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Comparison of Bit Error Rate for Multipath Fading Channel in DS-CDMA

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***Abstract*— In a wireless mobile communication system, a signal can travel from transmitter to receiver over multiple reflective paths; this phenomenon is referred to as multipath propagation. The distortion of signals caused by multipath is known as fading. Due to fading environment in wireless communication signal received with multiple numbers. By deep fade received power is less than noise power so performance of wireless system is bad i.e. Bit Error rate (BER) is high. To overcome this Multipath Diversity technique also called Rake Receiver is used to improve BER i.e. system reliability.**

Rake receiver is one of the receiver technique, consists of multiple correlators, in which the receive signal is multiplied by time-shifted versions of a locally generated code sequence. To maximize the Signal to Noise Ratio (SNR) and minimize the Bit Error Rate (BER) CDMA Rake receiver is used. In this paper we evaluated the performance of Direct Sequence Code Division Multiple Access (DS-CDMA) over multipath fading channel and compare the BER performance of wireless communication system with multiple paths using Rake receiver for AWGN, Rayleigh fading and Rician fading channel . The MATLAB software with relevant Toolboxes for developing simulink model is used for the simulation of system.

***Index Terms*— DS-CDMA, BER, SNR, Rake receiver, Multipath Fading Channel. MATLAB.**

I. INTRODUCTION

CDMA allow multiple users to share the same spectrum simultaneously. Direct Sequence Code Division Multiple Access (DS-CDMA) is the most popular of CDMA techniques. The DS-CDMA transmitter multiplies each user's signal by a distinct code waveform. In a conventional DS-CDMA system, a particular user's signal is detected by correlating the entire received signal with that user's code waveform.

Fading is another problem in a multipath channel. This "multipath fading" occurs because in general multipath components arrive with different phases. Multipath propagation causes the signal at the receiver to distort and fade significantly, decreasing Signal to Noise Ratio (SNR) hence leading to higher Bit Error Rate (BER).

Rake receiver is one of the receiver technique, consists of multiple correlators, in which the receive signal is multiplied by time-shifted versions of a locally generated code sequence. To maximize the Signal to Noise Ratio (SNR) and minimize the Bit Error Rate (BER) the CDMA Rake receiver is used. The aim of this work is to increase the quality or reducing the effective error rate in a multipath fading channel. The communication system to be healthy BER must be as low as possible.

II. MULTIPATH FADING CHANNEL MODEL

A tapped-delay line model shown in figure 1 demonstrates both the properties of flat and frequency selective fading. Each multipath signal has a different time delay (τ), amplitude level (α) and phase shift (Ǿ), which will interfere with one another at the receiver, producing a totally distorted version of the original transmitted signal with the additive of noise [5].

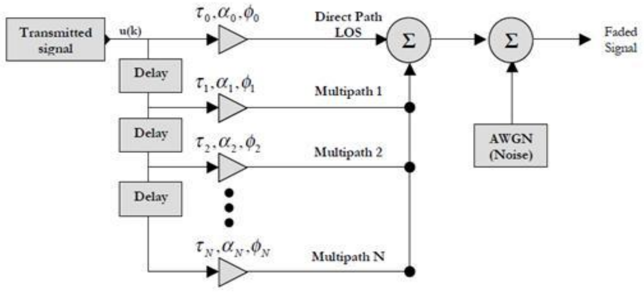

Figure 1: Tapped delay line model of a multipath fading channel

III. RAKE RECEIVER

RAKE receiver, used specially in CDMA cellular systems, can combine multipath components, which are time-delayed versions of the original signal transmission. This combining is done in order to improve the SNR at the receiver. The basic idea of A RAKE receiver was first proposed by Price and Green. These fellows also filed the RAKE receiver patent in 1956 [6]. Figure 2 shows principle of Rake receiver. .

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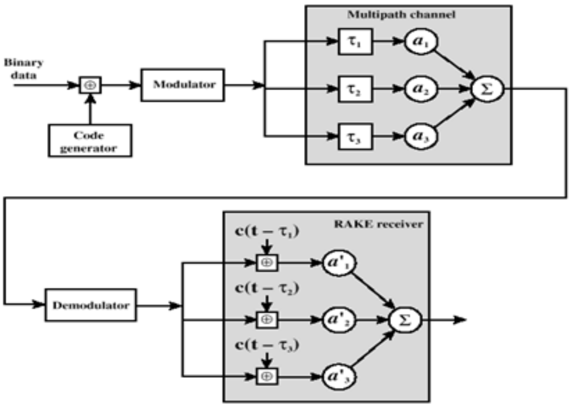


Figure 2: Principle of Rake Receiver.

RAKE receiver model with 3 correlators

Figure 3 shows the model of a RAKE receiver with three correlators. This RAKE receiver design is used in the IS-95 system, where each of the three strongest time-shifted multipath signals is demodulated and weighted independently. The spreading code in the despreading process needs to be synchronized to the delay spread of the multipath signal, so that the outputs of each correlator can be summed to produce a stronger and more accurate signal [5]. Decisions based on the combination of the three separate correlator outputs are able to provide a form of diversity, which can overcome fading and thereby improve the CDMA reception. The outputs of these three correlators are denoted as *Z1*, *Z2 and Z3*. The overall signal *Z'* is given by

$$Z' = \sum_{m=1}^{3} \alpha_m Z_m$$

Where, *m* represents each of the three correlators.
Each correlator of the RAKE receiver is represented by three coefficients: (1) Time delay (2) Phase shift (3) Amplitude gain/attenuation.

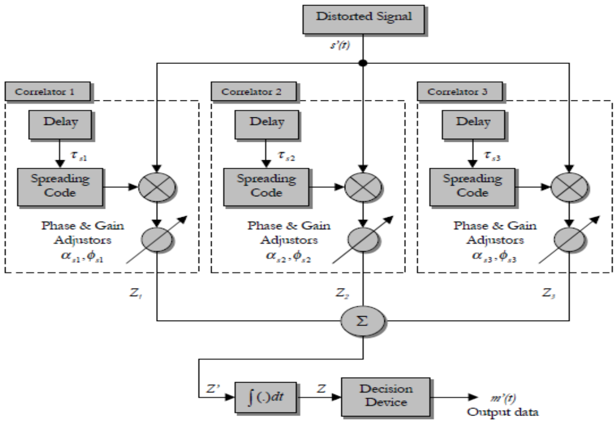


Figure 3: An implementation of a RAKE receiver with 3 correlators.

IV. SYSTEM OVERVIEW

The system overview for BER improvement of DS-CDMA with Rake receiver using Multipath fading channel is as shown in figure 4.

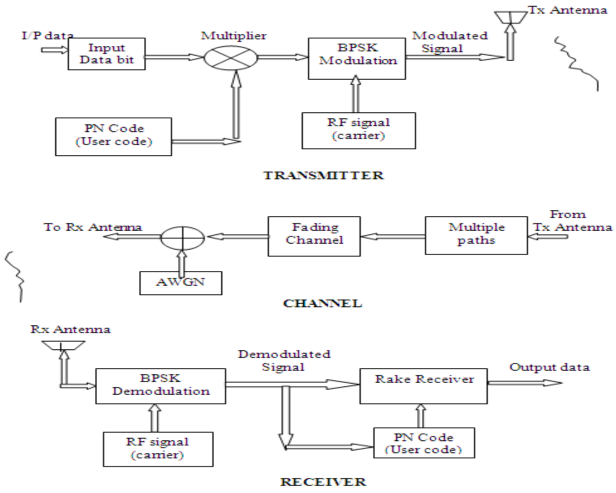


Figure 4: System overview.

At the transmitter, the information is encoded using codes. The encoded information is then transformed into a data modulated symbol sequence with a baseband modulator. The modulated symbol sequence is spread in time domain by a chip sequence of PN code generator, usually Walsh code and PN sequence. The information is shaped and passed through a channel for transmission. At the receiver, the information is multiplied with the chip sequence by the correlators in the rake receiver. The information is then summed and multiplied by local generated spreading code, which is despreading. The information is demodulated and decoded and original data can be recovered.

V. ANALYSIS OF DS-CDMA

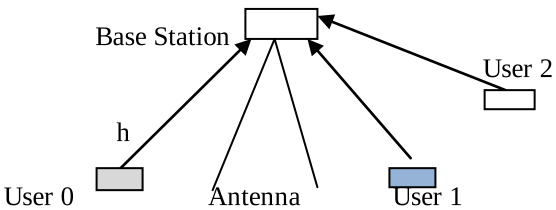
BER :

End to end performance measurements by means of digital communication over radio engineering. The measure of that performance is BER. Simply bits in to bits out
BER = Errors / Total number of bits
BER Expression of Wireless System

$$BER = \frac{1}{2} * \left(1 - \sqrt{\frac{SNR}{2 + SNR}}\right)$$

$$BER \cong \frac{1}{2\,SNR}$$

Performance of Multiuser with CDMA :
Downlink: BTS (Base station) to Mobile i.e. Forward Link
Uplink: Mobile to BTS i.e. Reverse Link



Reverse link DS- CDMA system is as shown in figure 5.
Let us consider K users,

$$0,1,2,3 \ldots\ldots\ldots\ldots K$$

Here 0 is desired user & others are interfering.
Symbols transmitted to K users are given below

$$S_0, S_1, \ldots\ldots\ldots\ldots S_K$$

Here, S_0 is user 0's information

PN sequences (Code) for K users are given below

$$C_0, C_1, \ldots\ldots\ldots\ldots C_K$$

Here, C_0 is spreading code for user 0

We assume that there are K active users transmitting signals in DS-CDMA system. Each of them transmits a signal which is described by

Signal of user 0 is $X_{0(m)} = S_{0(m)} C_{0(m)}$

Signal of user 1 is $X_{1(m)} = S_{1(m)} C_{1(m)}$

Signal of user K is $X_{K(m)} = S_{K(m)} C_{K(m)}$

Composite signal to be transmit is given as

$$X_{(m)} = X_{0(m)} + X_{1(m)} + \ldots\ldots\ldots\ldots + X_{K(m)}$$

$$X_{(m)} = \sum_{i=0}^{K} X_{i(m)}$$

$$X_{(m)} = \sum_{i=0}^{K} S_{i(m)} C_{i(m)}$$

Let, transmitted composite signal for user 0 transmit through channel h

$$h_{0(0)}, h_{0(1)}, \ldots\ldots\ldots\ldots h_{0(L-1)}$$

It denotes the L tap Multipath channel between Base station and user 0. Hence, output of this multipath channel i.e. received signal at user 0

$$y_{(m)} = h_{0(0)} X_{(m)} + h_{0(1)} X_{(m-1)} + \ldots\ldots + h_{0(L-1)} X_{(m-L+1)} + n_{(m)}$$

Here, $n_{(m)}$ is noise

Hence, this is an ISI (Inter Symbol Interference) channel, then

$$y_{(m)} = \sum_{d=0}^{L-1} h_{0(d)} X_{(m-d)} + n_{(m)}$$

$$y_{(m)} = \sum_{d=0}^{L-1} \sum_{k=0}^{K} h_{0(d)} S_k C_{k(m-d)} + n_{(m)}$$

Here, $\sum_{d=0}^{L-1}$ = Multipath of user 0.

$$r_{(0)} = \frac{1}{N} \sum_{m=0}^{N-1} y_{(m)} C_{0(m)}$$

Expanding using

$$r_{(0)} = \frac{1}{N} \sum_{d=0}^{L-1} \sum_{k=0}^{K-1} \sum_{m=0}^{N-1} h_{0(d)} S_k C_{k(m-d)} C_{0(m)} + \frac{1}{N} \sum_{m=0}^{N-1} n_{(m)} C_{0(m)}$$

Here, $\frac{1}{N} \sum_{m=0}^{N-1} n_{(m)} C_{0(m)}$ = Noise component

The received signal in CDMA at user 0 has (K+1) L components.

L = Multipath components corresponds to user 0

KL = Component belong to the rest of the K users

After decor relation

Here, $\sum_{d=0}^{L-1}$ = sum for multipath, $\sum_{k=0}^{K-1}$ = sum for users, $\sum_{m=0}^{N-1}$ = sum for chips

Separate all in different component, component corresponding to user 0, path 0 + (L-1) component of user 0, corresponding to the other (L-1) multipath paths + KL components corresponding to the multipath of the interfering users

$$= \frac{1}{N} \sum_{m=0}^{N-1} h_{0(0)} S_0 C_{0(m)} C_{0(m)} + \frac{1}{N} \sum_{d=1}^{L-1} \sum_{m=0}^{N-1} S_0 h_{0(d)} C_{0(m-d)} C_{0(m)}$$

$$+ \frac{1}{N} \sum_{k=1}^{K} \sum_{d=0}^{L-1} \sum_{m=0}^{N-1} h_{0(d)} S_k C_{k(m-d)} C_{0(m)}$$

Desired user, 0th path

$$= \frac{1}{N} \sum_{m=0}^{N-1} h_{0(0)} S_0 C_{0(m)} C_{0(m)}$$

$C_{0(m)} C_{0(m)} = 1$ by correlation property

$$= \frac{1}{N} \sum_{m=0}^{N-1} h_{0(0)} S_0$$

$$= h_{0(0)} S_0 \frac{N}{N}$$

$$= h_{0(0)} S_0$$

Multipath interference of user 0 (MPI)

$$MPI = \frac{1}{N} \sum_{d=1}^{L-1} \sum_{m=0}^{N-1} S_0 h_{0(d)} C_{0(m-d)} C_{0(m)}$$

$$C_{0(m-d)} C_{0(m)} = r_{00(d)} = Noise = 0$$

$$= \frac{1}{N} S_0 \sum_{d=1}^{L-1} h_{0(d)} r_{00(d)}$$

MPI = 0

KL component of multiuser interference (MUI)

$$MUI = \frac{1}{N} \sum_{k=1}^{K} \sum_{d=0}^{L-1} \sum_{m=0}^{N-1} h_{0(d)} S_k C_{k(m-d)} C_{0(m)}$$

$$C_{k(m-d)} C_{0(m)} = r_{0k(d)} = Noise = 0$$

$$= \frac{1}{N} \sum_{k=1}^{K} \sum_{d=0}^{L-1} \sum_{m=0}^{N-1} h_{0(d)} S_k r_{0k(d)}$$

MUI = 0

SNR for Downlink is given by

$$SNR = \frac{N \,||\, h_0 \,||^2 P_0}{\left(\sum_{k=0}^{K} P_K\right) ||\, h_0 \,||^2 - P_0 \sum_{i=0}^{L-1} \frac{|\, h_{0(i)} \,|^4}{||\, h_0 \,||^2} + \sigma_n^2}$$

SNR for Uplink is given by

$$SNR = \frac{N \,||\, h_0 \,||^2 P_0}{\left(\sum_{k=0}^{K} P_K\right) ||\, h_K \,||^2 - P_0 \sum_{i=0}^{L-1} \frac{|\, h_{0(d)} \,|^4}{||\, h_0 \,||^2} + \sigma_n^2}$$

Where,

N = Spreading gain

$||\, h_0 \,||^2$ = Multipath diversity

P_0 = Power of desired user

$\left(\sum_{k=0}^{K} P_K\right) ||\, h_K \,||^2 - P_0 \sum_{i=0}^{L-1} \frac{|\, h_{0(d)} \,|^4}{||\, h_0 \,||^2}$ = Multiuser + Multipath Interference

σ_n^2 = AWGN

Reverse link DS-CDMA system is shown in figure 5.

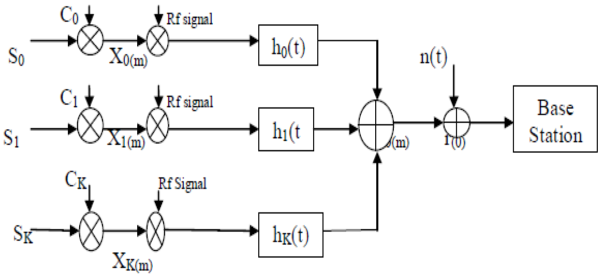


Figure 5: Reverse-link DS-CDMA systems.

VI. SIMULINK MODELS

In this paper we have developed three CDMA models to show the performance of the DS-CDMA with Rake receiver with AWGN, Rayleigh and Rican Fading Channel as shown in figure 6.. BER is observed for the system with BPSK modulation (baseband) and three propagation paths using the MATLAB® simulation software.

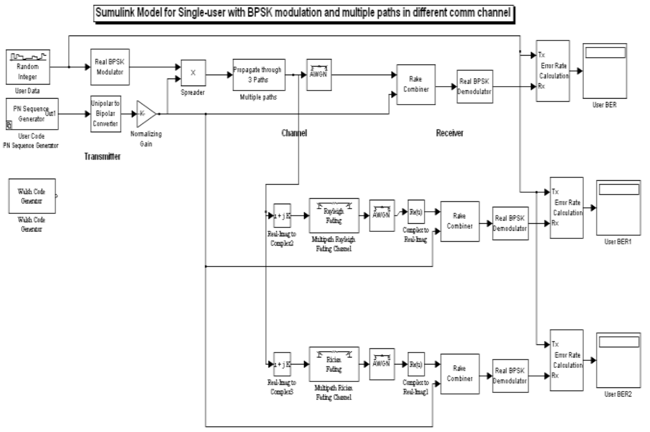


Figure 6: Simulink model.

VII. SIMULATION RESULTS

In this paper, one of the important topic in wireless communications , that is the concept of fading is demonstrated by approach available in MATLAB.In this section , the results obtained from the MATLAB simulations are discussed. It is necessary to explore what happens to the signal as it travels from transmitter to the receiver. Then it is very easy to understand the concept in wireless communications . As explained earlier, one of the important aspects of the path between transmitter and receiver is occurrence of fading. MATLAB provides a simple and easy way to demonstrate fading take place in wireless systems. The different fading models and MATLAB based on simulation approach will now be described.Simulink is a graphical extension to MATLAB for modeling and simulation of systems . In simulink, systems are drawn on screen as block diagrams. Many elements of block diagram are available as well as virtual input devices and output devices. Simulink is integrated with MATLAB and data can easily transferred between the programs.

The following parameters used for BER calculations :

(i) Sample time for input data = 1/192000 samples/sec
(ii)Generator polynomial = [1 0 0 0 0 1 1]
(iii) Total bit transmitted =24000
(iv)Samples per Frame = 63
(v)Sample time for PN = 192000*63 samples/sec = 1/12096000
(vi)Normalizing Gain = 1/sqrt (63)
(vii)Number of path = 3 with path delay [0 2 6]
(viii)Modulation type = BPSK
(ix)Maximum Doppler shift = 40Hz,
(x)K-factor = 4 in Rician channel
(xi)Doppler spectrum type =Jakes
(xii)Number of Rake finger = 3

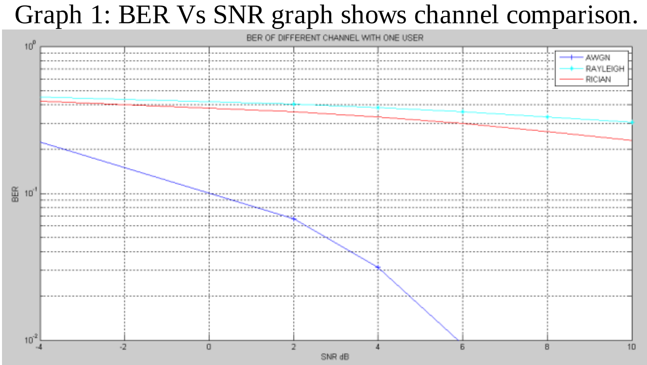
1) Matlab Simulink Model is used for Single user with BPSK modulation and Multipath with different Channels using Rake receiver.

Simulation result in bellow table shows that BER decreases with increases in SNR. The comparison of individual channel is given in table 1.

Table 1: BER in AWGN, Rayleigh and Rician fading channels over BPSK.

SNR in dB	BER in AWGN (%)	BER in Rayleigh (%)	BER in Rician (%)
-10	0.3529	0.4762	0.4621
-4	0.2231	0.4515	0.4252
2	0.0673	0.4065	0.3603
4	0.0313	0.3845	0.3305
6	0.0094	0.3593	0.3002
8	0.00145	0.3325	0.2691
10	0.000125	0.3052	0.2393

Graph 1: BER Vs SNR graph shows channel comparison.



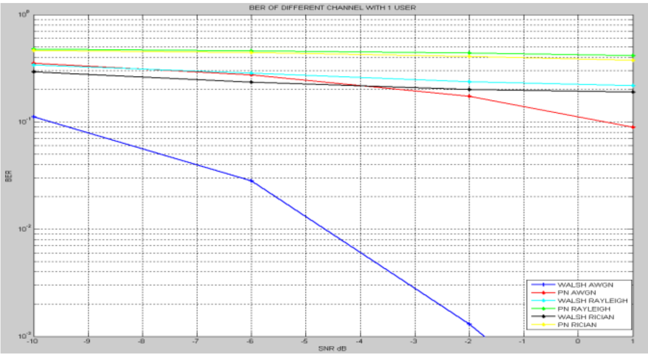
2) For comparison point of view I have taken two different codes PN Sequence and Walsh code. PN sequence generator Generate pseudo noise sequence. Walsh code generator Generate Walsh code from orthogonal set of codes.

Table 2: BER for different Channel with PN and Walsh code.

SNR	AWGN BER		RAYLEIGH BER		RICIAN BER	
	PN	WALSH	PN	WALSH	PN	WALSH
-10	0.35	0.1115	0.47	0.3403	0.46	0.2911
-6	0.27	0.02825	0.46	0.2833	0.44	0.2343
-2	0.17	0.0013	0.43	0.2376	0.40	0.2012
1	0.08	0.00008	0.41	0.218	0.37	0.1888

Simulation result as shown in table 2. For Walsh code (orthogonal code) BER performance is better as compared to PN code.

Graph 2: BER Vs SNR graph for different channels using PN code and Walsh code.



3) BER performance analysis for multi-user. The increasing number of users makes BER performance degradation. For each user different PN sequences code are used for spreading.

Table 3: BER for multiuser in AWGN channel.

SNR	USER 1 present	USER 1 & 2 present	USER 1, 2 &3 present
-10	0.3529	0.3526	0.3525
-4	0.2231	0.225	0.2268
2	0.0673	0.0704	0.0730
4	0.0313	0.0356	0.03731
6	0.0094	0.0121	0.0136
8	0.0014	0.0026	0.0046
10	0.0001	0.0002	0.0006

Graph 3: BER Vs SNR graph for multiuser in AWGN

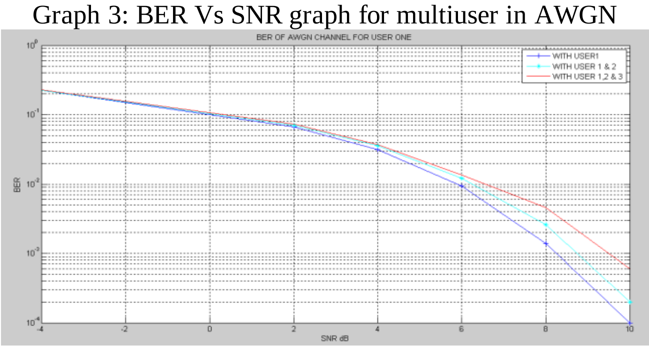


Table 4: BER for multiuser in Rayleigh channel.

SNR	USER 1 present	USER 1 & 2 present	USER 1, 2 &3 present
-10	0.4762	0.4764	0.4762
-4	0.4515	0.4627	0.4529
2	0.4065	0.4088	0.4094
4	0.3845	0.3892	0.3929
6	0.3593	0.3686	0.374
8	0.3325	0.3472	0.3557
10	0.3052	0.3246	0.3364

Graph 4: BER Vs SNR graph for multiuser in Rayleigh

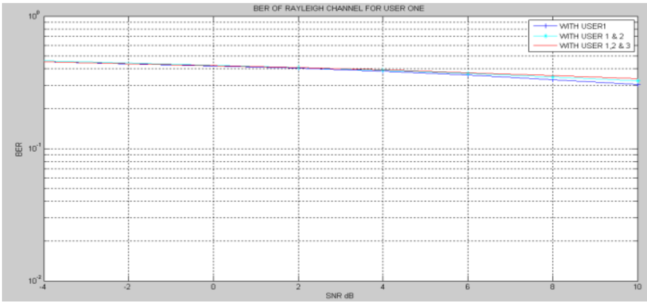
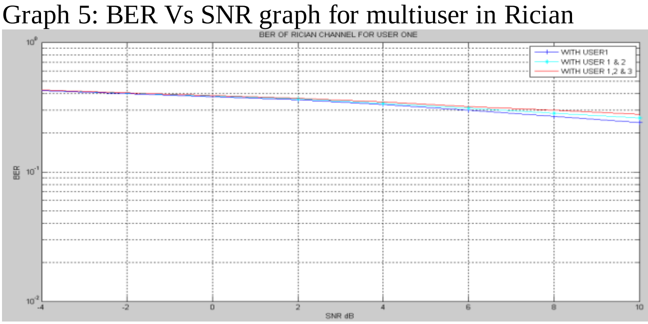


Table 5: BER for multiuser in Rician channel.

SNR	USER 1 present	USER 1 & 2 present	USER 1, 2 &3 present
-10	0.4621	0.4637	0.4637
-4	0.4252	0.4268	0.4287
2	0.3603	0.3651	0.3699
4	0.3305	0.3383	0.3454
6	0.3002	0.3112	0.3195
8	0.2691	0.2844	0.2982
10	0.2393	0.2598	0.2778

Graph 5: BER Vs SNR graph for multiuser in Rician



4) Performance analysis when number of rake fingers are lower than number of multipath (i.e. Rake finger = 3 and multipath = 3, 5, 10 and 15) with different path delays.

Table 6: BER for AWGN Channel with Multipath and Rake fingers 3.

SNR	PATH1	PATH3	PATH5	PATH10	PATH15
-10	0.3819	0.3525	0.3705	0.3928	0.4047
-4	0.2731	0.2231	0.2532	0.2911	0.3162
2	0.1123	0.0673	0.0934	0.1395	0.1736
4	0.0632	0.0313	0.0513	0.0922	0.1243
6	0.0277	0.0094	0.0204	0.0505	0.0799
8	0.0085	0.0014	0.0055	0.0215	0.0454
10	0.0013	0.0001	0.0005	0.0071	0.0205

Graph 6: BER Vs SNR graph for multipath in AWGN channel.

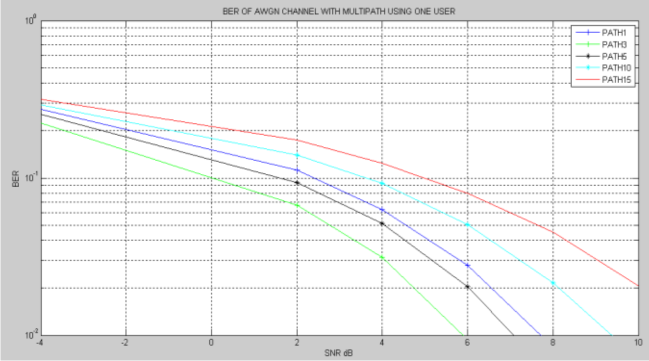


Table 7: BER for Rayleigh Channel with Multipath and Rake fingers 3.

SNR	PATH1	PATH3	PATH5	PATH10	PATH15
-10	0.4951	0.4762	0.4756	0.477	0.4932
-4	0.4937	0.4515	0.4519	0.4553	0.4808
2	0.4889	0.4065	0.4077	0.4135	0.4583
4	0.4874	0.3845	0.3886	0.3926	0.4498
6	0.4858	0.3593	0.3666	0.3714	0.4417
8	0.4825	0.3325	0.3429	0.3472	0.4318
10	0.4784	0.3052	0.3201	0.3215	0.4218

Graph 7: BER Vs SNR graph for multipath in Rayleigh fading

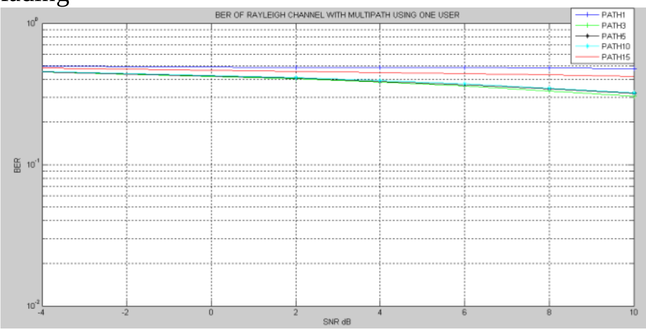
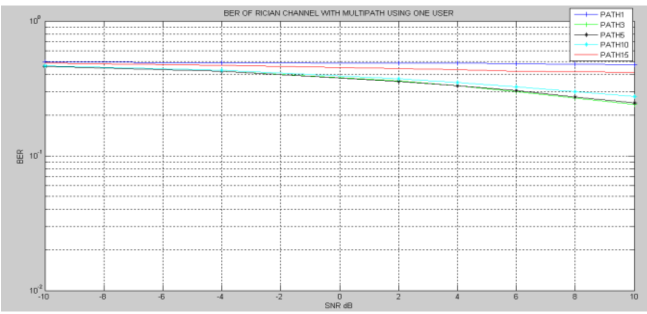


Table 8: BER for Rician Channel with Multipath and Rake fingers 3.

SNR	PATH1	PATH3	PATH5	PATH10	PATH15
-10	0.4949	0.4621	0.4616	0.4655	0.4886
-4	0.4922	0.4252	0.4238	0.433	0.4707
2	0.4881	0.3603	0.3579	0.3738	0.4437
4	0.4856	0.3305	0.3311	0.3496	0.4349
6	0.4823	0.3002	0.3041	0.325	0.4237
8	0.4793	0.2691	0.274	0.2998	0.42
10	0.4749	0.2393	0.2463	0.2752	0.4169

Graph 8: BER Vs SNR graph for multipath in Rician fading channel**.**



VIII. CONCLUSIONS

The developed simulation model for DS-CDMA with Rake receiver on different channel has been analyzed and the performance of each channel has been evaluated in terms of BER.

Rake receiver is used for CDMA technique rather than using conventional CDMA with matched filter. Rake receiver is used to minimize the bit error rate and obtain maximum SNR. The rake receiver is used in CDMA to decrease BER due to multipath interference.

From the simulation results, Bit Error Ratio of a digital communication system is an important figure of merit used to quantify the integrity of data transmitted through the system. By implementing the various multipath fading channels, the criterion is comparison of the variation of BER for different SNR.. It is observed that the performance of AWGN channel found better as compared to Rayleigh and Rician fading channel over Binary Phase Shift Keying modulation scheme. As per fading channel performance Rician is good than Rayleigh.

The BER will also increase, if the number of path increases with fixed Rake fingers in Rake Receiver. Better SNR in turn results in increase in BER performance. Thus BER decreases with the increase in the number of fingers in a rake receiver. It has been observed that as number of path (i.e. 1, 3, 5, 10 and 15) increases BER increases with 3 Rake fingers in Rake receiver.

Adding multiuser degrade the performance of system.

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