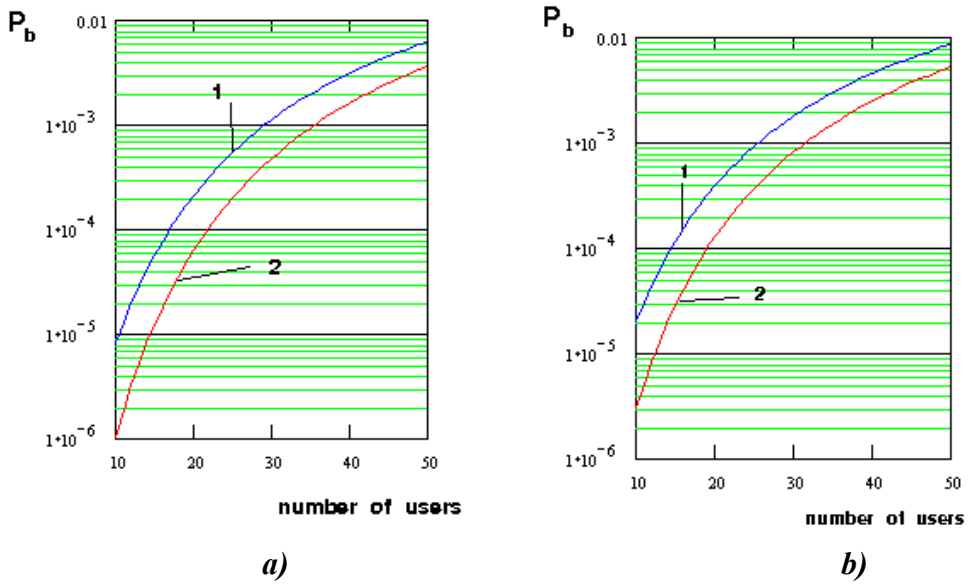

Figure 3. Bit error rate in terms of: the users' number in the cell:
1 – triple paths impulse response of channel (L=3)
2 – quadruple impulse response of channel (L=4).

6. CONCLUSION

As a result of the performed synthesis are obtained the dependence (12) and (14), which are under review as influence of the self users' interference in cell evoked by multipath propagation of the signals and the influence the interference evoked by multiple access.

The obtained analytical equations, according to (9) is correct as well large relative width of frequency spectrum as well for narrow one. The results of the analysis may be used for BPSK modulated signals in PN sequence in carrier frequency [2] .

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