DS-CDMA system with linear multiuser detection using kasami codes

***M.Mamatharani*[1], *R.Deepthi*[2], *V.Tarunkumar*[3], *S.Gopi*[4], *G.Sridharkumar*[5]**

[1]Under graduate,Electronics and Communication Engineering Department,
Sri Sivani College of Engineering,NH-5 ,Chilakapalem,Srikakulam.
princessesmamatha@gmail.com

[2]Under graduate,Electronics and Communication Engineering Department,
Sri Sivani College of Engineering,NH-5 ,Chilakapalem,Srikakulam.
deepuds722@gmail.com

[3]Under graduate,Electronics and Communication Engineering Department,
Sri Sivani College of Engineering, NH-5 ,Chilakapalem,Srikakulam.
tarunkumar.vanapalli@gmail.com

[4]Under graduate,Electronics and Communication Engineering Department,
Sri Sivani College of Engineering,NH-5 ,Chilakapalem,Srikakulam.
Simmagopi1994@gmail.com

[5] Asst.professor and Head of Department,Electronics and Communication Engineering Department,
Sri Sivani College of Engineering,NH-5 ,Chilakapalem,Srikakulam.
sridhar3818@gmail.com

Abstract—**Direct sequence code division multiple access (DS-CDMA) system suffers from Multiple Access Interference (MAI) caused by Direct Sequence users and Near–far effect. Multi-User Detection schemes are used to detect the users' data in presence of MAI and Near-Far effect. In this we present a comparative study between linear multiuser detectors and conventional single user matched filter in DS-CDMA systems. Simulation results depict the performance of the Conventional detector, Decorrelating detector and Minimum Mean Square Error (MMSE) detector. It shows that the performance of these above mentioned detectors depends on the length of PN code used and number of users. Linear multiuser detectors perform better than the conventional matched filter detector in terms of BER performance. And in case of flat fading channel for different Doppler shifts, performance of these three detectors observed and concluded that MMSE detector has better performance than the other detectors.**

Keywords-DS-CDMA; Matched Filter; Multiuser Detection; AWGN; Rayleigh Fading; BER

1.1 INTRODUCTION

Wireless communication is one of the most vibrant areas in the communication field today. While it has been a topic of study since the 1960s, the past decade has seen a surge of research activities in the area. This is due to a confluence of several factors. First, there has been an explosive increase in demand for tether less connectivity, driven so far mainly by cellular telephony but expected to be soon eclipsed by wireless data applications. Second, the dramatic progress in VLSI technology has enabled small-area and low-power implementation of sophisticated signal processing algorithms and codingtechniques. Third, the success of second-generation (2G) digital wireless standards, in particular, the IS-95 Code Division Multiple Access (CDMA) standard [3], provides a concrete demonstration that good ideas from communication theory can have a significant impact in practice. The research thrust in the past decade has led to a much richer set of perspectives and tools on how to communicate over wireless channels, and the picture is still very much evolving.

There are two fundamental aspects of wireless communication that make the problem challenging and interesting. First is the phenomenon of fading: the time variation of the channel strengths due to the small-scale effect of multipath fading, as well as larger-scale effects [1], [3] such as path loss via distance attenuation and shadowing by obstacles. Second, unlike in the wired world where each transmitter–receiver pair can often be thought of as an isolated point-to-point link, wireless users communicate over the air and there is significant interference between them. The interference can be between transmitters communicating with a common receiver (e.g., uplink of a cellular system), between signals from a single transmitter to multiple receivers (e.g., downlink of a cellular system), or between different transmitter–receiver pairs (e.g., interference between users in different cells). Traditionally the design of wireless systems has focused on increasing the reliability of the air interface; in this context, fading and interference are viewed as nuisances that are to be countered. Recent focus has shifted more towards increasing the spectral efficiency; associated with this shift is a new point of view that fading can be viewed as an opportunity to be exploited.

CHAPTER 2 MULTIUSER DETECTORS

2.1 INTRODUCTION

Conventional DS-CDMA system treats each user separately as a signal, with other users considered as noise or multiple access interference [6], [12]. This yields what is referred to as the near-far effect, users near the base stations are received at higher powers than those far away. Thus, those far away suffer degradation in performance. A tight power control is needed to overcome this problem, or one can use multiuser detection techniques. Multiuser detection considers all users as signals for each other's, and detects them jointly. This leads to reduced interference, and alleviates the near-far problem.

The DS-CDMA receivers are divided into Single user and Multiuser detectors. A single user receiver detects the data of one user at a time whereas a multiuser receiver jointly detects several users' information. Single user and multiuser receivers are also sometimes called as decentralized and centralized receivers [7-8] respectively.

2.2 CONVENTIONAL MATCHED FILTER DETECTOR

Conventional detector is the simplest way to demodulate the received signal, consists of a bank of matched filters, one matched to each user's spreading waveform, is applied to the received signal. Thus, it demodulates all users independent of each other.

The output of matched filter bank from the Figure 4.1 shown below $y_j = \int_0^{t_b} r(t) s_j(t) dt$ (2.1)

, by substituting in Eqn(2.1).

$$= A_j b_j + \sum_{\substack{k=1 \\ k \neq j}}^{K} A_k b_k(i) R_{kj} + n_j \qquad (2.2)$$

and from the Figure 4.1, the estimated value is given by the Eqn(4.3), i.e.,

$$\hat{b} = sign(y_j) \qquad (2.3)$$

When the DS-CDMA system can be guaranteed to be synchronous, it is preferable to use orthogonal sequences for spreading. This results in the complete elimination of MAI. The demodulated signal for the j^{th} user

$$y_j = A_j b_j + n_j \; \ldots\ldots\ldots (4.4)$$

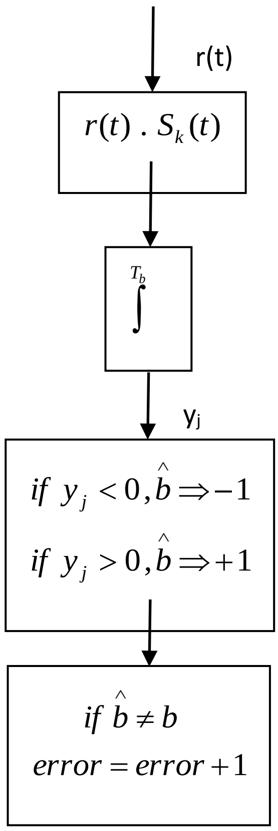


Figure 2.2 Algorithm for conventional matched filter receiver

2.3 MULTIUSER DETECTION RECEIVERS

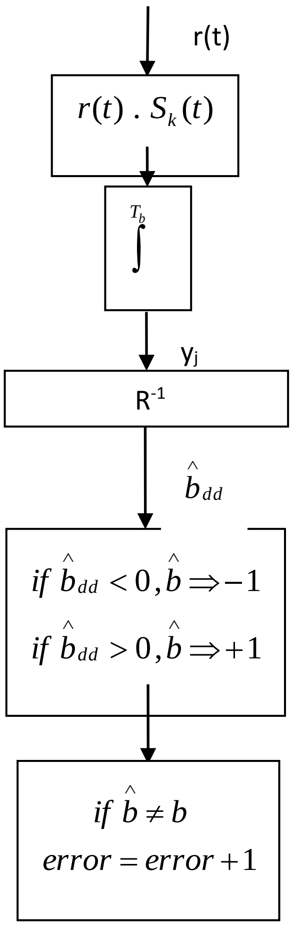
Optimal detector or maximum likelihood sequence estimation detector proposed by verdu. This detector is too complex for practical DS-CDMA systems. There are two categories of the most proposed detectors: linear multiuser detectors and non-linear detectors. In linear multiuser detection, a linear mapping (transformation) is applied to the soft outputs of the conventional detector to produce a new set of outputs, which hopefully provide better performance. In non-linear detection, estimates of the interference are generated and subtracted out [6].

2.4 LINEAR MULTIUSER DETECTORS

This type of algorithms involve, applying a linear transformation to the matched filter (single user detector) outputs. The output of the matched filter can be written in matrix form as

$$y_{mf} = RAb + n \qquad (2.5)$$

2.4.1 Decorrelating Detector



If we process the output vector as vector as

$R^{-1}y = Ab + R^{-1}n$ …(2.6) clearly the k[th] component of vector $R^{-1}y$ is free from interference caused by any other users for any k (since A is diagonal). Note that the cross correlation matrix R is invertible if signature sequences are linear independent. If the background noise is vanishing, i.e σ = 0, then .

$$\hat{b}_k = \mathrm{sgn}(R^{-1}y)_k = \mathrm{sgn}((Ab)_k), \ldots..(2.7)$$

Hence, in absence of background noise, we get error free performance. In the presence of the background noise, decision is affected only by the background noise, that is,

$$\hat{b}_k = \mathrm{sgn}(R^{-1}y)_k = \mathrm{sgn}((Ab + R^{-1}n)_k) \ldots\ldots.(2.8)$$

2.2.2 Minimum Mean-Squared Error (MMSE) Detector

Algorithm:

The MMSE detector implements a linear mapping L which minimizes the mean squared error $E\left[\left|(b_k - Ly)\right|\right]^2$. The detection scheme can be written as

$$\hat{b} = \mathrm{sgn}(Ly) \ldots\ldots.(4.8)$$

The approach here is to turn linear multi-user detection problem into a linear estimation problem.

Idea: Require MSE between the k[th] user bit b_k and the output of the linear transformation $m_k^T y_k$ to be minimized [5], [12].

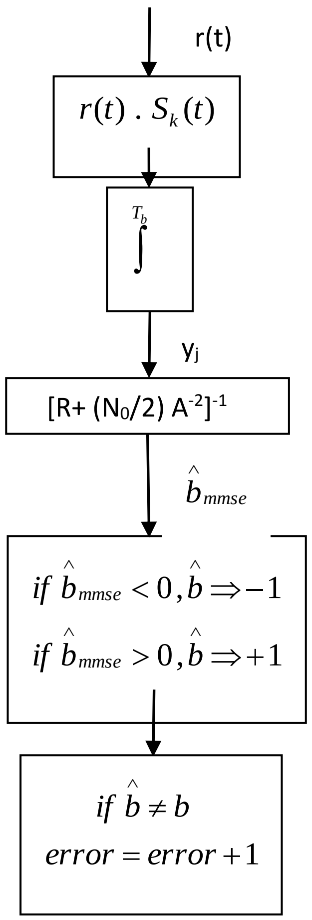


Figure 2.3 Algorithm for the Minimum Mean-Squared Error (MMSE) detector

This detector,

1. Performs better than the Decorrelating detector since it takes noise into account

2. Requires an estimate of the channel at the receiver.

CHAPTER 3

RESULTS AND DISCUSSION

3.1 INPUT PARAMETERS

The parameters used to simulate the performance of the three detectors over AWGN and flat fading channel for DS-CDMA systems for all cases are shown in the Table 3.1.

Table 3.1 List of Input Parameters for Simulation

S.No.	Parameters	Range of Parameters
1.	Number input data bits	100000
2.	Number of users	5, 10, and 15
3.	Length of the Gold sequence	31
4.	SNR in dB	[0 30]
5.	Doppler shift in Hz	50, 100 and 150
6.	Carrier Frequency in MHz	900
7.	Speed of the mobile in Km/hr	60, 118 and 180

3.3 DISCUSSION

3.3.1 BER performance in AWGN channel

Case 1:

Here the performance of Conventional detector, Decorrelating detector and MMSE detector over AWGN channel for five users are compared for DS-CDMA system. The MMSE implements the linear mapping which minimizes the men-squared error between the actual data and the soft output of the conventional detector. The MMSE detector applies a modified inverse of the correlation matrix to the matched filter outputs, and takes the background noise into account. So the performance of MMSE detector is better than the other two detectors. And from the simulation results shown in Figure 5.1, it is observed that to achieve the probability of error 10^{-4} the required SNR for Conventional detector is 14 dB, for Decorrelating detector required SNR is 11.9 dB and for linear MMSE detector required SNR is 11.8 dB. So theoretically and from the simulation results we can say that the performance of the MMSE detector is better than the remaining two detectors.

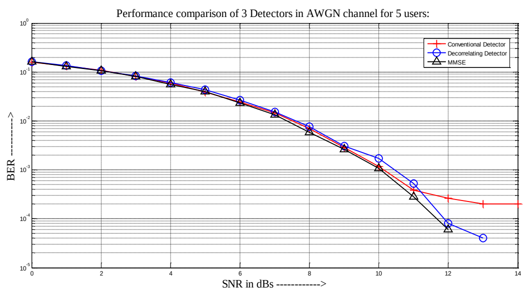


Figure 3.1 Performance comparison of three detectors in AWGN channel for 5 users

Case 2:

The performance evaluation of three detectors is compared for 5, 10 and 15 users over AWGN channel for the DS-CDMA system. First of all the performance of Conventional detector is compared for 5, 10 and 15 users over AWGN channel for the DS-CDMA systems. If the number of users increases then the Multiple Access Interference (MAI) increases, so there is a noise enhancement. Then the performance of the system degrades automatically. From the simulation results shown in Figure 5.2, it is observed that to achieve the probability of error 10^{-4} the required SNR for 5 users is 8.2 dB, for 10 users required SNR is 8.9 dB and for 15 users required SNR is 9.2 dB. So from the simulation results we can say that for 5 users the performance of the Conventional detector is better than the 10 and 15 users

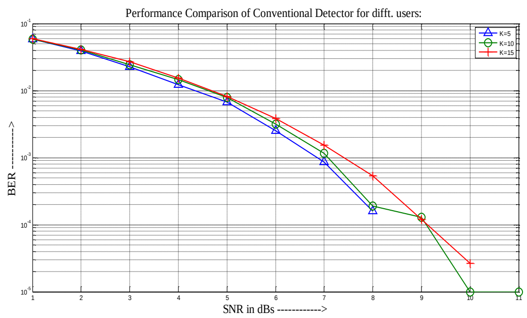


Figure 3.2 Performance comparision of Conventional Detector for different users

The performance of the Decorrelating detector is compared for 5, 10 and 15 users over AWGN channel for the DS-CDMA system. If the number of users increases then the Multiple Access Interference (MAI) increases, so there is a noise enhancement. Then the performance of the system degrades automatically. From the simulation results shown in Figure 5.3, it is observed that to achieve the probability of error 10^{-4} the required SNR for users k = 5 is 9.2 dB, for 10 users required SNR is 10.2 dB and for 15 users required SNR is 11 dB. From these results we can say that for 5 users the performance of the Decorrelating detector is better.

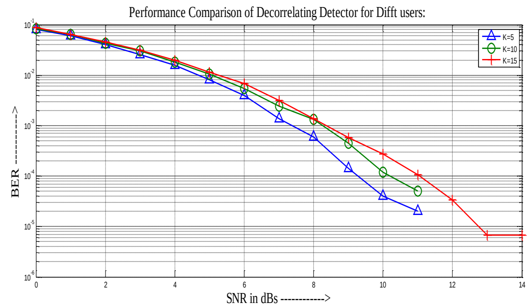


Figure 3.3 Performance comparison of Decorrelating Detector for different users

And at last in case 2, the performance of linear MMSE detector is compared for 5, 10 and 15 users over AWGN channel for the DS-CDMA system. From the simulation results shown in Figure 5.4, it is observed that to achieve the probability of error 10^{-4} the required SNR for 5 users is 8.2 dB, for 10 users required SNR is 8.3 dB and for 15 users required SNR is 8.4 dB. From these simulation results we can say that for k = 5 users the performance of the linear MMSE multiuser detector is better. The degradation of the DS-CDMA system over AWGN channel for linear MMSE multiuser detector is as shown in Figure 5.4. Theoretically the performance of the MMSE detector is better than the other detectors, as the MMSE detector minimizes the mean-squared error between the actual outputs and conventional detector outputs. And from these three simulation results in case 2, it is proved that the performance of the MMSE detector is better than the other two detectors.

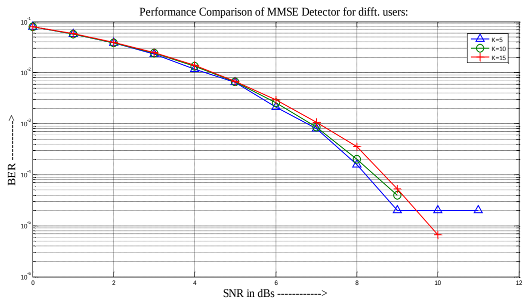


Figure 3.4 Performance Comparison of MMSE Detector for different users

3.3.2 BER performance in Rayleigh Fading channel

Case 3:

In case 3, performance of the three detectors is compared over the Flat Fading channel for the DS-CDMA system. Here the performance of the three detectors are compared for 10 users by considering the Doppler shift f_d = 100 Hz, carrier frequency is 900 MHz and velocity of the mobile is 118 Km/hr. Rayleigh fading envelope is generated by using Clarke's statistical model, and this Clarke's model was briefly explained in Chapter 3. From the simulation results shown in Figure 5.5, it is observed that to achieve the probability of error 10^{-4} the required SNR for Conventional detector is 30 dB, for Decorrelating detector required SNR is 29 dB and for MMSE detector required SNR is 27 dB. From the above simulation results we can say that the performance of the MMSE detector is better than the remaining two detectors in the flat fading channel. Performance comparison of three detectors for f_d = 100 Hz, carrier frequency at 900 MHz over flat fading channel is as shown in Figure 3.5.

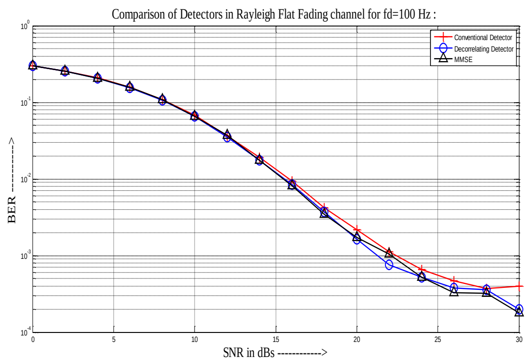


Figure 3.5 Comparison of Detectors in Rayleigh Flat Fading channel for f_d=100 Hz

Case 4:

The performance of three detectors is compared over flat fading channel for the different Doppler shifts f_d = 50, 100 & 150 Hz and the corresponding mobile velocities are 60, 118 and 180 Km/hr. First of all in case 4, the performance of Conventional detector is compared for the Doppler shifts f_d = 50, 100, and 150 Hz and the carrier frequency is 900 MHz for DS-CDMA system. The performance of the Conventional detector for flat fading channel is as shown in Figure 5.6. By observing the simulation results shown in Figure 5.6, it is observed that to achieve the probability of error (BER) 10^{-4} the required SNR for 50 Hz is 17 dB, for 100 Hz required SNR is 23 dB and for 150 Hz required SNR is 29 dB. Here for f_d =50 Hz the mobie is moving with less speed i.e. 60 Km/hr and for 150 Hz moving with high speed than the other two i.e. 180 Km/hr. So from these three results, the performance of the conventional detector for the Doppler shift f_d = 50 Hz is better than the other two Doppler shifts.

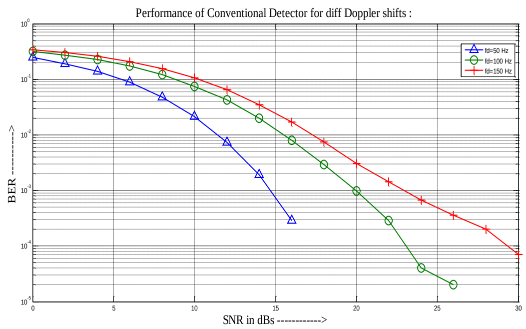


Figure 3.6 Performance of Conventional Detector for different Doppler shifts

The performance of linear Decorrelating detector is compared for the Doppler shifts f_d = 50, 100, and 150 Hz for DS-CDMA system. The performance of Decorrelating detector for flat fading channel is as shown in Figure 5.7. By observing the simulation results shown in Figure 5.7, it is observed that to achieve the probability of error (BER) 10^{-4} the required

SNR for 50 Hz is 13 dB, for 100 Hz required SNR is 14.5 dB and for 150 Hz required SNR is 23.5 dB. Here for f_d = 50 Hz the mobie is moving with less speed i.e. 60 Km/hr and for 150 Hz moving with high speed than the other two i.e. 180 Km/hr. So from these three results, the performance of the linear Decorrelating detector for the Doppler shift f_d = 50 Hz is better than the other two Doppler shifts. At last the performance of linear MMSE detector for flat fading channel by considering different Doppler shifts f_d = 50, 100, and 150 Hz for DS-CDMA system simulation results are as shown in Figure 5.8. It is observed that to achieve the BER at 10^{-4} the required SNR for the Doppler shift 50 Hz is 16 dB, for the Doppler shift 100 Hz required SNR is 23 dB and for 150 Hz required SNR is 24 dB. By observing these simulation results, the performance of the MMSE detector for f_d = 50 Hz is better than the other two Doppler shifts.

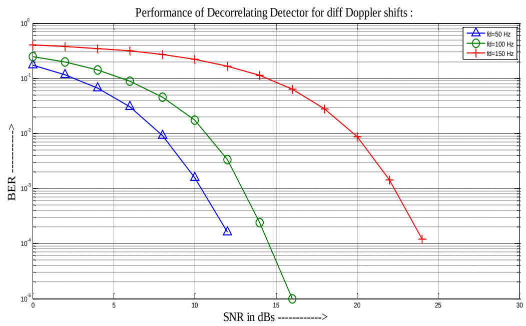


Figure 3.7 Performance of Decorrelating Detector for different Doppler shifts

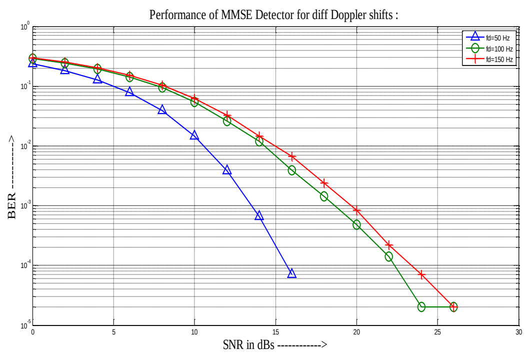


Figure 3.8 Performance of MMSE Detector for different Doppler shifts

CHAPTER 4

CONCLUSION AND FUTURE SCOPE

4.1 CONCLUSION

The performance evaluation of conventional detector, decorrelating detector and MMSE detector over AWGN channel for five users is compared and required SNRs for the BER at 10^{-4} are 14 dB, 11.9 dB and 11.8 dB respectively. So form these simulation results MMSE detector has better error performance than the other two detectors. In second case the performance of three detector is compared for 5, 10 and 15 users over AWGN channel, from the simulation results given in Chapter 5, it was that for five users the three detectors' performance is better than the users for k =10 and k =15.

In third case where the performance of three detectors have been compared over flat fading channel for Doppler shift 100 Hz. From the simulation results shown in Chapter 5, the performance of MMSE detector is better than the other two detectors. At last performance of each detector simulations have been compared for the different Doppler shifts. For the BER at 10^{-4} required SNRs at 50 Hz is 16 dB, at 100 Hz is 23 dB and at 150 Hz required SNR is 24 dB. By observing these results, the performance of the MMSE detector for f_d = 50 Hz is better than the other two Doppler shifts.

4.2 FUTURE SCOPE

In our work the performance of linear multiuser detectors is evaluated and these detectors will be used at the receiver section in order to get the better results in DS-CDMA system performance. Multiuser detection holds promise for improving DS-CDMA performance and capacity. Although multiuser detection is currently in the research stage, efforts to commercialize multiuser detectors are expected in the coming years as DS-CDMA systems are more widely deployed. The success of these efforts will depend on the outcome of careful performance for the realistic environment.

REFERENCES

[1] Theodore S Rappaport, "Wireless Communications Principle and Practice," *Prentice Hall of India*, 2nd edition, 2002.

[2] J.G. Proakis, "Digital Communications," *New York: McGraw-Hill*, 2nd edition, 1989.

[3] David Tse and Pramod Viswanath, "Fundamentals of Wireless Communication," *Cambridge University Press*, 1st edition, 2005.

[4] R Lupas and S. Verdu, "Linear Multiuser Detectors for Synchronous Code Division Multiple Access Channels," *IEEE Transactions on Information Theory*, Vol. 35, pp. 23-136, Jan 1989.

[5] Z. Xie, R. T. Short and C. K. Rushforth, "A Family of Suboptimum Detectors for Coherent Multiuser Communications," *IEEE Journal on Selected Areas In Communications*, Vol. 8, pp. 683-690, May 1990.

[6] S.R. Sheikh Raihan and B.C.Ng, "DS-CDMA System with Linear Multiuser Detection in AWGN Channel," *Georgian Electronic Scientific Journal: Computer Science and Tele-communications* 2008 No.1 (15).

[7] Kavita Khairnar, and Shikha Nema, "Comparison of Multi-User Detectors of DSCDMA System," *PWASET VOLUME* 10 DECEMBER 2005 ISSN 1307-6884, pp193-195.

[8] U. Madhow and M.Honig, "MMSE Interference Suppression for Direct–Sequence Spread-Spectrum CDMA," *IEEE Trans. Commun.*, vol. 42, pp. 3178-3188, Dec 1994.

[9] S. Moshavi, and Bellcore, "Multiuser detection for DS-CDMA communications," *IEEE Communications Magazine*, pp.124-135, October 1996.

[10] R. Lupas and S. Verdú, "Near-Far Resistance of Multi-User Detectors in Asynchronous Channels", *IEEE Trans. Commun.*, vol. 38, no. 4, pp. 496-508, 1990.

[11] Don Torrieri, "Principles of Spread-Spectrum Communication Systems," *Springer Science Business Media Inc*, 2005.

[12] X. Wang and H. V. Poor, "Blind Multiuser Detection: A Subspace Approach," *IEEE Transactions on Information Theory*, Vol.44, pp.677-690, Mar 1998.

Author Profile:

M.MamathaRani,R.Deepthi,V.Tarunkumar,S.Gopi are pursuing B.Tech final year of Electronics and Communication Engineering in Sri Sivani College of Engineering in Srikakulam under the guidance of G.SridharKumar Asst.Professor and Head of Department of ECE in Sri Sivani College of Engineering,chilakapalem,srikakulam.