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Analysis of BER and Degradation Factor in WCDMA System at 5 MHz Bandwidth

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Abstract: In present study, analyze the performance of a flexible multirate scheme with degradation factor for direct sequence Code-Division Multiple Access (CDMA) based radio systems called WCDMA. The proposed scheme uses a variable processing gain serial pseudo-noise modulation as a multirate strategy. Third Generation (3G) cellular mobile communications systems will support several kinds of communication services. Therefore, the users will be transmitting their information using different data rates and their performance requirements will vary from application to application. In WCDMA, each user transmits a data sequences spread by a code commonly called spreading code. This code is Unique to the Mobile Station (MS) to Base Station (BS) connection on both uplink and downlink. The analytical treatment and computer aided performance analysis for user BER and degradation factor of downlink FDD mode in WCDMA under the variable strategic conditions of processing gain, signal to noise and number of interference at 5 MHz bandwidth has been presented.

Key words: Error analysis, spread spectrum communications, AWGN channel, degradation factor

INTRODUCTION

Wideband Code Division Multiple Accesses (WCDMA) with variable processing gain (Gp) and multi-code modulation as a multi-rate scheme is emerging as one of the interfaces for the 3G mobile communications systems. In WCDMA system, the access scheme is Direct Sequence Code Division Multiple Access (DS-CDMA) in which each user is assigned a particular code sequence which is modulated on the carrier along with the digital data. The Spread Spectrum Multiple Access (SSMA) techniques are characterized by the use of high rate code which has the effect of spreading the band width of the data signal. The Direct sequence spectrum is the most commonly used technique among the different spread Spectrum techniques such as Frequency hoping and Time hoping. In this technique the transmission system combines with the sending data signals having high data rate sequence and that divides the user data according to a spreading ratio. Transmitter converts an incoming data (bit) stream into a symbol stream where each symbol represents a group of one or more bits. This technique is reliable and highly resistance to interference and give the opportunity to multiple users can communicate through one channel (Prasad, 1996).

Multiple Access Interference (MAI) has significant impact on the network capacity of the wireless communication system. However, it is not clear how exactly the MAI affects performance including throughput and delay. The overall performance also requires accurate calculation of Bit Error Rate (BER). In the presence of MAI, performance analysis is not easy to implement and can generally only be approximated with considerable computational effort (Gaurav *et al*., 2001). Carrasco (2006) presented the analytical expression for the average BER of a DSCDMA system with coexisting fast and slow power controlled user to reduce MAI. To compute BER of a DS/CDMA system, which depend on a set of parameters such as number of simultaneous user (K), the Processing Gain (G_P), Signal to Noise ratio (E_b/N_o). The exact calculation of BER in the presence of MAI is difficult and emphasis has been given to bounds and approximation (Pursley, 1977). A simple approximation is to treat MAI as standard Gaussian and the bit errors are independent.

In the present study, introduce a method to compute an estimation of the Bit Error Rate (BER) along with the degradation factor of wireless channel with perfect power. The presented method is used to estimate the current quality of the wireless channel using the data received by a rake receiver. This information can be used to adapt the receiver to obtain the desired Quality of Service (QoS) for a given application or protocol with minimal computational effort. This reduction in computational effort can be translated to a reduction in energy consumption for a mobile terminal or to a reduction in the amount of resources for the base station.

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SYSTEM MODEL

In Cellular Downlink Mobile Communication systems, base station transmit signal to all the users present in a cell independently, since their relative time delays are randomly distributed. K independently number of user use the same carrier frequency and may transmit simultaneously with the base station in a cell (Lister *et al*., 2000). The kth binary source generates a binary sequence $b_k(m)$ contain transmitted energy per chip (E_{ck}) with the time shift (τ_k) of the Kth user, where m is the time instant. The spreaded data is given by $X_k(t)$ (Dahlman *et al*., 1998).

$$X_k(t) = \sum_{m=-M}^{M} \sqrt{E_{ck} b_{kI}}(m) C_{kI}(t - mT - \tau_k) + j\sqrt{E_{ck} b_{kQ}}(m) C_{kQ}(t - mT - \tau_k) \quad (1)$$

C_{kI} = Pseudorandom Code Sequence of I channel
C_{kQ} = Pseudorandom Code Sequence of Q channel.

The difference between the users is due to the time delay, so the system becomes asynchronous system. Transmitted signals have different time shift but the symbol interval (T) for the different users are assumed to be equal and C_{kI}, C_{kQ} is the PN codes assigned to I and Q channel. Suppose the data at the I channel is represented by the signal $d_I(t)$, while the data at Q channel is $d_Q(t)$ in Eq. 1 (Cianca, 2005; Ojanpera and Prasad, 1998).

$$\text{Suppose, } C_I(t) = C_{kI}(t - mT - \tau_k) \quad (2)$$

$$C_Q(t) = C_{kQ}(t - mT - \tau_k) \quad (3)$$

$$d_I(t) = \sqrt{E_{ck} b_{kI}}(m) \quad (4)$$

$$d_Q(t) = \sqrt{E_{ck} b_{kQ}}(m) \quad (5)$$

Substitute

$$X_k(t) = d_I(t)C_I(t) + jd_Q(t)C_Q(t). \quad (6)$$
$$S_k(t) = X_k(t).C_{SC}(t)$$

Each transmitted signal is passed through a multipath channel. The channel is modeled by the zero mean Additive White Gaussian Noise (AWGN) n(t) with variance σ_n^2 and there is no other distortion in the channel apart from constant linear scaling of signal amplitudes and multiple access interference caused by the presence of other active users. R(t) is the received signal, $h(t, \tau_k)$ is the complex channel response due to multipath, n(t) is the complex Gaussian noise at the front end of the receiver, A_k is the attenuation of the kth signal, due to propagation (Khan *et al*., 2006).

$$R'(t) = \sum_{k=1}^{K} h(t, \tau_k) S_k(t - \tau_k) A_k \quad (7)$$

The receiver consists of number of rake finger for simultaneous demodulation of K user signals followed by a decision block. The out put of integrate rake finger block is sampled at the of the mth symbol interval.

$$Yk(m) = \frac{1}{T} \int_{\tau_k + mT}^{\tau + (m+1)T} R'_1(t) C_k(t - mT - \tau_k) dt \quad -M \le m \le M \quad (8)$$

Where m is the sampling instant, --M≤m≤M. The processing operation in the demodulator adds the received samples $Y_k(m)$ for all sampling instants within one bit and forms the decision variable $[Z_k(m)]$ represented in Eq. 9 (3GPP T.S 212, 3GPP T.S.213).

$$Z_k(m) = \sum_{m=1}^{Gp} Y_k(m) \quad (9)$$

Where Gp is the processing gain defined as the number of chips per bit. The kth decision device estimates the mth symbol of the kth user by examining the sign of the decision variable (Z_k). The average Probability of Bit Error, P_b can be expressed as:

$$P_b = ½ P_r\{Z_k > 0, b_k = -1\} + ½ P_r\{Z_k < 0 \text{ when } b_k = +1\}$$

Assume that the probabilities of transmitting symbols -1 and +1 are equal. The Bit Error Probability can be written as:

$$P_b = P_r\{Z_k > 0, b_k = -1\} = P_r\{Z_k < 0 \text{ when } b_k = +1\}$$

Assuming that the number of chips per bit, G_p is large, the decision variable Z_k can be approximated according to the Central limit theorem by a Gaussian random variable. The Bit Error probability is given by:

$$P_b = Q\sqrt{\frac{[E(Z_k)]^2}{Var(Z_k)}} \quad (10)$$

$E[Z_k]$ is the mean and $Var[Z_k]$ is the variance of the decision variable Z_k. The mean value of Z_k is given below:

$$E[Z_k] = E\left[\sum_{m=1}^{Gp} Y_{kl}(m) b_k = 1 + Y_{k2}(m) + Y_{k3}(m)\right]$$

$$E[Z_k] = E\left\langle \begin{bmatrix} \sum_{m=1}^{Gp} Y_{kl}(m) b_k = 1 + E\left[\sum_{m=1}^{Gp} Y_{k2}(m)\right] + \\ E\left[\sum_{m=1}^{Gp} Y_{k3}(m)\right] \end{bmatrix} \right\rangle \quad (11)$$

Since

$$E\left[\sum_{m=1}^{Gp} Y_{k2}(m)\right] = 0 \quad \text{and} \quad E\left[\sum_{m=1}^{Gp} Y_{k3}(m)\right] = 0$$

$$E[Z_k] = E\left[\sum_{m=1}^{Gp} Y_{kl}(m) b_k = 1\right] = Gp\sqrt{E_{ck}}$$

the variance var (Z_k) is given by

$$\text{var}(Z_k) = Gp\ \text{var}[Y_{k1}(m)] + \text{var}[Y_{k2}(m)] + \text{var}[Y_{k3}(m)]$$

The desired signal variance is:

$$\text{var}[Y_{k1}(m)] = 0$$

The variance due to thermal Gaussian noise is:

$$\text{var}[Y_{k1}(m)] = No/2$$

Where No is the one sided thermal noise power spectral density. The variance of the interfering signals can be computed assuming that the interfering signal is modeled as white noise with the two sided power spectral density of Ec/Tc. Taking into account the relative phase difference between the desired signal and interfering signals and averaging over them (Giilhousen *et al.*, 1991).

$$\text{var}[Y_{k3}(m) \geq \sum_{\substack{i=1 \\ i \neq k}}^{K} \frac{E_{ck}(i)}{2}$$

Then the bit error probability is lower bounded by

$$P_b \geq Q\left[\sqrt{\frac{2E_{ck}\,Gp}{No + \sum_{\substack{i=1 \\ i \neq k}}^{k} E_{ci}}}\right] \quad (12)$$

The term 2 E_{ck}Gp is the double bit energy 2 E_b and the denominator represents the total power spectral density coming for the thermal noise and multiple access interference. If we denote by I_o than

$$I_o = N_o + \sum_{\substack{j=1 \\ j \neq k}}^{k} E_{cj}$$

The bit error probability lower bound can be written as:

$$P_b \geq Q\left[\sqrt{\frac{2E_b}{I_o}}\right]$$

The bit error probability Pb on a Gaussian Channel can be approximated by (13)

$$P_b = Q\left\{\frac{[K-1]}{3G_p} + \frac{No}{2E_b}\right\}^{\frac{-1}{2}} \quad (13)$$

where N_o is the Gaussian noise one-sided power spectral density. The Bit Error Probability Eq. 13 is obtained with Perfect power Control. The degradation factor depends on operating E_b/N_o, number of User (k) and processing gain. More users imply greater degradation, as one might expect (Fu and Thompson, 2002; Haykin and Mohar, 2005).

DEGRADATION FACTOR

The degradation factor (Dg) depends upon the operating Eb/No, number of Users (K) and Processing gain (Gp). More users imply greater degradation, but a larger Gp value reduces the effect of the interference and decrease the degradation. Figure 2 shows the performance degradation in bit error rate with the operating signal to noise (Eb/No) for number of users.

$$P_b = Q\left\{\frac{[K-1]}{3G_p} + \frac{No}{2E_b}\right\}^{\frac{-1}{2}}$$

$$P_b = \frac{Q}{(No/Eb)^{\frac{1}{2}}}\left[\frac{1}{\frac{K-1}{3Gp}.\frac{Eb}{No} + \frac{1}{2}}\right]^{\frac{1}{2}} \quad (14)$$

$$D_g = \left[\frac{K-1}{3Gp}.\frac{Eb}{No} + \frac{1}{2}\right]^{-\frac{1}{2}}$$

Expression 14 is used to calculate the degradation in the system performance due to multiple-access interference.

PERFORMANCE EVALUATION

Figure 1 show the computational flow chart of BER and degradation factor with Number of interference at different value of signal to noise ratio in cell for performance evaluation. Figure 2 shows the variation of Bit Error Rate at number of user, when Eb/No is changed from (2-10). As the Number of interference is increased for the voice application in which bit rate is 12.2 kbps with the varying of Signal to noise ratio (Eb/No), the required quality of service (BER) is decreased. The effective value of BER is 10^{-3} is achieved at Eb/No is 6, when only one interference present with the desired user. But as the interference users are increased from 2 to 5 the achievable target i.e., BER 10^{-3} is achieved at Eb/No is 10. The decreased in Bit Error Rate is due to degradation factor, the Fig. 3-5 clearly shows that degradation value is going

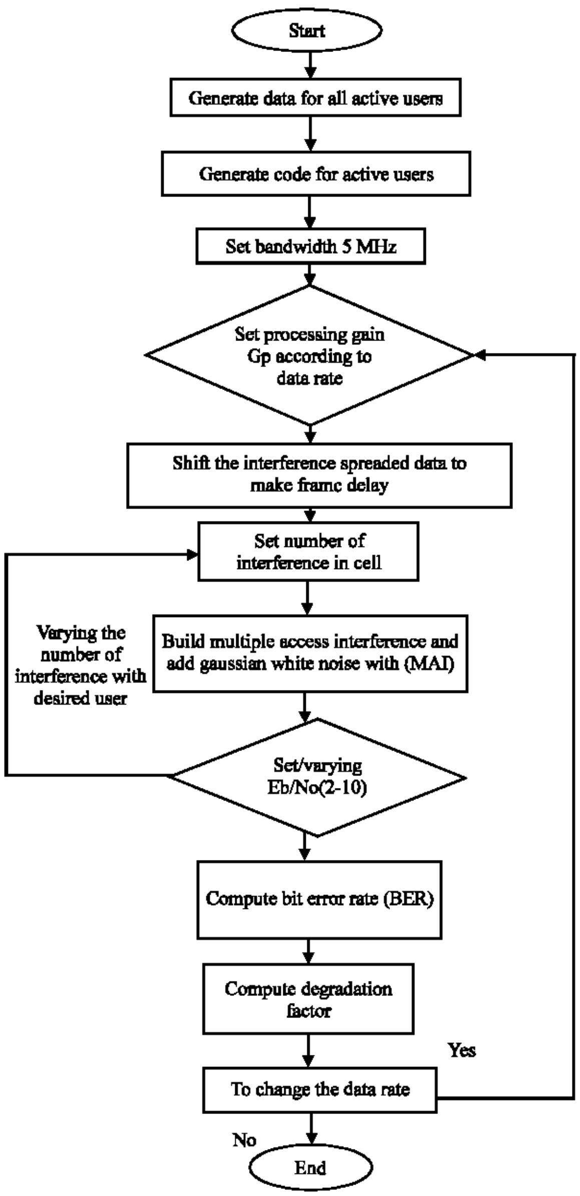

Fig. 1: Computational flow chart of BER with number of interference in cell for performance evaluation

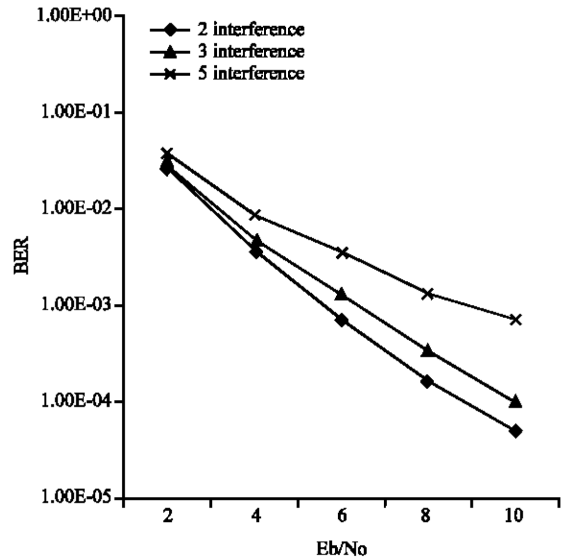

Fig. 2: BER vs Eb/No at 5 MHz bandwith with bite rate is 12.2 kbps

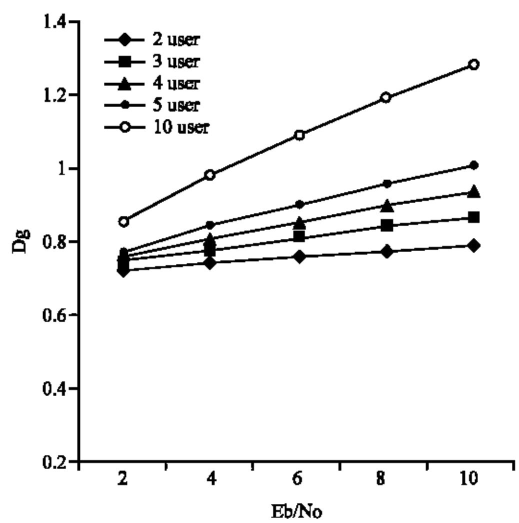

Fig. 3: Degradation (Dg) vs Eb/No at 5 MHz Bandwidth with bit rate 12.2 kbps, varying interference from 2 to 10

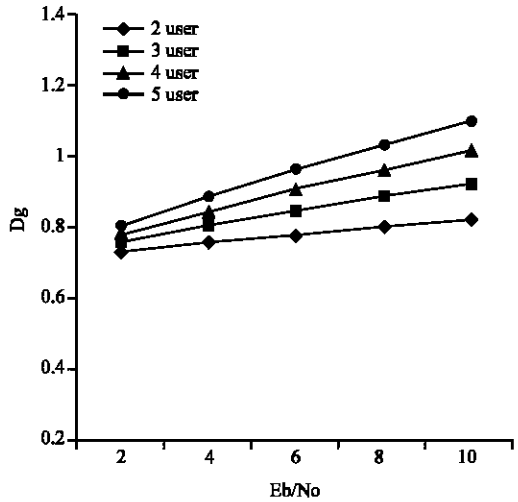

Fig. 4: Degradation (Dg) vs Eb/No at 5 MHz Bandwidth with bit rate 64 kbps, varying interference from 2 to 10

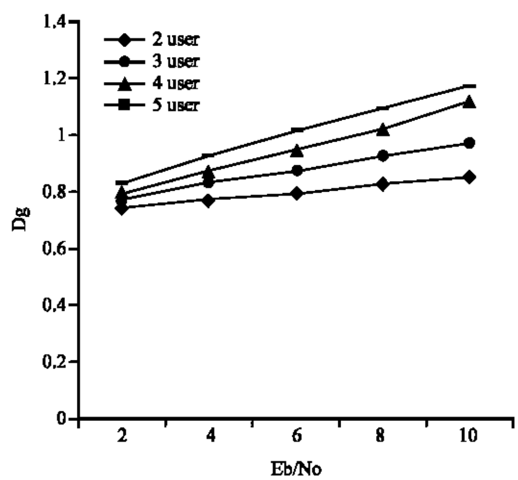

Fig. 5: Degradation (Dg) vs Eb/No at 5 MHz Bandwidth with bit rate 144 kbps, varying interference from 2 to 10

to increase as the number of interference increased from 2 to 5 for different value of data rates at fixed bandwidth 5 MHz. The other users are not aligned in time therefore the code do not align in an orthogonality way that is retain in the receiver. So these user's causes the multiple access interference to be non-zero and the performance of the system is deteriorates as the number of users is increased.

CONCLUSIONS

This study analyzes the capacity of a direct sequence-code division multiple access (DS-CDMA) cellular system supporting integrated (voice, data and multimedia) services. The capacity estimate (on the downlink) is the number of voice users, data users and multimedia at different data rates that the system can support with quality-of-service (QoS) guarantees Bit error rates (BER), outage probability. In WCDMA interface, different users can simultaneously transmit at different data rates for the multiple Application such as voice 12.2 kbps, data 64 kbps and multimedia 144 kbps. The processing gain, together with the wide band nature, suggests a frequency reuse between different cells of a wireless system (i.e., a frequency is reused in every cell/sector). This feature can be used to obtain high spectral efficiency.

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