BER Analysis for WCDMA System In Downlink FDD Mode

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Abstract— Wideband CDMA is one of the 3rd Generation technology, which is now popular in cellular systems due to its superior capacity and performance. Due to wide bandwidth of WCDMA system, support high data rate with variety of services on AWGN channel. Inspite of these advantages, Multiple Access Interference (MAI) is a factor which limits the capacity and performance of DS-CDMA based system. Present paper deals with the study of BER with three kinds of power control assumption (Perfect, Imperfect & variable power). The power control arises because of multiple access interference. The performance of the transmitter power control is one of the several dependent factors for deciding the capacity of WCDMA. It is observed that the performance degradation of a desired user depends on its spreading factor as well as every users (cause of MAI) present in the same network being operated at the variable power control. The performance is based on signal to noise ratio value in achieving the target value of BER (10^{-3}).

Keywords: BER Analysis, WCDMA, FDD

1. Introduction:

The existing mobile communication systems mainly support voice services. Other expected services are data transmission (facsimile) and multimedia services. Further, the increasing demand for information requires an easy way to access and process the information [1]. Several attempts have already been made to approximate the BER in DS-CDMA based system with reduction in MAI and improve the quality of service; [2,3,4]. The aim of 3G systems are to provide a multirate services (from 12.2 kbps to 2 Mbps) to all the users present in a cell, operates with single base station. There are of course many ways to design a multi-rate systems [5,6,7]. In [5] repetition coding was used to support different rates, but this is applicable for the few data rates. A more conventional way is to alter the processing-gain and spread all signals, independently of the bit rate, to the same bandwidth [6]. Different modulation schemes are also supported the multiple data rates in a direct sequences CDMA system as explained in [7]. Power control is the technique to mitigate the effect of interference [16]. In the present study, WCDMA system capacity has been analyzed on perfect, Imperfect & Variable power control. The study of multirate is based on the variable power control.

2. System Model:

In downlink Cellular 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 [2]. The binary source generates a binary sequence $b_k(m)$ contain transmitted signal energy per chip (E_{ck}) with the time shift (τ_k) for the K user, where m is the time instant and C_{kI},C_{kQ} are the PN codes assigned to I and Q channels. The spreaded data $X_k(t)$ is given in Eqn.(1).

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

Each transmitted signal is passed through a channel & reaches to the receiver. The channel is modelled by the zero mean Additive White Gaussian Noise (AWGN) n(t) with variance σ_n^2. The bit error probability (P_b) on AWGN Gaussian Channel for QPSK modulation is represented in Eqn (2) [2, 9,10].

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

Where No is the Gaussian noise one–sided power spectral density, E_b is the signal bit energy, k-1 are the interfering users & SF is the spreading factor. This expression for the Bit Error Probability is obtained with perfect power[14]. In downlink all the users are handled by a single base station and transmit their data with spreading factor (64) at 5 MHz bandwidth. Perfect Power means the entire signal transmitted from the base station is same for all the users present in the cell.

3. Study of Probability of Error with Spreading Factor at Imperfect Power:

The base station controls its transmission power to the different users according to the position and interference situation with in a cell. Imperfect power means the Users are operated at different power according their position[13].Those users present near the base station would be operating with the high power and suffer less interference. But those users present at the cell edge would operate at low power and also suffered by high interference form same cell and other cell. When the power control is imperfect, the received amplitude A_k of the k-th user can be modelled as random variable with uniform distribution around the nominal value of the received power level A_o. This means that the probability density function of A_k can be used

$$f(A_k) = \frac{1}{2V} \qquad A_0 - V \le A_k \le A_0 + V$$

Where, V is the maximum variation range of the received signal with respect to the mean value A_0 [16, 17]. Then, in the case of conventional correlation type receiver, the probability of Error are given in Eqn (3).

$$P_b = Q\left\{\frac{\left[2\sum_{i=1}^{N} K_i - 1\right]\left(1 + \frac{V^2}{3A_0^{\;2}}\right)}{3(SF)} + \frac{No}{2E_b}\right\}^{\frac{-1}{2}} \qquad (3)$$

4. Study of Multi-Rate Services with Spreading Factor at variable Power:

Multirate mean variable data rates, produced by varying received power of the user as a function of its position in a cell. The present study considers a single hexagonal cell configuration for multirate that consists of seven circular rings each having a different radius (r_i) and the numbering is start from the inner ring as shown in figure (1). A base station (BS1) is located at the centre of the hexagonal cell and all the mobile users present in a circular ring around the base station. Assuming that first ring is an active cell of desired user with radius (r_j) and their received signal power from the base station is P_j. Similarly, P_i is the received power of users present at adjacent cell of radius (r_i). Assume that the users are located in a cell are uniformly distributed. So those users present near the base station will operate at high signal power strength with those present at the far [10]. Kj is an active user in ring (j) and K_i -1 are the interfering user present at the different location. So the interference contribute from the interfering user (K_i-1) from the adjacent cell to the desired user is a function of power strength.

$$P_b = Q\left[\frac{N_0}{2E_b} + \frac{2}{3SF}\left(\frac{\sum_{i=2}^{7} P_i}{P_j} . K_i - 1\right)\right]^{\frac{-1}{2}} \qquad (4)$$

Since all users have the same signal to noise ratio per bit, the received power for the different users will be different for different data rates from the single base station, resulting in near far effects. Assume that the different users are operated with different data rate. Therefore, the data rates can be ordered as $R_1=1/T_1> R_2 = 1/T_2 >\ldots\ldots.>R_n=1/T_n$ with the spreading factor 64 at 5 MHz bandwidth. Also assume that all bit rates are multiples of the rates R_n and that the powers Pi, such that all users in sub cell transmit at same signal to noise ratio per bit E_b [8, 11]. Than the performance of user (K_i) with multirate (R_i) for probability of error in a QPSK modulated system is expressed in Eqn (5).

$$P_b = Q\left[\frac{N_0}{2E_b} + \frac{2}{3SF}\left(\frac{\sum_{i=1}^{n} R_i}{R_j} . K_i - 1\right)\right]^{\frac{-1}{2}} \qquad (5)$$

Where R_i refer to variable data rate, whereas R_j refer to active user data rate. In QPSK modulation many channels are available in parallel to achieve a high data rate for all the users at fixed spreading factor. Assume that Ro be the constant data rate in one QPSK Channel for desired user, for multirate data, which are multiples of this rate have been used [12]. So the effect of near far is negligible and Bit Error Rate is obtained by substitute the value of Ro in place R_j for an active user in a single QPSK channel in Eqn (5).

$$P_b = Q\left[\frac{N_0}{2E_b} + \frac{2}{3SF}\left(\frac{\sum_{i=1}^{n} R_i}{R_0}.K_i - 1\right)\right]^{\frac{-1}{2}} \qquad (6)$$

Eqn (6) is used to study the multirate scenario in the absence of any channel property for the calculation of BER in WCDMA system.

5. Performance Analysis:

The multi users have been operated with a single base station are spreaded by channelization sequence. The different sequences are assigned to the different users so that all users are being orthogonal in a cell. Orthogonal Variable Spreading Factor code (OVSF) are used as a channelization sequences [18] and they enable orthogonal transmission with variable spreading factor. Walsh-Hadamard codes are used to generate orthogonal codes with different spreading factors. Spreading Factor for FDD downlink mode of WCDMA is calculated by SF $=512/2^n$, where n is the number of bits in each slot [19]. At the receiver site, the capability to recover a given user signals are directly influenced by the spreading factor. Higher the spreading factor greater the capability to recover a given user's signal. The performance of WCDMA system is based on Bit Error Rate (BER) for the various number of interference at different value of Spreading factor, when E_b/N_o is varying from (2-20). Each user is a source of interference for other users, and the interference is bigger, if the operating users are high. Present study deals with three case of power control. In **first case**, assumes that all the users transmit at the same power (transmit power and received power are same) and the type of service is same for all. The Calculated result from Eqn (SF Last EQn), shows how the number of users and the type of service degrading the BER performances[15].

It is observed from the figure (1) that system becomes interference limited as the Number of Interference is increased (from 2 to 5) one by one at the fixed value of spreading factor (32) with the varying condition of Signal to Noise ratio (E_b/N_o), the required quality of service (BER) is decreased. The target value of BER (10^{-3}) is achieved at E_b/N_o is 5.9 dB, when there is single interference with the desired user. But as the interference users are increased from 1 to 4 the achievable target i.e BER 10^{-3} is achieved at E_b/N_o is 11.1 dB. At low spreading factor, 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 users' causes the Multiple Access Interference to be non-zero and the performance of the system is deteriorates as the number of users is increased.

Figure (2) shows that as the spreading factor increases from 32 to 64, the target BER (10^{-3}) is attained at E_b/N_o is 5.6 dB with the single interference present along with the desired user. But the main difference occurred at the higher number of user, the target value of BER is attained at E_b/N_o is 7.2 dB with the 4 user. The better orthogonality between the users with the spreading factor 64 are maintained and hence, decreases the MAI effect in WCDMA system and increase the performance of the network. The difference between the two services at higher number of interference is 3.9 dB in term of signal to noise ratio (E_b/N_o) for achieving the target value BER (10^{-3}). The spectral efficiency of a DS-CDMA system can be represented as $(E_b/N_o^*)/(E_b/N_o)$ where $(E_b/N_o) > (E_b/N_o^*)$. A reduction in the operating value of E_b/N_o from 11.1 dB to 9 dB is accompanied by an increase in spectral efficiency of 81.4 %. With a 2.1 dB decrease in E_b/N_o, the system utilization is increased from 4 to 7 Users. Figure (3) shows the comparison between the two services of SF 32 and 64 at varying condition of E_b/N_o for the fixed user (three). The performance of the desired user is much better with SF (64) for fixed number of interference. Increasing of SF leads to interference reduction. This conclusion is an intrinsic property in CDMA systems that interference is vice versa with spreading factor. In downlink, different signals of users are synchrounous and therefore because users orthogonally, a remarkable interference is eliminated and that paths that are not separable by rake receiver have effect on desired signal. But in Uplink because users transmit the signal randomly, there are not orthogonal codes and users are separated by scrambling codes. So, it is assumed that downlink performance is better than uplink.

In the **Second case**, assume that the transmitted power from the single base station to the number of user in the cell is not perfect. Figure (4 & 5) shows the effect of imperfect power control on the performance of a WCDMA system. When the power is imperfect, the transmitted amplitude A_k of the k_{th} user is a random variable with uniform distribution around the nominal value of the received power level A_o. The same performance has been carried out as in figure 1 & 2. The value of $k=V/A_o$ is 0.5 for imperfect power. The target value of BER (10^{-3}) is achieved at 6.8 dB value of Eb/No at SF 32 with single interference but the same result is achieved at 14.2 dB with 4Interference. Whereas, at SF

(64), E_b/N_o is 5.2 dB for single user and 9.2 dB for five users are required to achieve the target value of BER. As expected, that the BER is significantly lower increasing spreading factor. In all the analysis the performance of the system degrades respect to the case of perfect power as shown in figure (6).

In the **third case** varying power is the base multirate study. To evaluate the performance for multirate services in WCDMA system at 5 MHz Bandwidth, first fix, the number of user (K_i) at 5 and spreading factor (SF) with the function of signal to noise ratio. To study the different multirate schemes, three data rates such as $R_i = R_o$, $R_i = 2R_o$ & $R_i = 4R_o$ have considered. These different data rate services are occupied by the interfering users at fixed data rate of active user (R_o). High data rate users require greater value of E_b/N_o in achieving the target value of BER (10^{-3}) [12]. They achieve this by transmitted the signal at high power. This in turn implies higher level of interference and consequently a decrease in capacity in the network. So the presence of high data rate interferer user degrades the performance of the desired user more than the low data rate interferer's user as shown in figure 7 & 8.

The present study result has compared with Lehnert [4] result and showed the better performance with the combined effect

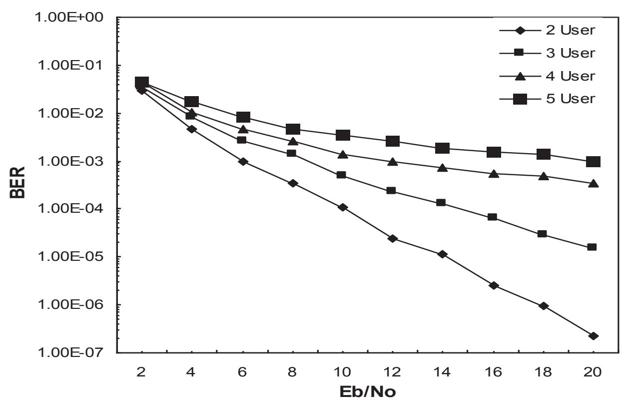

Figure 1 BER Vs E_b/N_o at Spreading Factor 32 in WCDMA Downlink Mode. The number of interferences users varies from 2 to 5.

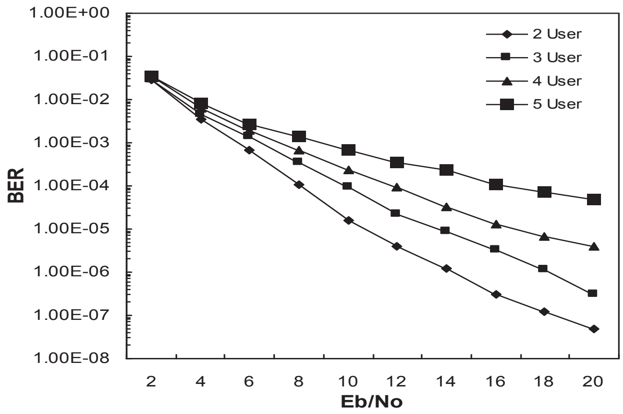

Figure 2 BER Vs E_b/N_o at Spreading Factor 64 in WCDMA downlink Mode. The number of interference users varies from 2 to 5.

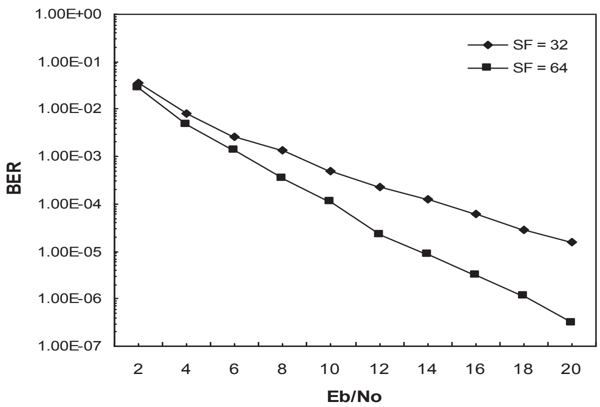

Figure 3 BER Vs E_b/N_o with two Spreading Factor (32, 64) at fixed Number of Interference Three.

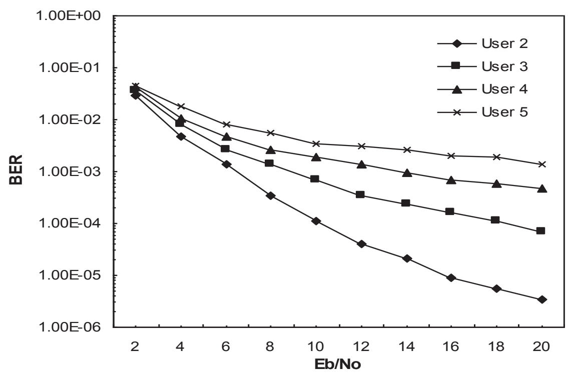

Figure 4 BER Vs E_b/N_o with Spreading Factor 32 in WCDMA downlink Mode at Imperfect Power. The number of interference users varies from 2 to 5.

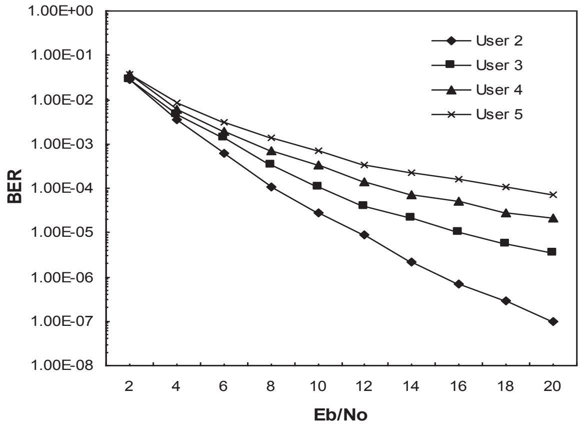

Figure 5 BER Vs E_b/N_o with Spreading Factor 64 in WCDMA downlink Mode at Imperfect Power. The number of interference users varies from 2 to 5.

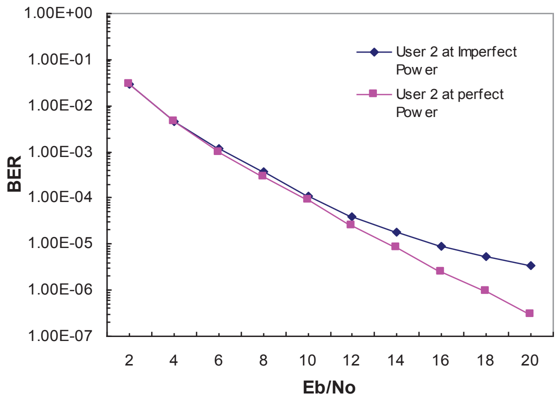

Figure 6 Comparison of BER at Perfect & Imperfect Power BER with Spreading Factor 64 at 2 User in WCDMA downlink Mode.

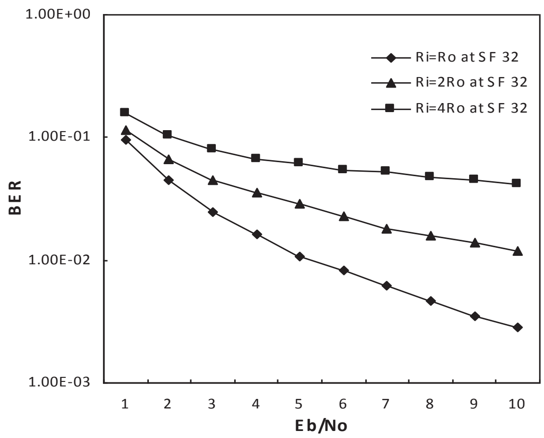

Figure 7 Study of Multi Rate services with SF (32)

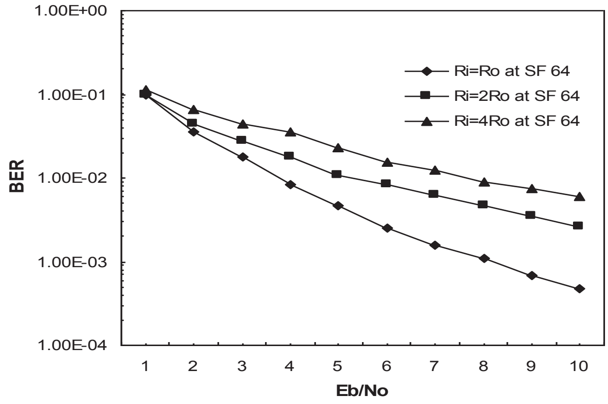

Figure8 Study of Multi Rate services with SF (64)

Conclusion:

The problem of describing the interference generated by a number of users in a asynchronous WCDMA system is made a complex task by the inherent unpredictability of the wireless communication scenario. The Gaussian Approximation, by mean of the central limit theorem theory and power control lead to a fundamental simplification of the MAI problem, thus allowing an analytical development and a very computationally efficient solution for the system performance estimate in term of BER. Different kind of data rates have studied on the basis of variable power control at constant chip rate in WCDMA system. It has been seen that the operating condition of signal to noise ratio with high data rate services is found to be high. But at high value of spreading factor independent to power control, the signal to noise ratio for achieving the target value of BER is found to be lower. It is due to the better orthogonality code are used to the desired user along with the interference users. In this paper we have only considered the simple multirate services for the performance of WCDMA system. The same performance can be improved by the inclusion of efficient coding methods and multiuser detection algorithm.

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