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Performance Analysis of DS-CDMA over a Non Fading Channel with Perfect Power Control under Different Processing Gain

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Abstract—Code Division Multiple Access (CDMA) is a well known access technology in which all the users share the spread spectrum.Again one of the most important challenges with respect to wireless access is to combat with fading and interference. CDMA is the technique that is more efficient to overcome frequency selective fading and interference than others. Direct Sequence (DS) - CDMA is one of the most well-known CDMA techniques. Hence we motivated to analyze it's important system performance with respect to SIR and BER.We considered a model of DS-CDMA where the power control is perfect and the propagation is modeled without fading using Standard Gaussian Approximation (SGA).Also we analysis the performance for interference limited case (ilc) and non-interference limited case (nilc).Simulations were done using chip rate is 3.84 Mbits/s,the Signal-to-Noise Ratio(SNR) E_b /N_o =10 dB and the processing gain is chosen arbitary such as 20,30,128,256.

Index Terms—CDMA, DS-CDMA, SGA, SNR.

1 INTRODUCTION

CDMA is a branch of multiple access radio communication processes in which multiple users have access to the same system, using the same frequency. This is accomplished by means of an m -bit PN generator, which provides 2m – 1 different code. Out of these codes, only m codes, known as orthogonal codes, are orthogonal codes, are derived and assigned to m users. The function of the PN code is to spread the traffic data the entire transmission band while uniquely identifying each user. Because the spreading is accomplished by direct application of a PN sequence, the overall process is described as direct sequence code division multiple access of DS-CDMA [2].

Multiple Access Interference (MAI) is a factor which limits the capacity and performance of DS-CDMA systems. MAI refers to the interference between direct- sequence users. This interference is the result of the random time offsets between signals, which make it impossible to design code waveforms to be completely orthogonal. While the MAI caused by any one user is generally small, as the number of interferers or their power increases, MAI becomes substantial. Therefore, any analysis of performance of a CDMA system has to take into account the amount of multiple-access interference and its effects on the parameters that measure the performance, in particular the signal-to-interference ratio at the receiver and the related bit error probability on the information bit stream. This paper analyzed the system performance of DS-CDMA over a non fading channel with perfect power control for different processing gain.

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2 TECHNIQUES OF ANALYSIS

2.1 Signal-to-Interference Ratio

In wireless communications, the Signal-to-Interference Ratio (SIR) is a predominant parameter that characterizes the system performance. In particular, SIR estimation is needed for taking various important decision makings. The tasks are handoff, dynamic channel assignment and power control [1].

In any multiple access system, one of the fundamental design parameters is the SIR at the receiver, which measures the ratio between the useful power and the amount of interference generated by all the other sources sharing the same resource. The SIR can be expressed as

$$SIR=\frac{E\{D_0(m)^2\}}{E\{(1+v)^2\}}=\frac{E\{D_0(m)^2\}}{E\{I_0^2\}+E\{I_1^2\}+E\{v^2\}} \quad (1)$$

The statistical averages in expression (1) can be calculated as follows.
For the significant term E{$D_0(m)^2$} is the expected information component and represents a deterministic variable given the transmitted bit

$$E\{D_0(m)^2\}=E\{(b_0(m)\sqrt{\frac{p_0}{2}\alpha_{0,0}T_b})^2\}=\frac{P_0T_b^2}{2}E\{\alpha_{0,0}^2\} \quad (2)$$

or maintaining the conditioning on the path gain $\alpha_{0,0}$,

$$E\{D_0(m)^2\mid\alpha_{0,0}\}=\frac{P_0T_b^2}{2}\alpha_{0,0}^2 \quad (3)$$

where P_o is the mean power and T_b is the bit duration.
The Expected noise Term is $E\{v^2\}$ in the equation (1) can be expressed as:

$$E\{v^2\}=\sigma_v^2=\frac{N_0T_b}{4} \quad (4)$$

where N_o is the noise power spectral density.
The Gaussian approximation of the summations in I, I_0, I_1 and operate subsequent statistical average over the environmental parameters. Thus they obtain

$$E\{I^2\mid P_k\}=\sigma_I^2|_{\{P_k\}}=\frac{G_pT_c^2}{6}\sum_{K=1}^{K_u-1}P_k \quad (5)$$

where G_p is the process gain and T_c is the chips duration in purely AWGN channel.
In the presence of flat fading

$$E\{I^2\mid P_k,\alpha_k\}=\sigma_I^2|_{\{P_k,\alpha_k\}}=\frac{G_pT_c^2}{6}\sum_{K=1}^{K_u-1}\alpha_k^2P_k \quad (6)$$

Finally, in case of frequency-selective fading, with the hypotheses of identical mean number a of multipath. For each source and identical mean number of users per cell, it is possible to obtain

$$E\{I_0^2\}=\frac{A^2T_b^2 2\sigma^2(MK-1)}{3G_p} \quad (7)$$

$$E\{I_I^2\}=2\sigma^2\frac{MK}{5}\frac{A^2T_b^2}{3G_p} \quad (8)$$

where $\alpha_{k_0,m_{k0}}$ are the path gains affecting signals of the reference cell, $\alpha_{k_1,m_{k1}}$ are the path gains affecting signals of the surrounding cells, $\beta_{k1}=\frac{r_{1,k1}}{r_{0,k0}}$ are the ratio between the distances of the *k-th* user of a surrounding cell from its home base station $(r_{1,k1})$ and from the reference base station $(r_{0,k0})$. If the path gains are identically Rayleigh distributed and β_{k1} is uniform in (0,1) , we obtain:

$$E\{\alpha^2_{k_0,0}\}=E\{\alpha_{k0,m_{k0}}{}^2\}=E\{\alpha^2_{k_1,m_{k1}}\}=2\sigma^2 \quad (9)$$

$$E\{\beta_{k_1}^4\}=\frac{1}{5} \quad (10)$$

2.2 Bit Error Rate (BER)

In digital transmission, the quality of the transmitted signal is often expressed in terms of how many of the received bits are incorrect. This is called Bit Error Rate (BER). BER defines the percentage of the number of received bits which are incorrectly detected [5].

Transmitted bits	1	1	0	1	0	0	0	1	1	0
Received bits	1	0	0	1	0	0	1	0	1	0
Errors		↑					↑	↑		

3 / 10=30% BER

This percentage should be as low as possible. It is not possible to reduce the percentage to zero because the transmission path is constantly changing.

2.3 Standard Gaussian Approximation (SGA)

The use of the Gaussian Approximation to determine the SIR and the BER for a CDMA communications system is based on the argument that the bit decision statistic Z_0 may be modeled as a Gaussian random variable [1] . We recall here the expression of the decision statistic of the transmitted bit as derived in the previous chapter:

$$Z_0(m)=D_0(m)+I+v \quad (11)$$

where D_0 is the useful information component and represents a deterministic variable given the transmitted bit, while the MAI and thermal noise components, I and V, are independent zero-mean Gaussian random variables. Thus, defining $\xi=I+v$, Z_0 is a Gaussian random variable with mean D_0 and a variance which is equal to the variance of ξ (σ_ξ^2) .

2.4 Propagation in Absence of Fading

Taking the statistical independence of the thermal noise and MAI terms, the variance σ_ξ^2 is directly expressed as:

$$\sigma_\xi^2=\sigma_I^2+\sigma_v^2=\frac{G_pT_c^2}{6}\sum_{k=1}^{K_u-1}P_k+\frac{N_0T_b}{4} \quad (12)$$

Then, because of the Gaussian distribution of the noise interference term ξ , the probability of a bit error over the channel is given by:

$$BER = Q\left(\frac{|D_0|}{\sigma_\xi^2}\right) = Q\left(\sqrt{\frac{P_0 T_b^2}{2\sigma_\xi^2}}\right) \quad (13)$$

Now consider that, for QPSK and BPSK modulation schemes, the relation between the bit error probability and the signal-to-noise ratio E_b / N_0 over Additive White Gaussian Noise (AWGN) channel in absence of interferers is expressed by the well-known relation:

$$BER = Q\left(\sqrt{2\frac{E_b}{N_0}}\right) \quad (14)$$

where E_b is the energy per bit and y N_0 is the two-sided power spectral density of the thermal noise. Therefore, the previous expression yields the definition of an equivalent SIR for the CDMA system.

By comparing equations (3) and (2), the following expression is obtained

$$SIR = \frac{P_0 T_b^2}{2\sigma_\xi^2} \quad (15)$$

$$= \frac{05}{\frac{1}{3G_p}\sum_{k=1}^{K_u-1}\frac{P_k}{P0} + \frac{N_0}{2T_b P_0}} \quad (16)$$

In typical mobile radio environments, communication links are interference-limited and not noise limited. For the interference-limited case the thermal noise term can be neglected and the average SIR and the average BER are given by

$$SIR/\{P_k\} = \sqrt{\frac{3G_p}{\sum_{k=0}^{K_m-1}\frac{P_k}{P_0}}} \quad (17)$$

$$BER/\{P_k\} = Q\sqrt{\frac{3G_p}{\sum_{k=0}^{K_m-1}\frac{P_k}{P_0}}} \quad (18)$$

Note that the previous expressions assume the knowledge of the set of the received powers $\{P_k\}$. CDMA systems generally implement some form of power control, in order to reduce the near-far effect. Thus, ideally, all the signals arrive at the receiver with the same power: $P_k = P_0 \ \forall k$. In this case

$$SIR = \frac{0.5}{\frac{K_u-1}{3G_p} + \frac{N_0}{2T_b P_0}} \quad (19)$$

$$BER = Q\sqrt{\frac{1}{\frac{K_u-1}{3G_p} + \frac{N_0}{2T_b P_0}}} \quad (20)$$

Finally, in the interference-limited case with perfect power control, the average SIR and the average BER can be approximated by

$$SIR = \frac{3G_p}{2(K_u-1)} \quad (21)$$

$$BER = Q\sqrt{\frac{3G_p}{K_u-1}} \quad (22)$$

3 SIMULATION RESULT

We considered the scenarios: the cases of a channel without fading and the cases of perfect power control. The received power of the desired signal is normalized to 1. In all the simulations the chip rate is equal to 3.84 Mbit/s, the Signal-to-Noise Ratio Eb/No =10 dB and the processing gain Gp is chosen arbitrarily such as 20, 30, 128, 256 etc.

In the simulation we mainly concentrated our attention on SGA (Standard Gaussian approximation). In this case of SGA approximation we use the equations (21) and (22), for interference limited case (ilc), (19) and (20) for non-interference limited case (nilc).

In the following figures the BER are plotted: in Fig1 G_p =30, in Fig.2. G_p =256(using equation 20 and equation 22). We can observe that the BER becomes significantly lower Increasing G_p which is our main expectation. In fig.3. We set G_p =20 and in fig.4 we took G_p =128, (using equation 19 and equation 21) we examined that SIR gradually increased as increasing G_p.

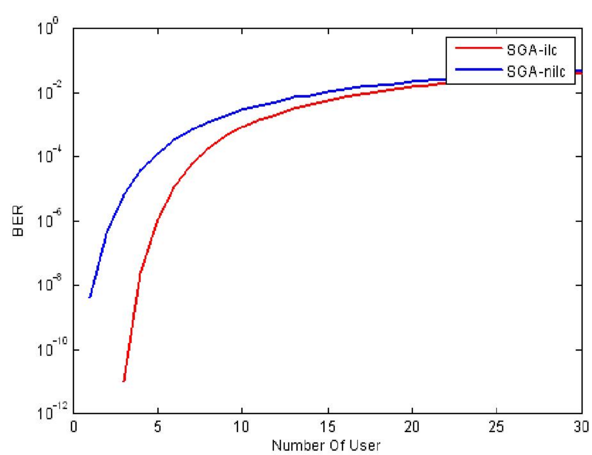

Fig.1. BER over a non fading Channel with perfect power control G_p =30

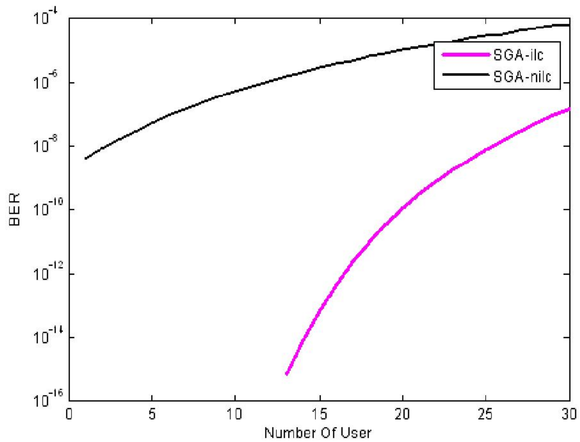

Fig. 2. BER over a non fading Channel with perfect power control Gp =256

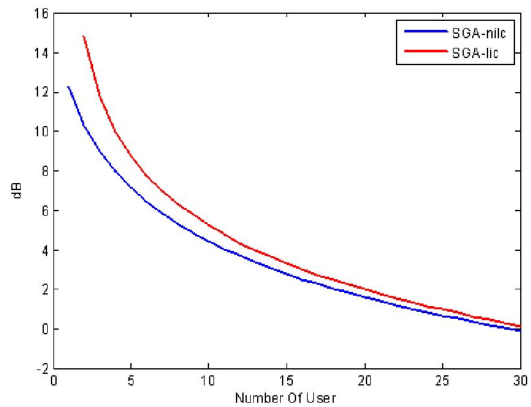

Fig. 3. SIR over a non fading Channel with perfect power control G_p=20

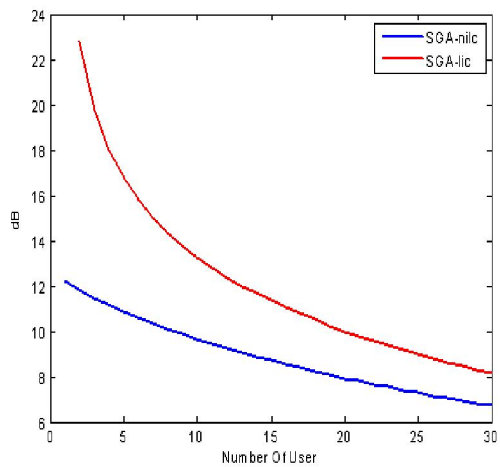

Fig. 4. SIR over a non fading Channel with perfect power control G_p =128

4 CONCLUSION

This paper focused the attention on the standard gaussian approximation (SGA).The types of scenarios were driven with respect to perfect power control over a non fading channel. For all the cases, the SIR and BER were evaluated. This paper evaluated SIR and BER as function of number of users. Here the parameter G_p is used as a variable and SIR and BER are compared. The others parateres such as the number of multipath, the number of interfering cell will be analyze in future.

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