A Review on Evaluation of BER in CDMA using SGA Technique

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Abstract:-In today's era wireless communication systems are one of the most essential part of this digitized world and evolution of CDMA system has made it more convenient and secure to communicate the information within the system. From past one decade CDMA system has met the rapidly developing need of a communication system by improving in terms of several problems like multipath fading, interference, cross-talk etc. This paper summarizes all the clusters of specific analysis techniques with different constraints and conditions to evaluate the performance of CDMA system. The major emphasis of this paper lies on the reasons behind the problems and their remedy technologies to find out the most efficient technique for a noise and distortion free communication system suitable for today's environment.

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I. Introduction:

Code Division Multiple Access (CDMA) inherently leverages the principle of spread spectrum that has intrinsic abilities to combat against multipath interference, increases system capacity and improves quality of service. This proves the reason behind extensive use of CDMA in wireless communication. A distinctive issue present in wireless communication as compared to wired communication is multipath fading. In urban areas congested with large number of buildings, vehicles, obstacles etc. results in reflection, refraction, deflection and scattering of transmitted radio signal which in-turn results in multiple copies of signal reaching at the receiver giving rise to multipath fading. Due to the time variant and selective nature of multipath fading at some point of time, some part of the spectrum of transmitted signal fades out at some specific location which consequently increases BER. The mobility of users (receiver) with respect to transmitter and time varying channel composed of moving obstacles make the problem of multipath inevitable. Much work has been reported till now on the calculation of average BER under different fading channel in a DS-CDMA System. Various techniques have been used to improve and analyze BER performance of CDMA system. In this paper review of such techniques has been done by categorizing them based on their line of approach while mentioning advantages, disadvantages and limitations with reasons for each of them.

II. Scope of the Study:

This paper presents a new approach to inculcate all the benefits and disadvantages of analysis techniques used for evaluating Bit Error Rate or Error Probabilities for various kind of CDMA System. For the purpose of this paper we have limited to Standard Gaussian Approximation (SGA) technique and some of the Miscellaneous Techniques.

III. Technical Evaluation Methods:

I. Standard Gaussian Approximations (SGA):

It is computationally difficult to calculate the exact BER of the CDMA System so, the emphasis lies on approximations. One of the most widely used techniques is Standard Gaussian Approximation (SGA) for evaluating BER based on approximation.

In SGA it is assumed that the Multiple Access Interference (MAI) has a Gaussian distribution. SGA is based on central limit theorem which states that, for given certain conditions, the arithmetic mean of a sufficiently large number of iterations of independent random variables, each with a well-defined expected value and well-defined variance, will be approximately Gaussian distributed.

As in SGA Multiple Access Interference (MAI) is Gaussian distributed so it is assumed to be equally distributed and independent of each other as well. The average variance of the Multiple Access Interference is used to calculate the SNR in all possible conditions of operations. The receiver design for any system model using SGA has a matched filter (single user) to detect the desired user signal in most of the cases. The individual signals transmitted by transmitter are received by matched filter. Then from the matched filter output these signals are summed up together to treat as a single strong signal for further processing that reduce the computational complexity of the system.

The authors S. Mahmoud and O'Shea [11] have used SGA technique for calculation of BER in DS-CDMA system under Rayleigh fading channel. Parameters used for analysis are number of interfering cells and processing gain. Authors designed a system model for transmitted signal, channel and received signal. For transmitted signal, they consider M_c number of cells in the reverse link in a DS-CDMA system that supports K active users. They assume that all K active users are transmitting. Each of them transmits a signal which consists of binary data and pseudorandom sequence. They also assumed that the desired user is at K= 0 and other users will play a vital role to produce MAI.

The channel is defined between the K^{th} user and the base station is a frequency selective multipath Rayleigh fading channel. Its impulse response is defined by taking in account to phase of the multipath component and the path delay.

At the receiver end matched filter (correlation receiver) is used to detect the desired user signal. Each cell is equipped with a conventional matched filter (correlation receiver) and it is assumed by the authors that the power received by the desired signal is normalized to 1.

From the simulation results the authors concluded that SGA results in better estimation of BER when number of interfering users became large. This is because with increased number of interfering users the resultant accumulated signal becomes stronger which allows easy calculations.

Holtzman [10] used an improved version of SGA i.e. Accurate Gaussian Approximation (AGA) which is again based on central limit theorem. AGA technique is based on delay of interfering signals. AGA requires certain prior MAI distributional analysis so that the information regarding delay of all interfering signals will be known. Delay between the multiple signals plays an important role to evaluate the BER. By providing proper delay between different signals, accuracy to decode the information at receiver side increases.

Author describes the system model as there are K active users. The transmitted signal consists of data & spreading signals. The data signal & spreading signal is a sequence of unit amplitude (positive & negative) rectangular pulses and chips respectively. The pulse and chip amplitudes are all identically distributed with probability of 1/2 of being ±1. At the receiver end the combine signal of entire users is multiplied by a synchronized spreading sequence of the transmitted signal. of the original signature sequence. Finally simulations results show very good accuracy for probability of error greater than 10^{-5}.

Cheng & Stark [9] combined encoding technique with SGA to evaluate the BER for DS-CDMA system suffering from MAI under the fading environment. They considered coded modulation with the Trellis Coded Nordstrom Robinson (TCNR), Trellis Coded Reed-Muller (TCRM) Code and a conventional 64-ary Orthogonal (M_{64}) Code. These codes are concatenated with (63, K) Reed Solomon (RS) outer code. Reed Solomon codes are non-cyclic error correcting codes used to detect and correct multiple random symbols errors. The analysis is considered with frequency hopped spectrum with one modulation symbol transmitted per slot. If a frequency-hopped system has more than one modulation symbol transmitted over the time interval in which carrier frequency is constant then some interleaving is required in addition to hopping. The key assumption they considered is that different code symbols experience independent channel statistics.

They also discussed about the basics of Orthogonal Codes, TCNR & TCRM Codes. They defined the transmitted and received signal for M_{64} Orthogonal Code of length N where N=64n and replace the orthogonal codes by biorthogonal ones i.e. for M_{64} it is $B_{128.}$ Biorthogonal codes are the set of complementary words orthogonal to each other and also w.r.t. each code word in original set. Biorthogonal codes increases the data rate by 1 bit. Nordstrom- Robinson codes are also generated by using a biorthogonal code of 256 code words by adding selected cosets of the biorthogonal code to the original code with minimum distance of 6. The 256 code words are divided in 8 cosets, each of 32 biorthogonal code words. They combine these 8 cosets with a 4 state trellis to form a Trellis Coded Nordstrom-Robinson (TCNR) Code. Trellis Codes are a basically convolutional code which allows highly efficient transmission of information over-band limited channels. The Trellis Coded Reed-Muller (TCRM) codes are also generated by combining 16 cosets of biorthogonal codes with 16 states Trellis.

Finally they concluded that for $B_{128,}$ TCNR & TCRM code the data rate is 7/N instead of 6/N i.e. increase in data rate at the expense of additional circuitry needed for carrier phase synchronization. Due to increase in data rate there is significant improvement in BER as well.

Jong and E.Stark [6] analyzed the performance of convolutionally coded multicarrier spread spectrum under AWGN & multipath fading. They evaluate BER and ACPR (Adjacent Channel Power Ratio). ACPR is the ratio of out-band signal power to in-band signal power.

The transmitter model (for q users) has the convolutionally encoded information sequence that is interleaved and converted to M parallel streams from a serial stream. The information bit duration before the serial to parallel process is T_b and the code rate is $R_{c.}$ The code symbol stream for the qth carrier is multiplied by a random spreading code. Each spreading code has a chip duration of $T_c = T_s /N$ where N is the spreading gain of the system. Finally the signals on all the carriers are added together before amplification. The signal is transmitted over a frequency selective channel and demodulated with the help of conventional matched filter. SGA technique is used for the analysis and the simulation results shows that BER reduces in AWGN as compare to multipath fading and Adjacent Channel Power consumption is also optimize by minimizing the total degradation (TD) i.e. the ratio of maximum possible amplifier output power to average amplifier output.

Xiang Liu & Hanjo [3] used SGA technique for exact BER analysis. They consider different fading channels Rayleigh, Rician, Hoyt and Nakagami-m channels for the analysis. For whole analysis background noise is ignored. They considered a BPSK modulated DS-CDMA system communicating over above mentioned fading channels. There are K active users transmitting in the system. The transmitted signal comprises of binary data and spreading sequence. Here short codes are used as spreading sequence. Short codes have good cross-correlation properties. It is also used for synchronization in forward link and reverse link. The transmitted signal passes through different fading channels and output signal is received at coherent receiver. For each fading channel BER is evaluated by using simulation technique with SGA.

BER performance versus the number of users in context of Rician fading channel, shows that SGA slightly over-estimates the average BER, when Rician factor K=0 (i.e. Rayleigh channel) and under-estimates when K increases to 9. When K -> ∞ which corresponds to having no fading and no noise, SGA will more severely under-estimates the average BER, basically in context of AWGN channel. For Hoyt fading channel the SGA over-estimates average BER when limited numbers of interferers are there and for Nakagami-m fading channels, SGA slightly over-estimates the average BER when the Nakagami-m fading parameter is low & marginally under-estimates the average BER, when the Nakagami-m fading parameter is high.

Finally they concluded that SGA remains fairly accurate for most practical scenarios, although slightly over-estimates the average BER when fading is severe while it under-estimates the average BER, when fading is low, especially when either low number of interferers are there or the SNR is high.

Pravindra Kumar, Kanuajia & Gangadharappa [1] evaluate the BER performance of Rake Receiver in reverse link (mobile to base station) under Rayleigh fading channel (frequency selective). They employed SGA technique with Convolutional Coding at transmitter and Viterbi Decoding at the receiver. They examined the BER performance of RAKE Receiver by varying Interfering Cells, number of users, RAKE fingers, spreading factor, and the value of directivity of antenna base station. They use BPSK modulation for the analysis. They define the reverse link (transmitter model) for K active users with M_c number of interfering cells. The assumption they follow is that the desired user is at K = 0 and other users will contribute to MAI. They also assume that the channel $h_k(t)$ is multipath Rayleigh frequency selective channel. At the receiver end RAKE receiver is used which works on the principle of multipath diversity i.e. it process several multipath components and the combine output of the correlator is used to achieve improved communication reliability and performance.

The authors also discussed about how directive antennas can improve the system performance. Omni directional Receiver Antenna will receive the greatest amount of noise as it will detect signal from all users in the system. The sectored antenna divides the received noise in to a smaller value as to enhance the number of users in CDMA system. In Adaptive Antenna the base station tracks each user in the cell as it moves. It provides a high gain in the system.

Finally they concluded that BER performance of RAKE Receiver will degrade, if there is increase in the number of users (there is ≈5.2 dB degradation with increasing users from 1 to 5). The BER performance also degrades, if number of interfering cells increases (there is ≈ 1.8 dB degradation with interfering cells increases from 1 to 6) but BER performance increases with respect to spreading factor (there is ≈ 6.4dB advantage with increasing spreading factor from 16 to 32), BER performance increases with increased number of RAKE fingers (≈ 9.5dB advantage with increase in RAKE fingers from 2 to 5), BER performance also increases with increase in directivity of base station antenna (≈ 2.4dB advantage with increase in directivity of base station antenna from 4 to 8 dB)

Cheng and Beaulieu [5] estimate the accurate BER for DS-CDMA system over Rayleigh fading environment. The authors introduce a new analytical approach which is a closed form expression. The overall error rate can be expressed by a single integral instead of individual signals. The authors compare the analytical approach with three approximations techniques i.e. Standard Gaussian Approximation (SGA), Improved Gaussian Approximation (IGA) and Simplified Improved Gaussian Approximation (SIGA).

In Standard Gaussian Approximation (SGA) a Central Limit Theorem (CLT) is applied to approximate the sum of different multiple-access interference (MAI) signals as an additive white Gaussian process. At the filter (correlator) output the average variance of all the different MAI signal is used to compute the SNR in all kinds of possible operating conditions.

Improved Gaussian Approximation (IGA) is also CLT based technique which requires numerical integration and multiple numerical convolutions. IGA is more accurate than SGA. Simplified Improved Gaussian Approximation (SIGA) is also CLT based technique neither requires the knowledge of variance distribution nor numerical integration & convolution to achieve BER estimation.

The transmitted signal is defined for K active users transmitted over Rayleigh fading channel and decoded by using a matched filter. For BER analysis above defined analytical and approximation techniques are used. The simulation results shows that closed form expression is more accurate with less computational complexity as compare to CLT based approximations.

From above discussion we can understand that SGA is easy to use because of its computational simplicity. SGA easily adapts with different types of parameter for evaluation like BER, Throughput, Processing Gain, Power etc. SGA can also be used with different modulation systems, but SGA overestimates the system performance when less number of users are present in the system so less accuracy is there as interference becomes a dominant feature over small number of users.

IV. Miscellaneous Techniques:

Several authors have used some different approach to calculate BER in CDMA communication system to achieve improved system capacity, bandwidth efficiency, spectral efficiency & high data rate etc.

It has been seen that DS-CDMA system bandwidth efficiency can also be improved by increasing the number of bits/symbol but the complexity of the receiver increases exponentially with the number of bits/symbol and linearly with the M (number of orthogonal sequences). So Yang & Hanjo [8] had proposed an alternative method based on Residue Number System (RNS) in which receiver complexity increases linearly, rather than exponential with number of bits per symbol. In this method any information x is to be transmitted as a set of residues r = {r_1, r_2,......r_n} with respect to the set of moduli{m_1, m_2,.......m_n} where r_i is reminder of r with respect to m_i for i=1 to u. These residues are mapped into a set of orthogonal sequences and are transmitted in parallel. The operations on individual residue channels are mutually independent due to the carry free nature of residue arithmetic. Also some residue digits can be discarded without affecting the result provided sufficient number of residue digits are retained for the reconstruction of the symbol.

Madhukar & Francois Chin [7] proposed an enhanced model of Residue Number System (RNS) based on DS-CDMA for high rate data transmission. They have designed a Transmitter, Receiver and Channel model in such a way that information can be transmitted or received serially and parallel both the way. They have use PSK/QAM modulation scheme which uses lesser spreading factor than RNS CDMA of same capacity. It can also be used for faster data transmission without affecting the system performance.

Transmitter portion of the proposed model is used to converts M-ary symbol into parallel residue channels. Each residue channel consists of spread code and information data. In order to extract both, the residue channel is converted to binary data and the data is modulated with the help of MPSK/MQAM modulation scheme and multiplexed for transmission. The multiplexed spread code corresponding to each residue symbol is scrambled using a scrambling code and transmitted after pulse shaping. The transmitted signal is scattered by many obstacles between transmitter and receiver. Due to interference among multipath with different time delays, the received signal suffered from multipath fading. As per residue arithmetic, the residue operations belonging to different moduli are mutually independent so, at the receiver side parallel sub channels are placed equal to the total number of residue channel. Assuming the perfect synchronization, each sub receiver is descrambled using scrambling code and the data is decoded with the help of a suitable error correction code. The authors have used orthogonal Walsh sequence as short codes and random codes as long codes for spreading faster data rates. The authors compare their proposed RNS based technique with the RNS technique used by Yang & Hanjo and their simulation result shows that BER performance of Enhanced RNS technique has become 1/4 of the RNS technique proposed by Yang & Hanjo.

Salman Durrani & Marek [4] had proposed an analytical model to analyze BER of CDMA system. They had used an antenna array at the Base Station (BS) in a Rayleigh & Rician fading environment. They evaluated BER with reference to varying number of users, number of antenna, noise levels and single user performance. They consider the transmitter model in reverse link (mobile station to base station) with K number of mobile stations (MS) which are randomly distributed. The k=1^{th} user is assumed to be desired user. They considered an adaptive antenna beam forming for the designed system model which utilizes the space domain and can suppress interfering signals by acting as a spatial filter. The authors assumed that the Base Station (BS) is equipped with a Uniform Linear Array (ULA) comprising of N antenna elements like base station. The individual antenna elements are assumed to be Omni-directional with an inter spacing of d=λ/2. The channels are taken as Rayleigh and Rician channel for analysis and they had analytically designed the receiver model as well which incorporates the Uniform Linear Array (ULA) of N elements. Their analytical result shows that in case of Singer User Performance in Rician Fading with Rician Factor K_r = 1, 5, 7, 10 dB respectively for N=6 antennas is similar to Rayleigh fading for low values of K_r. There is tremendous improvement in BER for larger values of Rician Factor. In case of Different Number of Users in Rician Fading for N=6 antennas & E_b/N_o = 10 dB the BER vs. E_b/N_o shows good results as compare to Rayleigh Fading. For varying the Noise Level and Number of Antennas for N=6 antennas, E_b/N_o = 10 dB & K=15 users BER reduces in Rician Fading.

Yang, Haoshan & Han [2] analyzed BER of MC-CDMA system with effect of multipath fading. They compare the BER of MC-CDMA system with CDMA system. They introduce the MC-CDMA system as an integrated technology of OFDM and CDMA both. They also told the advantage of MC-CDMA over OFDM system, In OFDM technology a sub-carrier corresponds to information symbol, so to avoid deep fading there must be some redundant sub-carriers to provide correction in the code while the same information symbol for MC-CDMA system has different sub-carriers, which enables frequency diversity and does not need correction coding. The authors also told OFDM symbols rely on orthogonal sub-carriers, but in MC-CDMA the orthogonalities are among different sub-carriers and user's frequency spreading code sequences. OFDM could increase the spectral efficiency while MC-CDMA sharing system frequency resource as well as increasing the spectral efficiency.They used analytical method to design the transmitter and receiver model for M active users which uses BPSK modulation technique and operate over Rayleigh Fading Channel. Finally the simulations results shows that for Number of Multipath is 12, MC-CDMA system has better BER performance than CDMA which presents its excellent ability to suppress ISI and multipath interference.

V. Conclusion:

It has been seen that SGA and other techniques can be easily used with different evaluation parameters. These techniques are useful for analytical as well as simulation approaches.

VI. References:

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