BER Performance Analysis of CDMA Reverse Link under AWGN Channel

Sanjeev Kumar
AP, Deptt.of ECE, ACET
12 km stone,Amritsar-Jalandhar, GT road,
Amritsar, Punjab, India

Monika Tuteja
Lecurer, Deptt. of ECE
College of Engineering & Mangement,
Kapurthala, Punjab, India

Ramneek Singh
Lecturer, Deptt.of ECE
DAV Institute of Engineering & Technology
Jalandhar, Punjab, India

ABSTRACT
The bit error rate (BER) performance of the Code Division Multiple Access (CDMA) cellular system based on IS-95 standard in the presence of an additive white Gaussian noise (AWGN) and interference has been investigated in this paper. The performance is evaluated under two types of decision feedback receivers for the CDMA reverse link. These two feedback receivers are: (a) Hard decision Viterbi decoder in which coded bit is estimated based on Hamming Distance method and (b) Soft decision Viterbi decoder in which Euclidean Distance method is used for coded bit estimation. The comparison of these two techniques of decision feedback receivers of CDMA is done under AWGN channel. The performance of CDMA system is shown in graphs between BER versus Energy per bit to Noise Ratio i.e. Eb/No ratio.

Keywords
CDMA, BER, Chip Rate, Chip period, Eb/No, PN codes.

1. INTRODUCTION
Code Division Multiple Access (CDMA) is a digital radio system that transmits streams of bits (PN codes). CDMA permits several radios to share the same frequencies and have a significant economic advantage over TDMA-based standards, or the oldest cellular standards that used frequency-division multiplexing. Its greater bandwidth efficiency and multiple access capabilities make it the leading technology for relieving spectrum congestion caused by the explosion in popularity of cellular mobiles and fixed wireless telephones and wireless data terminals [1].

The IS-95 standard describes a Code Division Multiple Access (CDMA) system in which the data signal is multiplied by a high rate spreading signal. This spreading signal is formed from a pseudo-noise code sequence, which is then multiplied by a Walsh code for maximum orthogonality to the other codes use in that cell. Typically, CDMA pseudo-noise sequences are very long, thereby giving excellent cross correlation characteristics [2].

The IS-95 standards describe an air interface, a set of protocols used between mobile units and the network. It is widely described as a three-layer stack, physical (PHY) layer, Media Access Control (MAC) and Link-Access Control (LAC) sub layers, and call-processing state machine. In IS-95 system forward channel carries information from the base station to the mobile unit whereas the reverse channel carries information from the mobile unit to the base station. The forward channels are between 869 and 894 MHz, while the reverse channels are between 824 and 849 MHz [3]. The various Modulation parameters like user data rate, coding rate data repetition rate, PN chip rate etc. for forward & reverse link channel are given in the table 1 & 2 given below:

Table 1. Forward Link Channel Parameters

Parameter	Data Rate(bps)			
User data rate	9600	4800	2400	1200
Coding Rate	1/2	1/2	1/2	1/2
User Data Repetition Period	1	2	4	8
Baseband coded Data Rate	19,200	19,200	19,200	19,200
PN Chips/Coded Data Bit	64	64	64	64
PN Chip Rate	1,2288	1,2288	1,2288	1,2288
PN Chips/Bit	128	256	512	1024

Table 2. Reverse Link Channel Parameters

Parameter	Data Rate(bps)			
User data rate	9600	4800	2400	1200
Coding Rate	1/3	1/3	1/3	1/3
Coded Data Rate	28,800	28,800	28,800	28,800
Bits per Walsh Symbol	6	6	6	6
Walsh Symbol Rate	4800	4800	4800	4800
Walsh Chip Rate	307.2	307.2	307.2	307.2
PN Chips/Code Symbol	42.67	42.67	42.67	42.67
PN Chips/Walsh Symbol	256	256	256	256
PN Chips/Walsh Chip	4	4	4	4
PN Chip Rate	1,2288	1,2288	1,2288	1,2288

Most of the related work in CDMA cellular performance has been focused on the reverse channel as in [4] through [6]. While these investigations consider both shadowing and fading effects, they do not incorporate forward error correction in the analysis. The Performance of CDMA using forward error correction with soft decision decoding has been given in [7] through [10]. The performance of the forward DS-CDMA channel with power control in a Rayleigh fading channel was investigated in [11]. The effects of lognormal shadowing and Rayleigh fading using forward error correction in the form of Golay codes with hard decision decoding is given in [12] whereas in [13], Nakagami fading channels were considered using a weak Golay Code with hard decision decoding.

2. CDMA TRANSMITTER & RECIEVER

The forward Link transmitter interoperations comprise of convolution encoding and repetition, block interleaving, long PN sequence, data scrambling, Walsh coding and Quadrature modulation. Diagram is shown below in Fig.1.

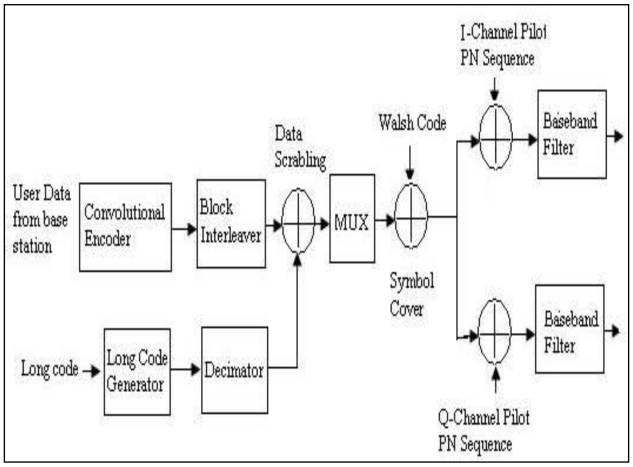

Fig 1: CDMA Forward Link Transmitter Modulation

The processing performed in the terminal receiver of CDMA is being complementary to those of the base station modulation process on the forward Channel and is shown in Fig.2.

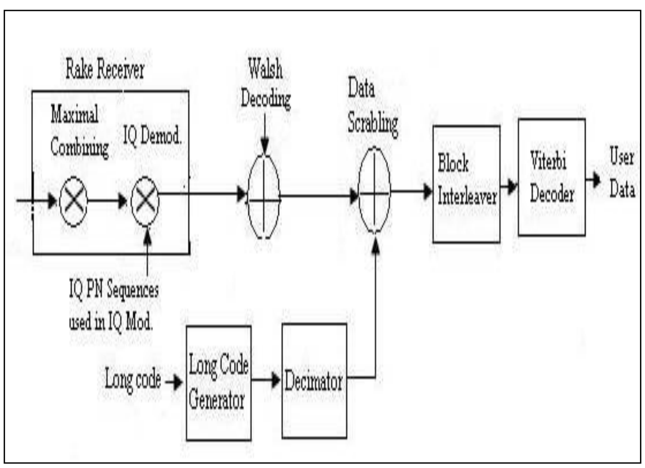

Fig 2: CDMA Reverse Link Receiver Demodulation

The receiver in CDMA used two types of viterbi decoding: Hard decision & soft decision viterbi decoding.

Soft decision viterbi decoder used euclidean distance method for coding bit estimation. Euclidean distance is found out between the received symbol & portable transmitted symbol.

The received coded sequence is

$$y = c + n,$$

Where c is the modulated coded sequence taking values $+\sqrt{E}$ if the coded bit is 1 and $-\sqrt{E}$ if the coded bit is 0, n is the Additive White Gaussian Noise. The probability distribution function of Soft decision decoding is given as

$$P(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{\frac{-(x-\mu)^2}{2\sigma^2}}$$

With mean $\mu = 0$ and variance $\sigma 2 = No/2$.

The conditional probability distribution function (PDF) of Y if the coded bit is 0 is,

$$P(Y/Co) = \frac{1}{\sqrt{\pi No}} e^{\frac{-(Y+\sqrt{Ec})^2}{No}}$$

Conditional probability distribution function (PDF) of Y if the coded bit is 1 is,

$$P(Y/C_1) = \frac{1}{\sqrt{\pi No}} e^{\frac{-(Y-\sqrt{Ec})^2}{No}}$$

In soft decision decoding, Euclidean distance is found out between the received symbol & portable transmitted symbol. Euclidean distance if transmitted coded bit is 0 is,

$$ED_0 = (y{-}{-}\sqrt{E_C})^2 = (y^2 + 2y.\sqrt{E_C} + E_C)^2$$

Euclidean distance if transmitted coded bit is 1 is,

$$ED_1 = (y{-}{-}\sqrt{E_C})^2 = (y^2 - 2y.\sqrt{E_C} + E_C)^2$$

The terms y2, $\sqrt{E_C}$ and E_C are common in both the equations they can be ignored. The simplified Euclidean distance is,

$$ED_0 = +y \text{ and } ED_1 = -y$$

As the Viterbi algorithm takes two received coded bits at a time for processing, we need to find the Euclidean distance from both the bits.

$$ED_{00} = (y_{i,1}{-}{-}\sqrt{E_C})^2 + (y_{i,2}{-}{-}\sqrt{E_C})^2 = (+y_{i,1} + y_{i,2})$$

$$ED_{01} = (y_{i,1}{-}{-}\sqrt{E_C})^2 + (y_{i,2}{-}{+}\sqrt{E_C})^2 = (+y_{i,1} - y_{i,2})$$

$$ED_{10} = (y_{i,1}{-}{+}\sqrt{E_C})^2 + (y_{i,2}{-}{-}\sqrt{E_C})^2 = (-y_{i,1} + y_{i,2})$$

$$ED_{11} = (y_{i,1}{-}{+}\sqrt{E_C})^2 + (y_{i,2}{-}{+}\sqrt{E_C})^2 = (-y_{i,1} - y_{i,2})$$

Hard decision viterbi decoding, based on the location of the received coded symbol. Hamming distance is found out between the received symbol & portable transmitted symbol. Hard decision decoding takes a stream of bits say from the 'threshold detector' stage of a receiver, where each bit is considered definitely one or zero.

3. SIMULATION RESULTS

The capacity of CDMA communication system depends heavily on spreading factor and receiver's performance. The receiver performance largely depends on the BER of system. BER is defined as source of performance measurement that specifies the number of bits corrupted or destroyed as they are transmitted from its source to destination. So, in order to improve the performance of system, BER should be minimum. There are several factors that affect BER include bandwidth, SNR, transmission speed and transmission medium. The expression for BER is given as.

$$BER = Q\,[Es/2\sigma n^2]^{1/2}$$

$Es = M^2$ of average power of original signals, σn^2 = variance of noise in decision variable which may include the AWGN & processing noise incurred in system.

CDMA IS-95 standard using BPSK modulation in presence of AWGN channel was simulated using MATLAB. The CDMA signal parameters used in simulation are given in table 1 and table 2.The results presented show the BER performance as a function of the channel SNR.

The SNR for each modulation takes into account the number of bits per symbol, and so the signal power corresponds to the energy per bit times the number of bits per symbol. The higher Eb/No required for transferring data means that more energy is required for each bit transfer.

As two coded bits are required for transmission each data bit (BPSK), the relation between coded bits to noise ratio Ec/No with bits to noise ratio Eb/No is

$$E_c/N_0 = ½(E_b/No).$$

The Probability of BER with hard decision and soft decision viterbi decoding are given in figure 3 and figure 4.

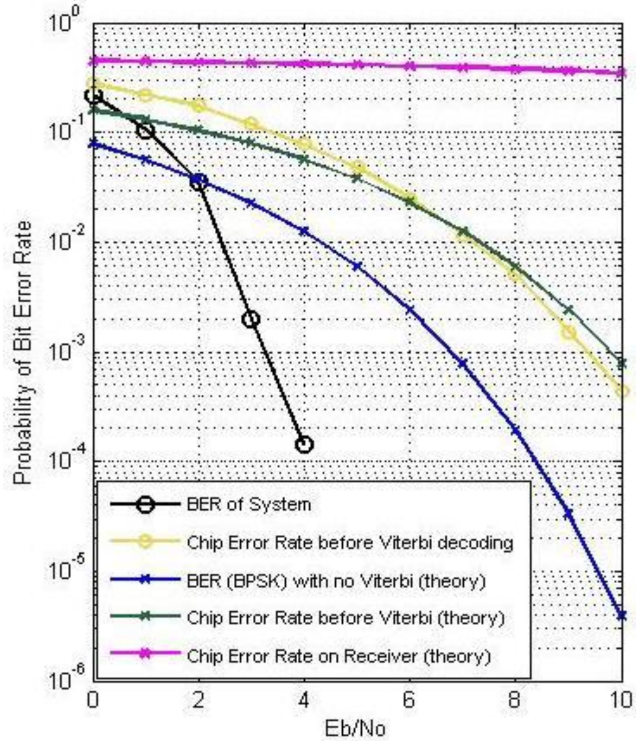

Fig 3: BER Probability with Hard Decision Decoding

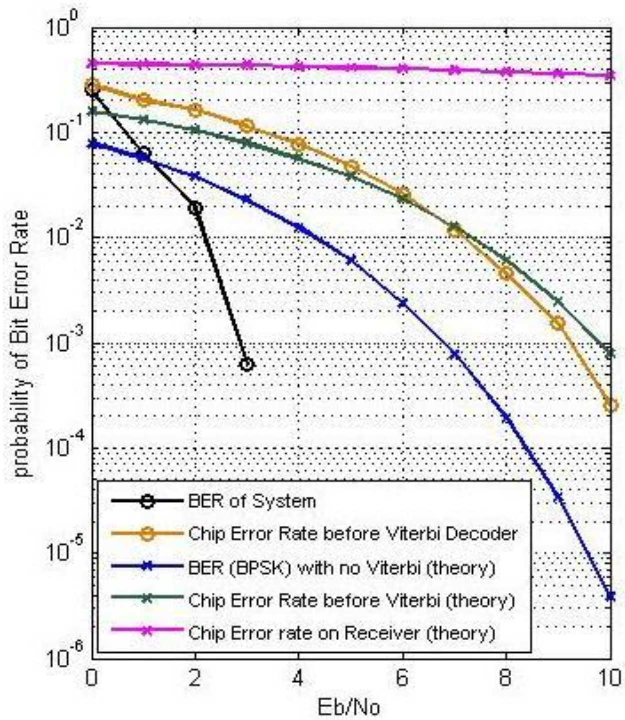

Fig 2: BER Probability with Soft Decision Decoding

4. CONCLUSION

The results shown in figure 3 and figure 4 gives the probability of BER when we use two different viterbi decoding i.e Soft decision and hard decision decoding. It is concluded from results that probability of BER is found to be less with hard decision viterbi decoding as compared with Soft decision viterbi decoding.

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