International Journal of Electronics Communication and Computer Engineering
Volume 3, Issue 6, ISSN (Online): 2249–071X, ISSN (Print): 2278–4209

BER Analysis of DS-CDMA Using LMS Algorithm and Rake Receiver

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***Abstract* – CDMA is interference limited system hence the capacity of the system is limited by interference as number of users' increases. This problem occurs when many mobile users share the same channel. CDMA takes the advantage of multipath fading .This system is resistant to multipath fading & also use the delayed multipath components to improve the performance of the system. This can be done using RAKE receiver in which multipath propagation delays of the transmitted signals are considered and combines the information obtained from several resolvable multipath components to form a stronger version of the signal using Rake receiver.. To overcome the problem of fading in channel Rake receiver can be used against mismatch & modeling errors which enhance its interference cancellation capability. This receiver consists of three stages. In the first stage, with LMS algorithm, which reduces BER i.e. there is reduction in interference. The matched filter (MF) can use for more reduction of the IPI and MAI in each RAKE finger in the second stage. In the third stage, the output signals from the matched filters can be combined according to the conventional maximal ratio combining (MRC) principle and then are fed into the decision circuit of the desired user. By measuring BER we can conclude that using rake receiver &LMS algorithm BER of the system for AWGN & Rayleigh Fading channelcan beminimized at lower SNR.**

***Keywords* – DS-CDMA, Rake receiver, LMS algorithm.**

I. INTRODUCTION

CDMA is a code division multiple access technique [5] in which the narrowband message signal is multiplied by a very large bandwidth signal called the spreading signal, which is generated by pseudo-noise generator. All users in this system use the same carrier frequency & may transmit simultaneously. Each user has its own pseudorandom code word which is approximately orthogonal to all other code word. A directsequence spread spectrumspreads the baseband data by directly multiplying the baseband data pulses with a pseudo-noise sequence that is produced by pseudo-noise code generator. Due to spreading multipath fading can be reduced using various diversity techniques.From Fig. 1, we have$y(t) = x(t)+i(t)$

$$= c(t).s(t)+i(t)$$

$$u(t)= c(t).y(t)$$

$$= c^2(t).s(t)+c(t).i(t) \text{ ----- } (1)$$

$$= s(t)+c(t).i(t)$$

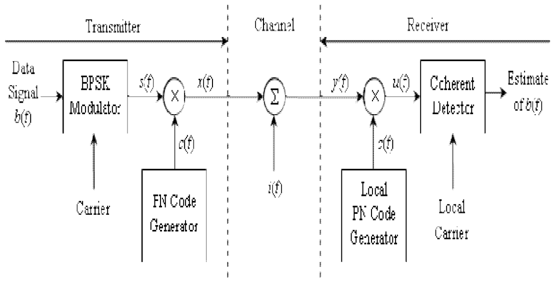

Fig.1. Block diagram of DS-CDMA

II. MULTIPATH FADING

Multipath is a term used to describe the multiple paths a radio wave may follow between transmitter and receiver. Such propagation paths include the ground wave, ionospheric refraction, reradiation by the ionospheric layers, reflection from the earth's surface or from more than one ionospheric layer, and so on.Fading is deviation of the attenuation affecting a signal over certain propagation media [5]. The fading[8] may vary with time, geographical position or radio frequency, and is often modeled as a random process. A fading channel is a communication channel comprising fading. In wireless systems, fading may either be due to multipath propagation, referred to as multipath induced fading, or due to shadowing from obstacles affecting the wave propagation, sometimes referred to as shadow fading. The presence of reflectors in the environment surrounding a transmitter and receiver create multiple paths that a transmitted signal can traverse. As a result, the receiver sees the superposition of multiple copies of the transmitted signal, each traversing a different path. Each signal copy will experience differences in attenuation, delay and phase shift while travelling from the source to the receiver. This can result in either constructive or destructive interference, amplifying or attenuating the signal power seen at the receiver. Strong destructive interference is frequently referred to as a deep fade and may result in temporary failure of communication due to a severe drop in the channel signal-to-noise ratio.

Mitigation:

The effects of fading can be combated by using diversity to transmit the signal over multiple channels that experience independent fading and coherently combining them at the receiver. Diversity can be achieved in time, frequency, or space. Common techniques used to overcome signal fading include i)Diversity reception and transmission ii) MIMO iii)OFDM iv) Rake receivers v) Space–time codes.

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A. Diversity

Diversity is one of the techniques for enhancing the signal to interference plus noise ratio (SINR).Diversity exploits the random nature of radio propagation by finding independent (or, at least, highly uncorrelated) signal paths for communication[1]. If one radio path undergoes a deep fade, another independent path may have a strong signal. By having more than one path to select from, the SINR at the receiver can be improved.The diversity scheme can be divided into three methods: 1) The space diversity; 2) The time diversity; 3) The frequency diversity. In these schemes, the same information is first received (or transmitted) at different locations (or time slots/frequency bands). After that, these signals are combined to increase the received SINR. The antenna array is an example of the space diversity, which uses a beam former to increase the SINR for a particular direction. Diversity techniques can be applied either at Base station or at mobile station. Most diversity systems areimplemented in receiver instead of transmitter sinceno extra transmitter power is needed to install the receiver diversity system. In CDMA PN sequence has the property that time shifted versions of itself are almost uncorrelated .Thus a signal that propagates from transmitter to receiver over multiple paths can be resolved into separately fading signals by cross –correlating the received signal with multiple time shifted versions of pseudo random sequence .Fig. 2 shows a block diagram of a typical system. In the receiver, the outputs are time shifted and so must be sent through a delay line before entering the diversity combiner. This receiver is called RAKE receiver.

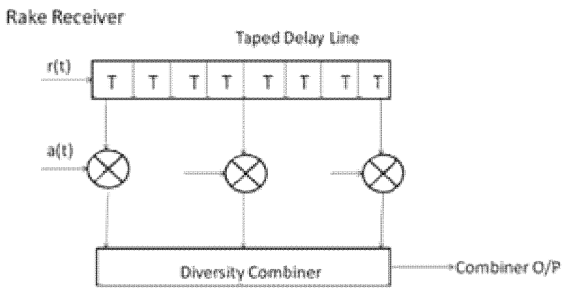

Fig.2. Diversity

B. Rake Receiver

A rake receiver is a radio receiver designed to counter the effects of multipath fading. [6] It does this by using several "sub-receivers" called fingers, that is, multipath component. Each finger independently decodes a single multipath component; at a later stage the contribution of all fingers are combined in order to make the most use of the different transmission characteristics of each transmission path. This could very well result in higher signal-to-noise ratio (or E_b/N_0) in a multipath environment than in a "clean" environment. The multipath channel through which a radio wave transmits can be viewed astransmitting the original (line of sight) wave pulse through a number of multipath components. Multipath components are delayed copies of the original transmitted wave traveling through adifferent echo path, each with a different magnitude and time-of-arrival at the receiver. Since each component contains the original information, if the magnitude and time-of-arrival (phase) of each component is computed at the receiver (through a process called channel estimation), then all the components can be added coherently to improve the information reliability. The main advantage of Rake Receiver is that it improves the SNR (or Eb / No). Naturally, this improvement is observed in larger environments with many multipaths than in environments without obstruction. The Rake Receiver correlator is shown in Fig. 3. The rake receiver uses multiple correlators to separately detect the M strongest multipath components. The outputs of M correlators are denoted as Z_1, Z2… and Z_M The weights of the outputs are a_1, a2…and $a_M$respectively. The weighting coefficients are based on SNR from each correlator output.

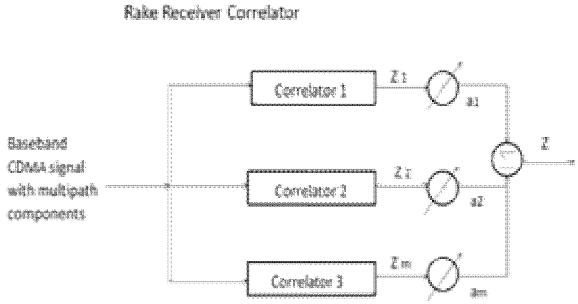

Fig.3. Rake Receiver correlator

III. LEAST MEAN SQUARES (LMS)

The receiver uses LMS adaptive beam forming algorithm to find optimum weights assuming perfect estimation of the channel parameters for the desired user. The desired user resolvable paths directions are fed to the beam former to reduce the interpath interference from other directions [2]. To reduce the interference is to use the multisectorized antennas, which results in spatial isolation of users. The directional antennas receive signals from a fraction of the current users, thus leading to the reduction of interference.

This algorithm is a gradient based algorithm to minimize the total processor output power, based on the look direction constraint. Block diagram of LMS is shown in Fig. 4.

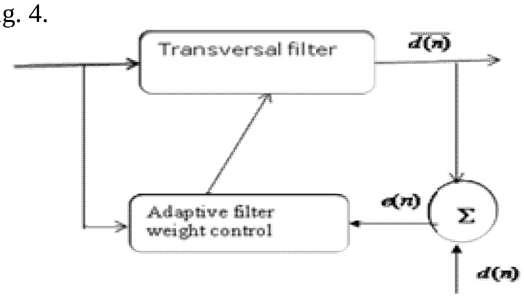

Fig.4. Block diagram of LMS

LMS consists of two processes, namely [7]

1. Filtering process:-It involves computing the output of a linear filter in response to an input signal &generating an estimation error by comparing this output with a desired response.

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2. Adaptive process:-It involves the automotive adjustment of the parameters in accordance with estimation error.

The combination of filtering & adaptive process working together constitutes a feedback loop.The adaptive algorithm is designed [2] to adapt efficiently in agreement with the environment & able to permanently preserve the desired frequency response in the look direction while minimizing the output power of the array. This method computes the weight vector recursively using the equation

$w(n)=[w_1(n)\ w_2(n)----w_N(n)]^T$---------------------(2)

and the signal impinges in all elements of the smart antenna array in the nth iteration as

$x(n)=[x_1(n)x_2(n)-----x_N(n)]^T$-----------------------(3)

The output of the array in the nth iteration is given by

$y(n)=w(n)^H x(n)$---------------------------------(4)

The expected output power of the array in the nth iteration is given by

$E(y(n)^2)=E[y(n).y^*(n)]$----------------------(5)

$=E[w(n)^H.x(n).x^H(n).w(n)]$

$=w(n)^H.R_{xx}.w(n)$

Where E(.) is denoted the expectation &Rxx is referred as input covariance matrix.

A real time LMS algorithm for determining the optimal weight vector is

$w(n+1)=w(n)+\mu g(w(n))$ ----------------------(6)

if $w^H e_\Phi=1$ it is called constrained LMS algorithm.

Where e_Φ denotes spatial response of the array for desired user &$w_{(n+1)}$ is the new weight computed at the $(n+1)^{th}$ iteration. μ is a gain constant and controls the rate of adaptation i.e. how fast & how close the estimated weights approach the optimal weight. The LMS algorithm requires knowledge of the desired signal. This can be done in a digital system by periodically transmitting a training sequence that is known to the receiver, or using the spreading code in the case of a direct-sequence CDMA system.

The LMS algorithm is a fast convergence algorithm. However, it is drastically sensitive to the mismatch in the direction of arrival. The weights estimated by the standard algorithm are sensitive to the signal power, requiring a lower step size in the presence of strong signal for algorithm to converge [3].

IV. Simulink Model Using LMS and Rake Receiver for AWGN and Rayleigh Fading Channel

The LMS Filter block can implement an adaptive FIR filter using five different algorithms. The block estimates the filter weights, or coefficients, needed to minimize the error, *e(n)*, between the output signal *y(n)* and the desired signal, *d(n)*. Connect the signal you want to filter to the Input port. [4] This input signal can be a sample-based scalar or a single-channel frame-based signal. Connect the desired signal to the desired port. The desired signal must have the same data type, frame status, complexity, and dimensions as the input signal. The Output port outputs the filtered input signal, which is the estimate of the desired signal. The output of the Output port has the same frame status as the input signal. The Error port outputs the result of subtracting the output signal from the desired signal. Step size & leakage factor must be same for simulation.When you select LMS for the Algorithm parameter, the block calculates the filter weights using the least mean-square (LMS) algorithmfrom the desired signal. standard algorithm are sensitive to the signal power, requiring a lower step size in the presence of strong signal for algorithm to converge [3].

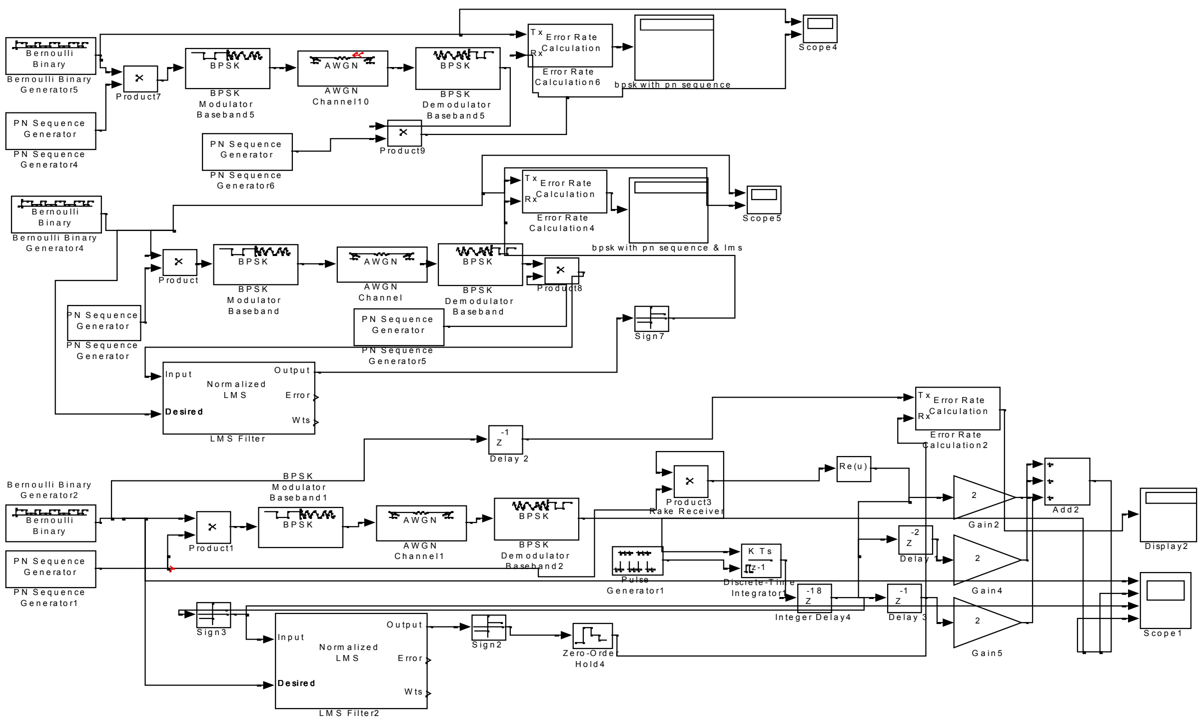

Fig.5. BPSK with pn sequence, LMS & Rake receiver for AWGN channel

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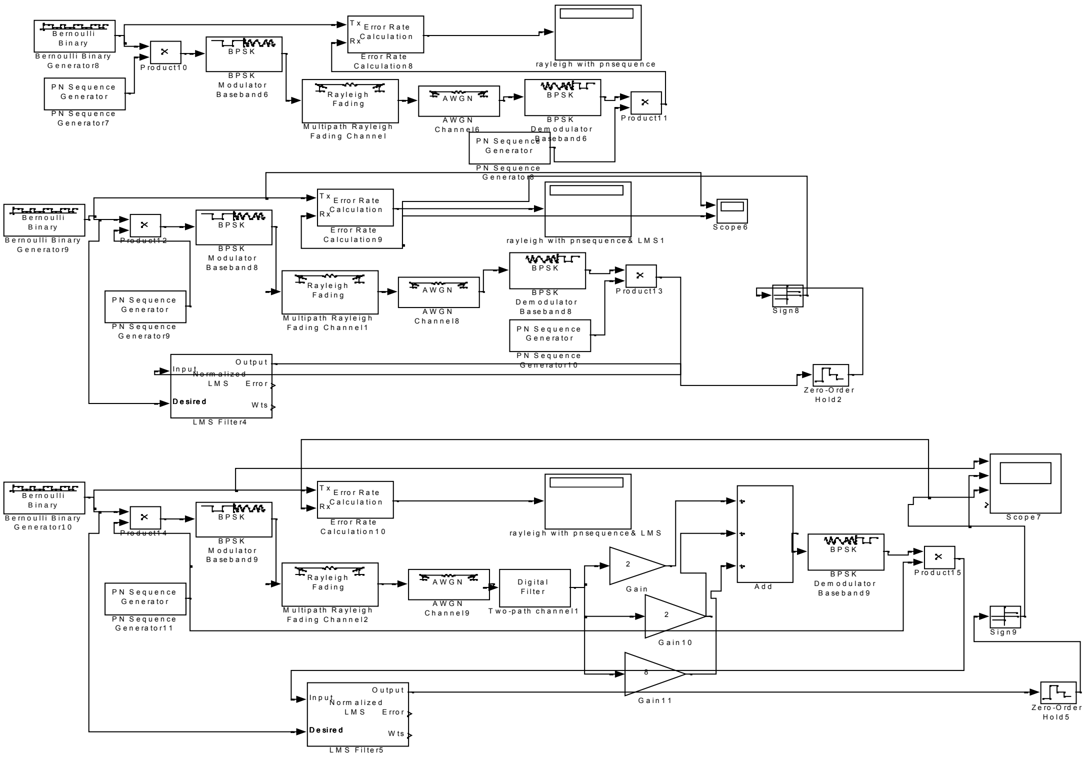

Fig.6. BPSK with pn sequence, LMS & Rake receiver for Rayleigh fading channel

V. Results and Performance

A. Performance in AWGN channel using LMS & Rake:

This study finds that BER using BPSK modulation for this channel gets reduced using LMS & Rake receiver.Table 1 shows the results in term of BER Vs. SNR for AWGN channel without LMS & Rake and with LMS & Rake.

Table 1: BER VS SNR for AWGN channel with & without LMS & Rake

SNR	BER without LMS & Rake	BER With LMS	BER With LMS& Rake
0	0.2376	0.04895	0.02174
4	0.1485	0.008991	0.001106
8	0.0396	0.000689	0.0000002

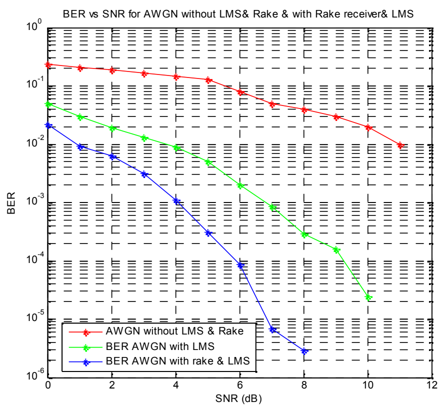

Fig.7. Performance Analysis of LMS & Rake receiver in AWGN channel

B. Performance in Rayleigh channelUsing LMS& Rake :

The performance in the Rayleigh fading channel is different than AWGN channel.

Table 2: BER VS SNR for Rayleigh channel with & without LMS & Rake

SNR	BER without LMS & Rake	BER With LMS	BER With LMS& Rake
0	0.3437	0.1049	0.023
4	0.3277	0.0999	0.008176
8	0.3257	0.0979	0.0038

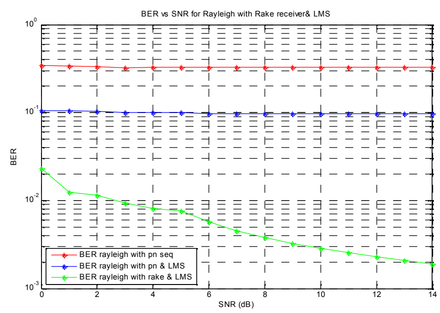

Fig.8 Performance analysis of LMS& Rake in Rayleigh channel

C. Performance in AWGN & Rayleigh channel with LMS & Rake:

Comparing the performance in AWGN & Rayleigh fading channel, it is obvious that BER in AWGN is lesser than Rayleigh channel for same SNR

Table 3: BER VS SNR for AWGN & Rayleigh channel with LMS& Rake

SNR	BER in AWGN with LMS & Rake	BER in Rayleigh with LMS & Rake
0	0.02174	0.023
4	0.001106	0.008176
8	0.0000002	0.0038

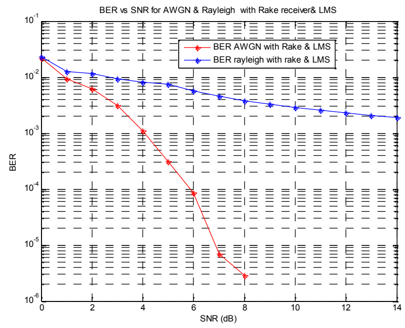

Fig.9. Performance analysis of LMS & Rake in AWGN & Rayleigh channel

D. Performance Analysis of diversity branchesin AWGN Channel

As the number of diversity branches increases BER reduces. From graph BER for 4 branchesis lower than 2 & 3 branches.

Table 4: BER VS SNR for AWGN channel with different diversity branches

SNR	BER in AWGN with 2 branches	BER in AWGN with 3 branches	BER in AWGN with 4 branches
0	0.1242	0.04969	0.02174
4	0.02795	0.0053106	0.001106
8	0.0005011	0.0000014869	0.0000002

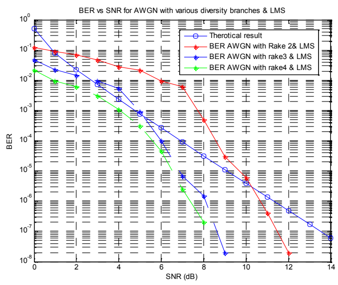

Fig.10 Performance analysis of diversity branches in AWGN channel

E. Performance Analysis of step size for LMS in AWGN channel

The BER in DS-CDMA also depends on step size of LMS algorithm. As step size reduces the BER also reduces at lower SNR but there is no effect on BER at higher SNR.

Table 5: BER VS SNR for AWGN channel with different step size

SNR	BER in AWGN with step size 0.5	BER in AWGN with 0.05	BER in AWGN with 0.005
0	0.02484	0.02174	0.01553
4	0.003106	0.001106	0.001106
8	0.000004	0.0000002	0.0000002

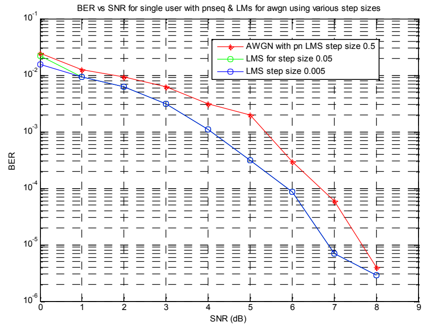

Fig.11. Performance analysis of step size in LMS for AWGN channel

VI. Conclusion

From simulation result BER for AWGN channel using LMS & Rake receiver is better as compared to without LMS & Rake. As number of Diversity branches increases the BER decreases. The results are shown for 2, 3 & 4 branches .The BER is reduced for same SNR using 4 branches than 2 & 3. BER is also affected by Step size in LMS .As step size decreases the BER is also decreases. The results are shown for step size 0.5, 0.05 & 0.005.BER is good for step size 0.005. At higher SNR BER is very less i.e. the power of transmitting signal gets controlled using LMS & Rake receiver.

Acknowledgment

The authors would like to thank the reviewers for their helpful comments & their thorough review. Their suggestions greatly improved the presentation of the paper.

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