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Performance Analysis of Multi User Detectors for Synchronous DS-CDMA Systems

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Abstract*: Direct sequence code division multiple access (DS-CDMA) is a prevalent remote innovation. This framework experiences from Multiple Access Interference (MAI) brought about by Direct Sequence users and near –far effect. Multi-User Detection plans are utilized to recognize the users' information in nearness of MAI and near- far problem. In this paper, we present similar examination between linear multiuser detectors and conventional single user matched filter in DS-CDMA system. Investigation and reproductions are led in synchronous AWGN channel, and Gold sequence and Kasami sequence are utilized as the spreading codes. Reproduction results portray the exhibition of three detectors, conventional detector, Decorrelating detector and MMSE (Minimum Mean Square Error) detector. It shows that the presentation of these detectors relies upon the length of PN code utilized and Number of users. Linear multiuser detectors perform superior to the conventional matched filter as far as BER performance. All the simulations have been performed on MATLAB 7.0.
Keywords: DS-CDMA, AWGN, MAI, MSME, BER, PN code

I. INTRODUCTION

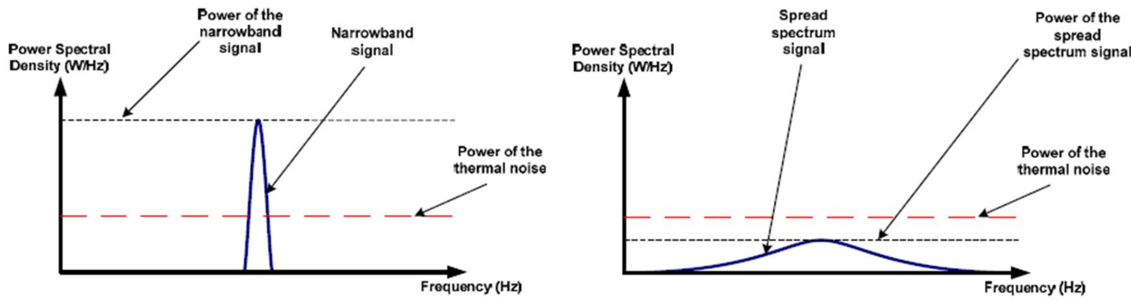
The communication system has challenge of obliging numerous users in a little region. The wireless space is the present territory of intrigue. The conventional systems utilized either frequency spectrum sharing or timesharing and henceforth there was the restriction on the limit. With the approach of spread spectrum and hence CDMA, fixed bandwidth was utilized to oblige numerous users by utilizing certain coding properties over the bandwidth. Be that as it may, this system suffers from MAI (Multiple Access Interference) brought about by direct sequence users. Multiuser Detection Technique will be the way in to this issue. These detection schemes were acquainted with distinguish the users' information within the sight of Multiple Access Interference (MAI), Inter Symbol Interference and noise. Spread spectrum CDMA systems (DS/CDMA) are ending up broadly acknowledged and guarantee to assume a key role in the future of wireless communications applications due to their productive utilization of the channel and there allowness for non-planned user transmissions. Subsequently recent interests are in techniques, which can improvise the strength of CDMA systems. The focal point of most ebb and flow research is on Wideband CDMA (W-CDMA) or NG (next generation) CDMA. In W-CDMA, the multimedia wireless network will end up attainable. Voice, yet in addition pictures, video and information can be transmitted by cell phones or other convenient gadgets. Accomplishing a higher information rate and higher limit are two significant objectives for W-CDMA, which makes the multiuser impedance issue increasingly pivotal. As Mobile communication systems dependent on CDMA are inalienably dependent upon Multiple-Access Interference (MAI), since it is difficult to keep up symmetrical spreading codes in versatile conditions. MAI (Multiple-Access Interference) restrains the limit of Conventional detectors and expedites severe power control prerequisites to ease the Near-Far problem.

II. DS-CDMA SYSTEM

The fast overall development in cell phone subscribers over the previous decade has clearly demonstrated that the wireless communication is a viable methods for moving data in the present society. Time Division Multiple Access (TDMA) and Frequency Division Multiple Access (FDMA) are two methodologies that have added to this headway in the media communications industry. Be that as it may, the across the board achievement of these communications systems has prompted the improvement for fresher and higher innovation methods and norms so as to encourage fast communication for mixed media, information and video notwithstanding voice transmissions. Code Division Multiple Access (CDMA) is the present prevailing innovation for the advancement of third era (3G) versatile communications systems with the improvement of two significant plans: Wideband CDMA (W-CDMA) and CDMA2000. The W-CDMA innovation also called the Universal Mobile Telecommunications System (UMTS) is planned with the aim of giving an overhaul way to the current Global System for Mobile Communications (GSM) while CDMA2000 depends on the crucial advancements of IS-95, IS-95A (cdmaOne) just as the 2.5G IS-95B frameworks. These two plans are comparable for their capacity to give high information rates and the productive utilization of data transmission yet are incongruent as they utilize distinctive chip rates. The accompanying segments of this section will depict and clarify the essential ideas driving the CDMA innovation.

A. Spread Spectrum

In Code Division Multiple Access (CDMA) systems all users transmit in the same bandwidth simultaneously. Communication systems following this concept are "spread spectrum systems". In this transmission technique, the frequency spectrum of a data-signal is spread using a code uncorrelated with that signal. As a result the bandwidth occupancy is much higher than required. The codes used for spreading have low cross-correlation values and are unique to every user. This is the reason that a receiver which has knowledge about the code of the intended transmitter is capable of selecting the desired signal. In spread spectrum systems, a stream of data is spread from narrow band signal to a wideband signal and then transmitted. One advantage of this is that the signal amplitude does not have to be higher than the noise in transmission. The Figure 1 shows the spectrum of the signal before and after spreading.



(a) Before spreading and after spreading (b) After spreading

Fig 1: Spread Spectrum Concept

B. Direct-Sequence Spread Spectrum (DS-SS)

The DS-SS system is one of the most prevalent types of spread range. This is presumably because of the effortlessness with which direct sequencing can be actualized. Figure 2 shows the fundamental model and the key attributes that make up the DS-SS correspondences framework. In this type of adjustment, a pseudo-arbitrary commotion generator makes a spreading code or also called the pseudo-noise (PN) code sequence. Each piece of the first info information is legitimately regulated with this PN sequence and is spoken to by numerous bits in the transmitted sign. On the receiving end, just the equivalent PN grouping is equipped for demodulating the spread range sign to effectively recoup the info information.

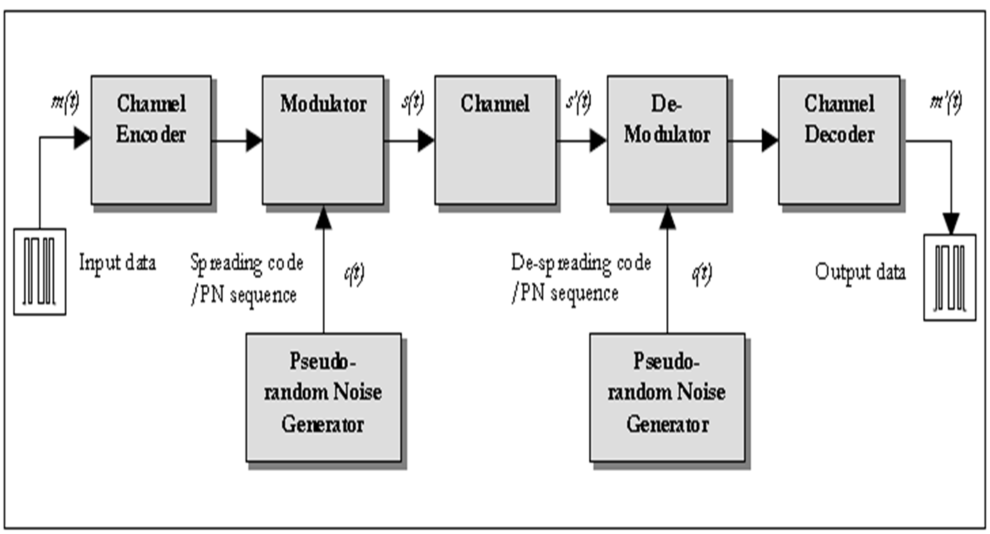


Fig 2: Basic model of the direct-sequence spread spectrum communications system

The data transfer capacity of the transmitted sign is straightforwardly corresponding to the quantity of bits utilized for the PN Sequence. A 7-bit code sequence spreads the sign over a more extensive recurrence band that is multiple times more prominent than a 1-bit code sequence, generally named as having a preparing increase of seven. Figure 3 illustrates the generation of a DS-SS signal using an exclusive-OR (XOR) operation. The XOR obeys the following rules:

0□0 □□0 0□1 □□1 1□0 □□1 1□1 □□0

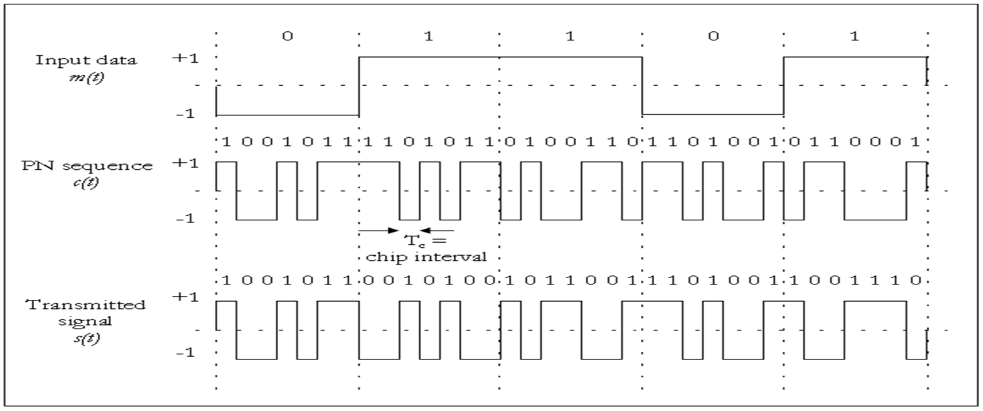


Fig 3: Generation of a DS-SS signal with processing gain = 7

Note that an input data bit of zero causes the PN sequence coding bits to be transmitted without inversion, while an input data bit of one inverts the coding bits. Rather than to represent the binary data with bits 0's and 1's, the input data and PN sequence are converted into a bipolar waveform with amplitude values of ±1.

1) *Spreading Codes:* The DS-CDMA system uses two general categories of spreading sequences: PN sequences and orthogonal codes
2) *PN Sequence:* The PN sequence is produced by the pseudo-random noise generator that is simply a binary linear feedback shift register, consisting of XOR gates and a shift register. This PN generator has the ability to generate an identical sequence for both the transmitter and the receiver, and yet retaining the desirable properties of a noise-like randomness bit sequence. A PN sequence has many characteristics such as having a nearly equal number of zeros and ones, very low correlation between shifted versions of the sequence and very low cross correlation with any other signals such as interference and noise. However, it is able to correlate very well with itself and its inverse. Another important aspect is the autocorrelation of the sequence as it decides the ability to synchronize and lock the spreading code to the received signal. This effectively combats the effects of multipath interference and improves the SNR. M-sequences, Gold codes and Kasami sequences are examples of this class of sequences.

III. MULTIUSER DIRECT SEQUENCE SPREAD SPECTRUM SYSTEMS

Spread spectrum can also be used as a mechanism for many users to share the same spectrum. Using spreading code properties to support multiple users within the same spread bandwidth is also called spread-spectrum multiple access (SSMA), which is a special case of code-division multiple access (CDMA). In multiuser spread spectrum, each user is assigned a unique spreading code or hopping pattern, which is used to modulate their data signal. The transmitted signal for all users is superimposed in time and in frequency. The spreading codes or hopping patterns can be orthogonal, in which case users do not interfere with each other under ideal propagation conditions, or they can be non-orthogonal, in which case there is interference between users, but this interference is reduced by the spreading code properties. Thus, while spread spectrum for single-user systems is spectrally inefficient, as it uses more bandwidth than the minimum needed to convey the information signal, spread spectrum multiuser systems can support an equal or larger number of users in a given bandwidth than other forms of spectral sharing such as time-division or frequency-division. However, if the spreading mechanisms are non-orthogonal either by design or through channel distortion, users interferer with each other. If there is too much interference between users, the performance of all users degrades.

Performance of multiuser spread spectrum also depends on whether the multiuser system is a downlink channel (one transmitter to many receivers) or an uplink channel (many transmitters to one receiver). These channel models are illustrated in Figure 4 the downlink channel is also called a broadcast channel or forward link, and the uplink channel is also called a multiple access channel or reverse link. The performance differences of DSSS in uplink and downlink channels result from the fact that in the downlink, all transmitted signals are typically synchronous, since they originate from the same transmitter. Moreover, both the desired signal and interference signals pass through the same channel before reaching the desired receiver. In contrast, users in the uplink channel are typically asynchronous, since they originate from transmitters at different locations, and the transmitted signals of the users travel through different channels before reaching the receiver.

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Fig 4: Down link and uplink channel

IV. MULTI-USER DETECTION

A. Basic principles of Multi-user Detection

The practical problem that often arises in CDMA is the fact that the code sequences are not completely orthogonal, either because they are chosen not orthogonal to avoid capacity limitation, or because the signal coming from each user at the receiver have a random delay, and thus the matched corresponding to one code will not totally suppress the interference caused by other signals. A conventional DS/CDMA system treats each user separately as a signal, with other users considered as noise or multiple access interference. 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 multi-user detection techniques. Multi-user 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 Multi-User detectors. A single user receiver detects the data of one user at a time whereas a multi-user receiver jointly detects several users' information. Single user and multi user receivers are also sometimes called as decentralized and centralized receivers respectively.

V. SIMULATION RESULTS

Detectors that are simulated include conventional single user matched filter (MF), Decorrelating and Minimum mean-squared error (MMSE). First of all, the BER performance comparison between the conventional detector and two suboptimal linear multiuser detectors is conducted. The performance evaluation with increasing number of active users is carried out. These simulations are done with the assumption that all active users have equal power.

Simulations are carried out considering Conventional detector, Decorrelating detector and MMSE (Minimum Mean Square Error) detector. AWGN channel is considered and there is perfect power control. To simplify the discussion, we make assumptions that all carrier phases are equal to zero. This enables us to use baseband notation while working only with real signals. We also assume that each transmitted signal arrives at the receiver over a single path.

A. Performance Analysis

1) *Case 1:* Gold sequence of length 31 and 2 users

Two users synchronously transmitting the 5000 bits through an AWGN channel. For spreading gold sequence of length Lc=31 is used.SNR is varying from 1dB to 8 dB. Here K=Number of users and Lc= PN sequence length the number of user is 2 the three detectors performance is almost similar. If number of user are increasing then the effect of MAI also increase that influence the detection of data.

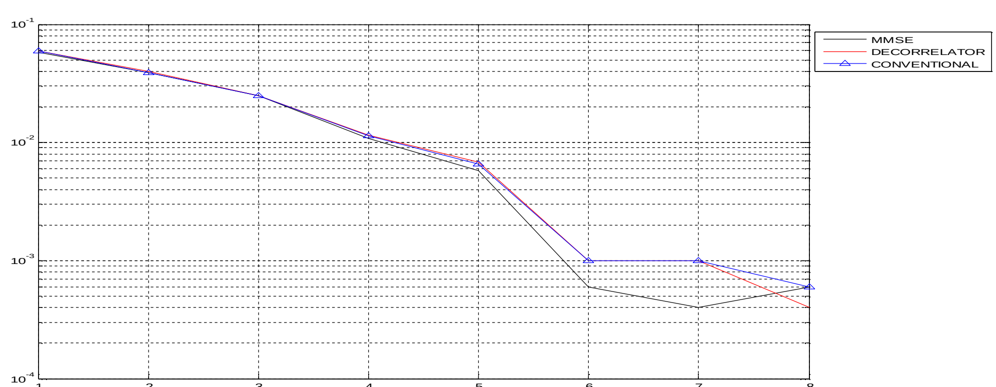

Fig 5.1 BER performance of the three detectors for K= 2, Lc=31

2) Case 2: Gold sequence of length 31 and 4 users

Four users synchronously transmitting the 5000 bits through a AWGN channel. For spreading gold sequence of length Lc=31 is used.SNR is varying from 1dB to 8 dB

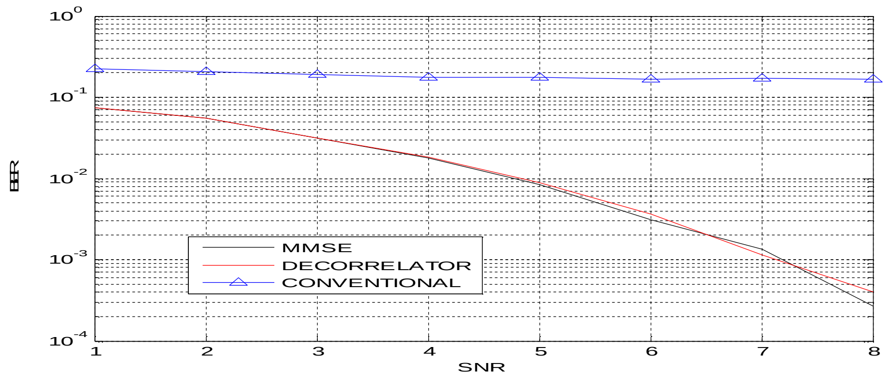

Fig 5.2 BER performance of the three detectors for K= 4, Lc=31

Table 1: SNR VS BER for K=4,L=31

SNR	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Conventional(BER)	0.2259	0.2089	0.1918	0.1768	0.1767	0.1653	0.1704	0.1657
decorrelator	0.0744	0.0559	0.0318	0.0185	0.0089	0.0037	0.0011	0.0004
MMSE	0.0737	0.0546	0.0317	0.0178	0.0084	0.0031	0.0013	0.0003

3) Case 3: Gold sequence of length 31 and 8 users

Eight users synchronously transmitting the 5000 bits through an AWGN channel. For spreading gold sequence of length Lc=31 is used.SNR is varying from 1dB to 8 dB.

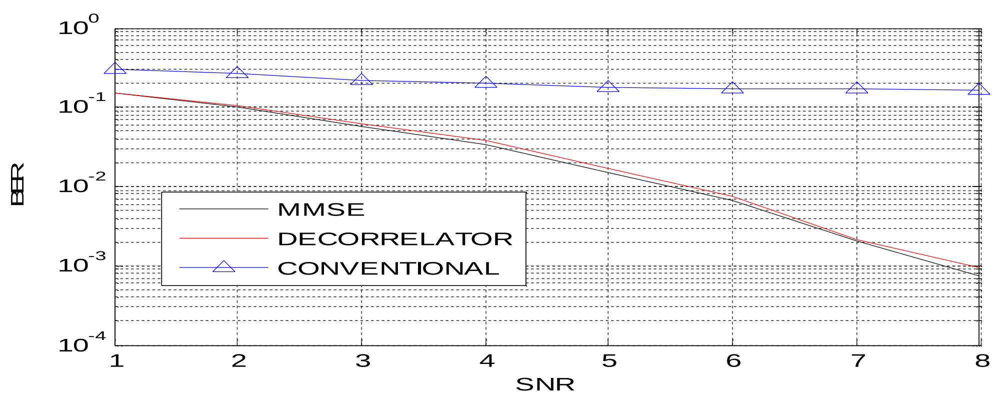

Fig 5.3 BER performance of the three detectors for K= 8, Lc=31

Table 2: SNR VS BER for K=8,L=31

SNR	1	2	3	4	5	6	7	8
Conventional(BER)	0.304	0.2625	0.2228	0.2038	0.0152	0.1707	0.1683	0.1647
decorrelator	0.1529	0.1055	0.0633	0.0374	0.0171	0.0075	0.0021	0.0009
MMSE	0.1487	0.1020	0.0579	0.0345	0.0152	0.0066	0.0021	0.0007

The Linear multiuser detectors has less bit error rate ($\sim 10^{-3}$) compare to the conventional detector (10^{-1}). Linear multiuser detectors are outperforming the Conventional detectors.

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4) Case 4: Gold sequence of length 63 and 8users

Eight users synchronously transmitting the 5000 bits through an AWGN channel. For spreading gold sequence of length Lc=63 is used.SNR is varying from 1dB to 8 dB.

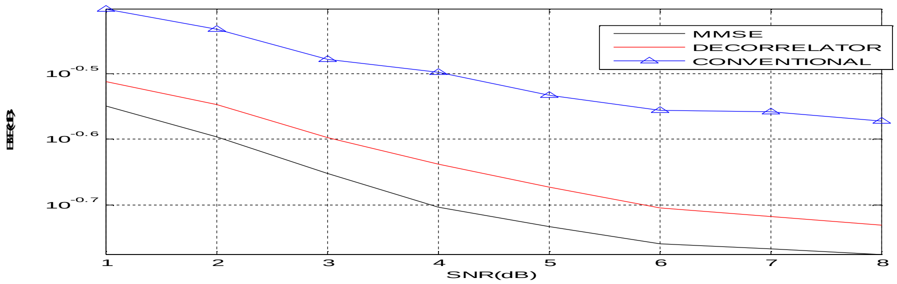

Fig 5.4 BER performance of the three detectors for K= 8, Lc=63

The performance comparison of the three detection schemes can be done by varying the length of the Gold code used (63).The increase in the length of the Gold codes leads to a significant rise of the non-orthogonality of the signature sequences. This leads to a considerable degradation in the system performance shown in above figure 5.4.

5) Case 5: Performance comparison with near-far effect

Eight users synchronously transmitting the 5000 bits through a AWGN channel. For spreading gold sequence of length Lc=31 is used.SNR is varying from 1dB to 8 dB. The signal strength is different for different users.

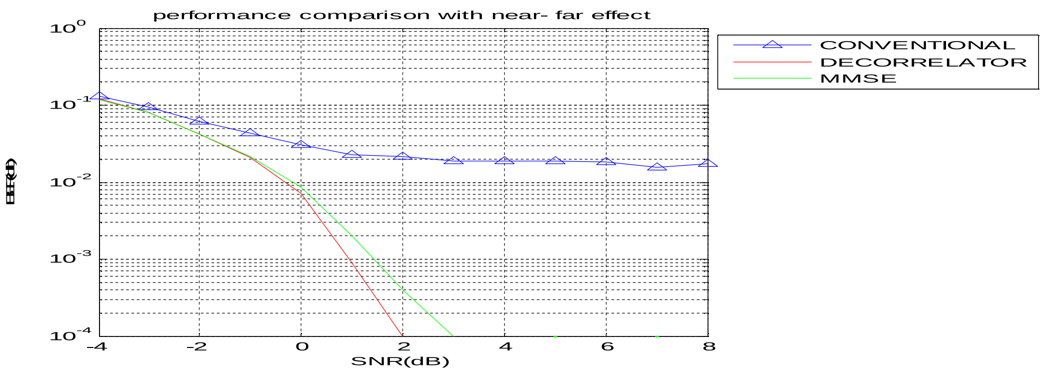

Fig 5.5 BER performance of the three detectors for K= 4, Lc=31 with Near-far effect

An important disadvantage of this detector is that, unlike the Decorrelating detector, it requires estimation of the received amplitudes. Another disadvantage is that its performance depends on the powers of the interfering users. Therefore, there is some loss of resistance to the near-far problem shown in above fig as compared to the Decorrelating detector.

6) Case 6: Comparison of multi user detection of DS CDMA system with single user bound.

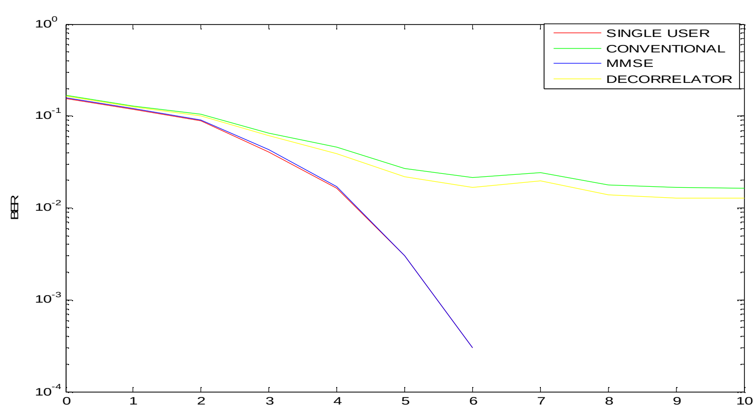

Fig 5.6 BER performance of the three detectors for K= 4, Lc=31

7) Case 7: Comparison of multi user detection of DS CDMA system using orthogonal codes

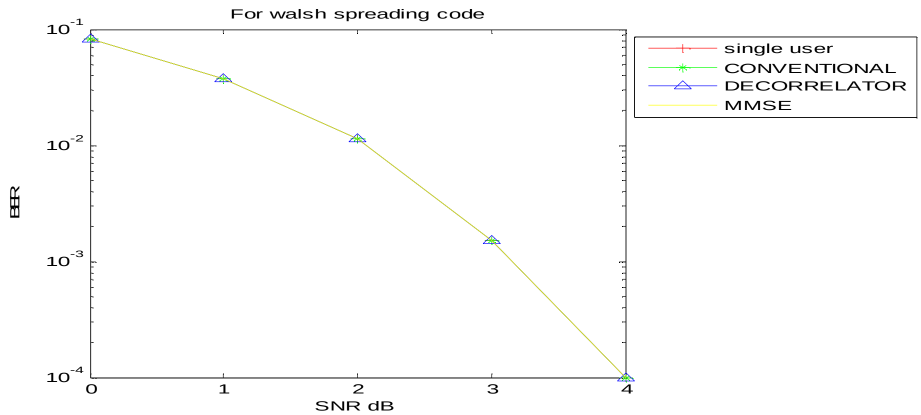

Fig 5.7 BER performance of the three detectors for Walsh code Lc=16

From Fig 5.7 we can say that if we use orthogonal spreading codes, the effect of MAI is zero. So the detectors are having the same performance.

Using kasami sequence

8) *Case 8:* Two users synchronously transmitting the 5000 bits through an AWGN channel. For spreading kasami sequence of length Lc=63 is used.SNR is varying from 1dB to 8 dB.

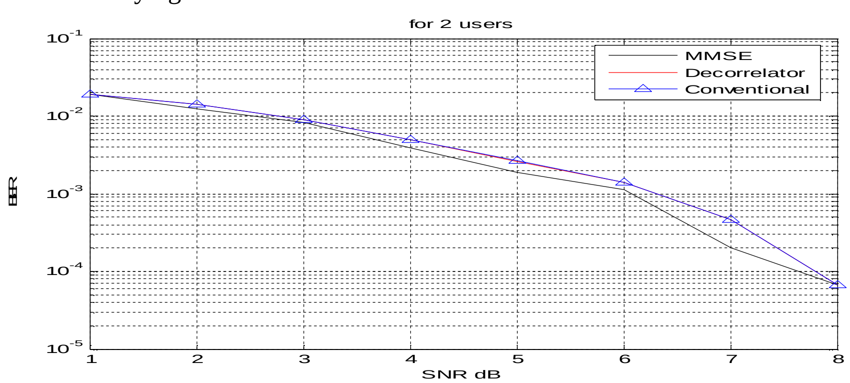

Fig 5.8 BER performance of the three detectors for Kasami code Lc=63, K=2.

9) *Case 9:* Four users synchronously transmitting the 5000 bits through an AWGN channel. For spreading Kasami sequence of length Lc=63 is used. SNR is varying from 1dB to 8 dB.

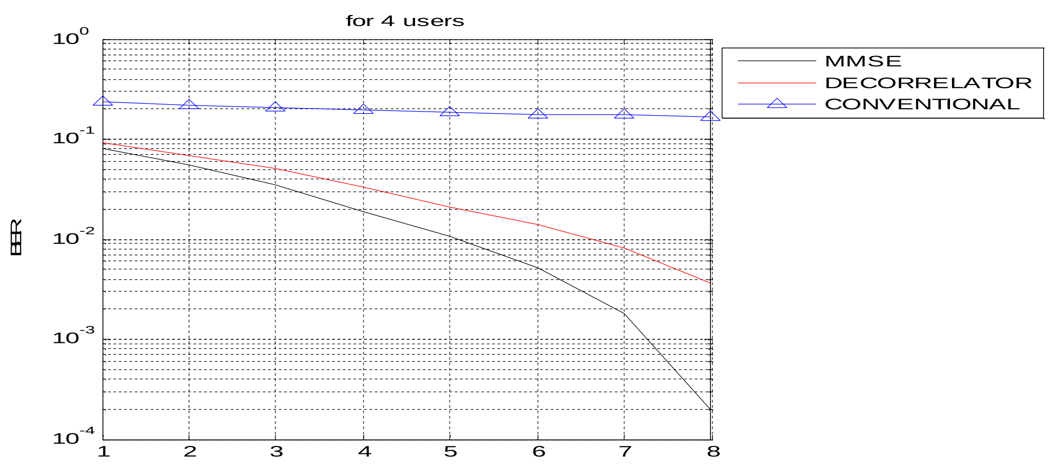

Fig 5.9 BER performance of the three detectors for kasami code Lc=63, K=4

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10) Case 10: Eight users synchronously transmitting the 5000 bits through an AWGN channel. For spreading kasami sequence of length Lc=63 is used.SNR is varying from 1dB to 8 dB.

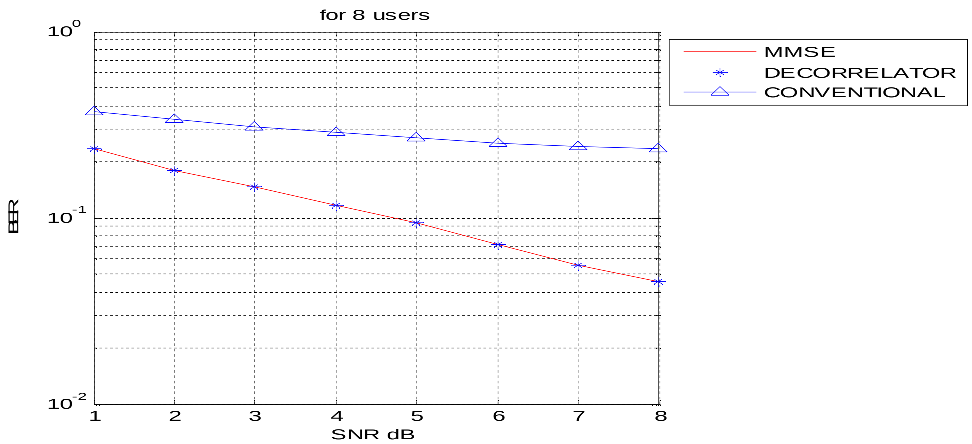

Fig 5.10 BER performance of the three detectors for kasami code Lc=63, K=8

11) Case 11: Two users synchronously transmitting the 5000 bits through an AWGN channel. For spreading kasami sequence of length Lc=255 is used.SNR is varying from 1dB to 8 dB.

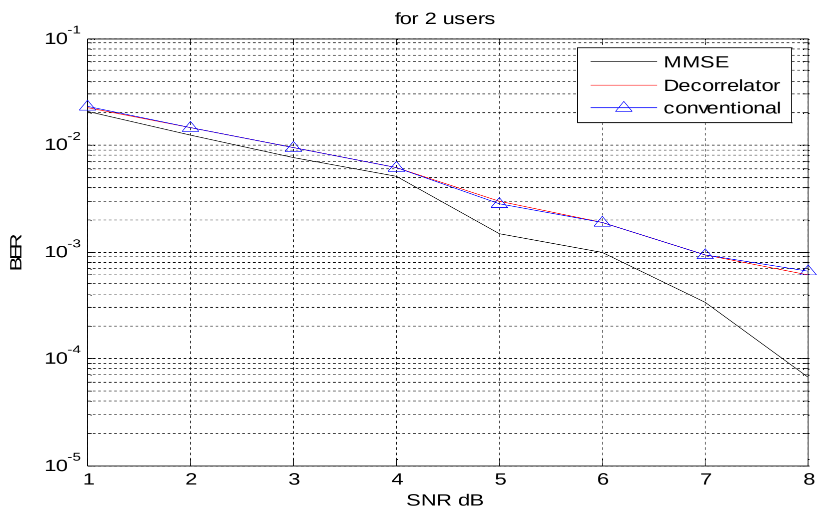

Fig 5.11 BER performance of the three detectors for kasami code Lc=255, K=2

12) Case 12: Four users synchronously transmitting the 5000 bits through an AWGN channel. For spreading kasami sequence of length Lc=255 is used.SNR is varying from 1dB to 8 dB.

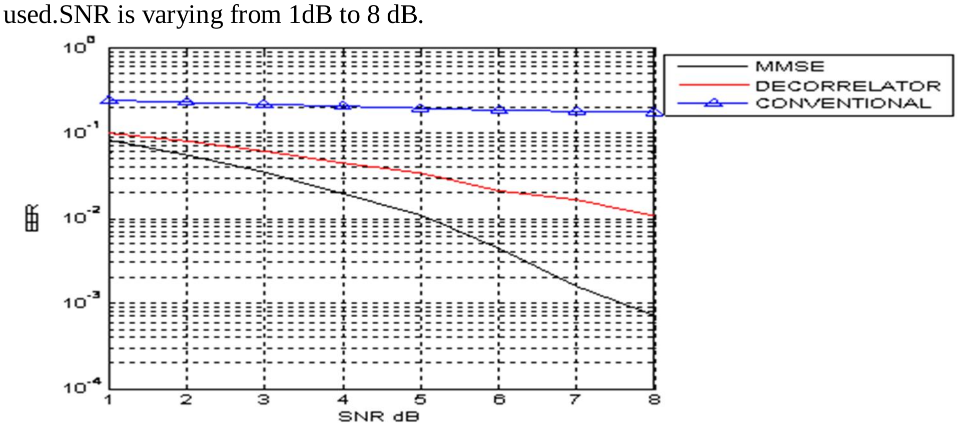

Fig 5.12 BER performance of the three detectors for kasami code Lc=255, K=8

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13) *Case 13:* BER performances of the detectors for increasing number of active users

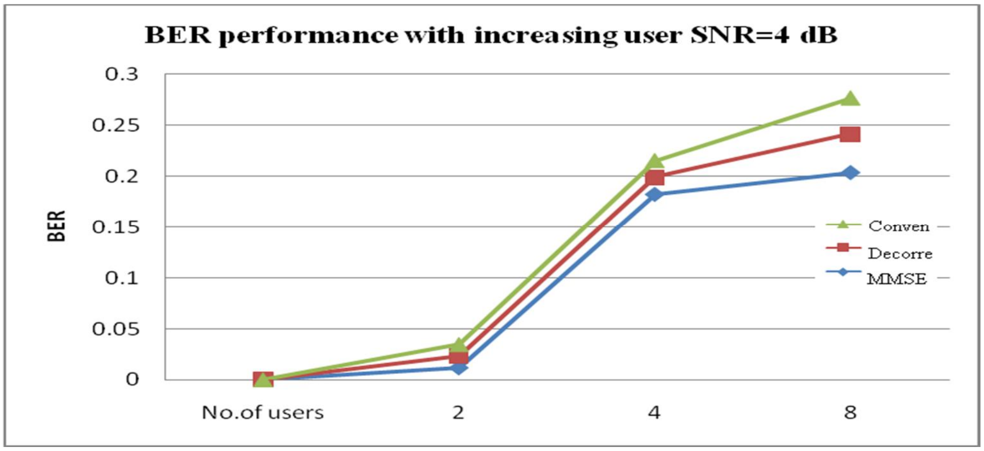

Fig 5.13 BER performances of the detectors for increasing number of active users at SNR= 4 dB and Gold sequence Lc==31.

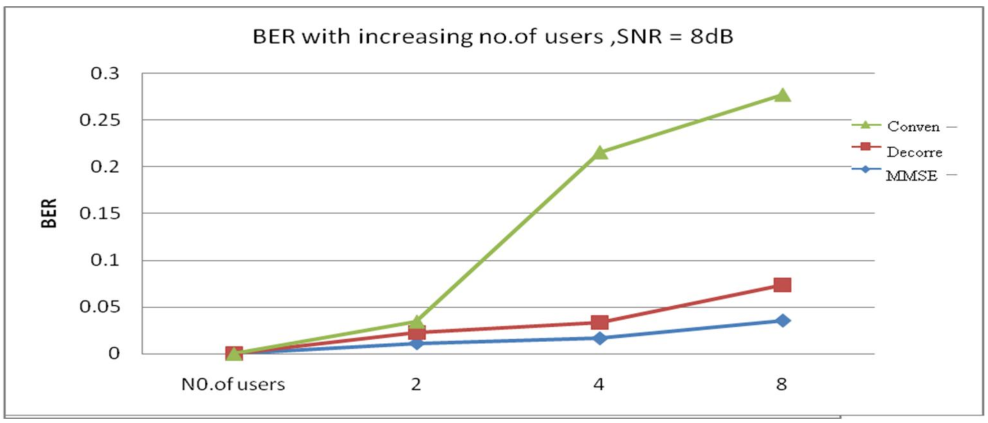

Fig 5.14 BER performances of the detectors for increasing number of active users at SNR=8 dB

Figure 5.13 and 5.14 shows the BER performances of the detectors are investigated for increasing number of active users in the same channel. All interfering users, from K=1 through K=8are signalling at SNR=4dB & SNR=8dB. The performance of the conventional detector degrades sharply than the linear detectors as the number of active users' increases. For example for a system of K=8 users in Gaussian noise, the conventional detector error is more than 10^{-3} while the linear detectors errors are still less than10^{-3}. The linear detectors degrade slightly with increasing number of equal-power active users, although for very large loads, the performance of Decorrelating and MMSE detectors are slightly similar. This is due to the fact that as the number of interfering users increases so does the MAI term becomes more significant than the channel noise interference which only forms a small part of the total interference

VI. CONCLUSION

The ideal multiuser finder performs superior to the regular coordinated channel and the straight multiuser indicators. In any case, this detector is unreasonably unpredictable for pragmatic DS-CDMA framework. MMSE detector for the most part performs superior to the Decorrelating identifier since it considers the foundation commotion. With expanding in the quantity of clients, the exhibition of all finders will debase too. This is on the grounds that as the quantity of meddling clients builds, the measure of MAI winds up more noteworthy also. In this manner there is an exchange of between the exhibition measures (BER versus SNR) and the common sense measure (multifaceted nature and detection delay). Depending upon the circumstances, a suboptimum collector fulfilling the usage obliges can be picked. Multiuser detection holds guarantee for improving DS-CDMA execution and limit. In spite of the fact that multiuser location is presently in the examination organize, endeavors to market multiuser finders are normal in the coming a very long time as DS-CDMA frameworks are all the more broadly sent. The accomplishment of these endeavors will rely upon the result of cautious execution and cost examination for the reasonable.

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