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Performance Estimation of 2*2 MIMO-MC-CDMA using Different Modulation Technique

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ABSTRACT

*In this paper we estimate the performance of MIMO-MC-CDMA system in Rayleigh fading environment in QPSK, 8-PSK, 8-QAM, 16-QAM, 32-QAM and 64-QAM modulation technique using MATLAB this technique is highly optimized in 3G and 4G wireless communication system to reducing BER. CDMA (Code Division for Multiple Access) is a multi-user system also called as spread spectrum system for which spreading of sequence is done by using PN (Pseudo-random Noise) sequence generator at the transmitter. This system then combined with OFDM (Orthogonal Frequency Division Multiplexing) which is multi-carrier system in which single broadband frequency selective carrier is converted into parallel narrowband flat fading multiple sub-carriers to optimize the performance of system which forms MC-CDMA (multi-carrier – Code Division Multiple Access) system. Now this system further improved by combination of 2*2 MIMO (Multiple Input Multiple Output) system contains 2 tranmit antennas and two receive antenna which utilizes ZF (Zero Forcing) decoder at the receiver to reduce BER and also ½ rate convolutionally encoded Alamouti STBC (Space Time Block Code) block code as transmit diversity of MIMO for multiple transmission of data through multiple transmit antenna. By using MIMO-OFDM [7] combination remove the probability of ISI at the transmitter without using ZF equalizer. Resultant system with the combination of OFDM-CDMA and MIMO-OFDM gives MIMO-MC-CDMA which is optimized system for 3G and 4G wireless communication system. Now after forming MIMO-MC-CDMA using MATLAB [3] we analyze system performance in above mentioned modulation schemes in Rayleigh fading channel.*

Keywords: *OFDM, CDMA, MIMO, MIMO-MC-CDMA and MC-CDMA.*

1. Introduction

Due to increased demand of high data rate and low probability of error in this paper we utilize the technique of MIMO, CDMA and OFDM to enhance the technique by minimizing error rate. MC-CDMA is combination of CDMA (Code Division for Multiple Access) and OFDM (Orthogonal Frequency Division Multiplexing) system. CDMA is multiple access system and OFDM is multiple access system in frequency selective channel that is in OFDM, the frequency selective channel is converted into a group of N narrowband flat-fading channel, one channel across each sub-carriers. The combination of both the technique cause improved efficiency of the wireless communication system which results high data rate and low probability of error.

This experience is further improved by combination of MIMO with MC-CDMA to increase the throughput of the wireless. MIMO (Multiple Input Multiple Output) is multiple antenna system in which multiple receive diversity and multiple transmit diversity is used for synchronization of system for reduction of ISI. ZF equalizer is used to minimize mean square error. And for transmit diversity half-rate convolutionally encoded Alamouti STBC block code is used. And finally combined MIMO-MC-CDMA [1] is formed by all above operations using MATLAB. This MIMO-MC-CDMA then analyzed using *QPSK, 8-PSK, 8-QAM, 16-QAM, 32-QAM and 64-QAM modulation techniques*.

2. Multiple Input Multiple Output (MIMO)

MIMO system is based on multiple transmitting and multiple receiving antennas to achieve very high data rates in rich multipath scattering environments without increasing the transmission bandwidth or the total transmitted power of the system. The point-to-point MIMO channel of m transmit (Nt = m) and n receive (Nr = n) antennas is shown in Figure 1.

MIMO techniques provide high data rates through spatial multiplexing and increase the spectral efficiency of the system which is rich in scattering environments by providing spatial diversity. The capacity of MIMO system is increases as the number of transmit-receive antenna pairs increases. So due to this it is called spatial multiplexing architectures. The received signal for the MIMO system is given as mathematically

$$\begin{bmatrix} r(1) \\ \cdot \\ \cdot \\ \cdot \\ r(Nr) \end{bmatrix} = \begin{bmatrix} h(1,1) & \cdot & \cdot & \cdot & h(1,Nt) \\ \cdot & \cdot & & & \cdot \\ \cdot & & \cdot & & \cdot \\ \cdot & & & \cdot & \cdot \\ h(Nr,1) & \cdot & \cdot & \cdot & h(Nr,Nt) \end{bmatrix} \begin{bmatrix} d(1) \\ \cdot \\ \cdot \\ \cdot \\ d(Nt) \end{bmatrix} + \begin{bmatrix} n(1) \\ \cdot \\ \cdot \\ \cdot \\ n(Nr) \end{bmatrix} € C^{Nr*Nt} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

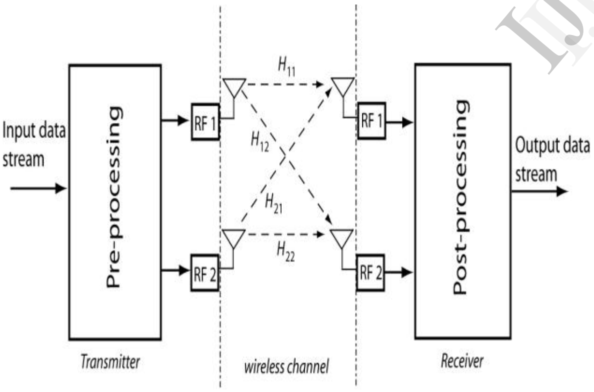

Figure 1: MIMO channel.

The channel model in (1) can be simplified to equation can be represented as

$r = Hd + n$ …………………….…….(2)

where d denotes the transmitted symbol of dimension Nt, n is the noise vector dimension Nr with zero mean and variance σ_n^2 and H indicates the Nr*Nt complex matrix of channel coefficient gains hi,j from transmit antenna j to receive antenna i.

2.1 Spatial Multiplexing

Figure 2 shows the block diagram for a spatial multiplexing (SM) technique with parallel symbol mapping. Spatial multiplexing divides a single bit stream into Nt parallel sub streams which are mapped into symbol streams by appropriate constellation before simultaneous transmission over the wireless channel. The Nt sub streams forms the vertical vector

$d = [d1\ d2 \ldots\ldots\ldots\ldots\ dNt]^T € C^{Nr*1}$ …(3)

which contains the mapped symbols. This process illustrates the encoding of the input serial data into a vertical vector which is referred to as vertical encoding. As parallel transmit antennas Nt are used for spatial multiplexing, the transmission rate is Nt times greater than systems with a single transmit antenna.

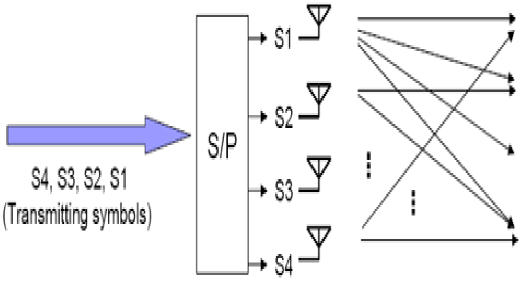

Figure 2: Spatial multiplexing architecture.

2.1.1 Linear Detection (Nulling)

Spatial interference can be suppressed by Linear filtering (or nulling) which arises when multiple antennas transmit multiple substreams simultaneously called co-antenna interference (CAI). By nulling, we considered one received desired signal while other symbols are suppressed. This procedure is repeated for each of the received sub streams. For this two different linear filters are used for the purpose of this research and these include the ZF and the minimum mean square error (MMSE) filters. In this paper we are considering on ZF receiver. Provided that the number of transmit antenna should not greater than the number of receive antenna (Nt ≤ Nr), their transform matrices are given by

$GZF = H^+ = (H^H H)^{-1} H^H$ ……………...(4)

$GMMSE = [H^H H + N0INt]^{-1} H^H$ ……..(5)

respectively, where H^+ and H^H represent the pseudo inverse and Hermitian matrices of H respectively, and INt stands for the Nt * Nt identity matrix. The decision statistics of the transmitted symbols is given as

$y = Gr = Gd + Gn$ …………………...(6)

where G represents the ZF or MMSE spatial suppression matrix given by (4) or (5) respectively.

2.2 Spatial Diversity

Transmitting and receiving multiple copies of the same data streams under independent fading paths using multiple transmit and multiple receive antennas is an alternative approach to spatial multiplexing to achieve transmit and/or receive diversity. By which detection of signals in deep fades is avoided so spatial diversity increases the system performance. This method is called space-time coding (STC) and it is shown in Figure 3.

There are two main STC schemes for spatial diversity and these are: (i) space-time trellis code (STTC) and (ii) space-time block code (STBC). STBC bring out spatial correlation into the signals transmitted from different antennas, in order to give spatial diversity and coding gain without offering extra bandwidth. However, STTC require trellis decoding which is a high complexity detection process that is exponentially as a function of the transmit antennas and the transmission rate. Here, this work is focused on the STBC, which is explained in the following section.

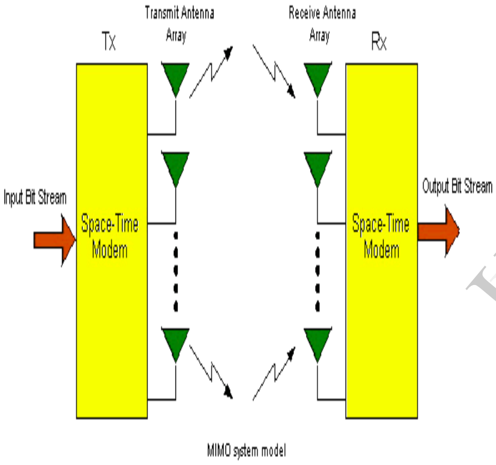

Figure 3: Space-time coding (STC).

2.2.1 Space-Time Block Code (STBC)

A low complexity system that achieves transmit diversity was proposed by Alamouti for 2 transmit antennas. This scheme is noted as STBC and is later generalized to an arbitrary number of antennas. In the Alamouti's transmission scheme, let us consider two symbols d0 and d1 in two consecutive symbol periods transmitted over two successive transmissions. In first transmission, d0 and d1 are transmitted simultaneously at time t from the two transmit antennas. During the second transmission, different symbols -d1* and d0* are transmitted at time t + Td where Td denotes the symbol period. So, the transmission matrix is represented by

$$D = \begin{bmatrix} d0 & d1 \\ -d1* & d0* \end{bmatrix} \ldots\ldots\ldots\ldots\ldots\ldots(7)$$

The transmission matrix is orthogonal i.e.

$$DD^H = \begin{bmatrix} d0 & d1 \\ -d1* & d0* \end{bmatrix} \begin{bmatrix} d0* & -d1 \\ d1* & d0 \end{bmatrix}$$

$$=(|d0|^2+|d1|^2)I \ldots\ldots\ldots\ldots\ldots\ldots\ldots(8)$$

The first and second received signals are given by

$$r(1) = h1d0 + h2d1 + n(1)\ldots\ldots\ldots\ldots(9)$$

$$r(2) = -h1d1^* + h2d0^* + n(2) \ldots\ldots\ldots(10)$$

where h1 and h2 denote the channel gain coefficients from transmit antenna 1 and 2 to receive antennas respectively and it is assumed that h1 and h2 are constant over two successive symbol periods. In addition, n(1) and n(2) represent the AWGN noise components with zero mean and variance N0. The received signal matrix are as follows

$$r = \begin{bmatrix} r(1) \\ r(2)* \end{bmatrix}$$

$$= \begin{bmatrix} h1 & h2 \\ h2* & -h1* \end{bmatrix} + \begin{bmatrix} n(1) \\ n(2)* \end{bmatrix} = Hd+n\ldots\ldots(11)$$

Similar to (8), the orthogonal channel matrix H is such that

$$H^H H$$

$$= \begin{bmatrix} \lfloor h1 \rfloor^2 + \lfloor h2 \rfloor^2 & 0 \\ 0 & \lfloor h1 \rfloor^2 + \lfloor h2 \rfloor^2 \end{bmatrix} \ldots\ldots\ldots(12)$$

The transmitted signal can be separated by pre-multiplying the received signal in (11) with H^H as given by

$$y = H^H r = \begin{bmatrix} \lfloor h1 \rfloor^2 + \lfloor h2 \rfloor^2 & 0 \\ 0 & \lfloor h1 \rfloor^2 + \lfloor h2 \rfloor^2 \end{bmatrix} d + H^H n$$

$$=(|h1^2| + |h2^2|d+\check{n}\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(13)$$

The modified noise ň is an AWGN with zero mean but with power equal to $|h1^2| + |h2^2|N_oI$.

Maximum likelihood (ML) symbol-by-symbol detection can be used to obtain the estimated data. The above analysis has shown that the Alamouti's STBC scheme achieves a rate of 1 (R=1) also called full rate convolution code as it transmits two symbols in two symbol periods.

3. Multi Carrier Code Division Multiple Access (MC-CDMA)

MC-CDMA [2,6,4] is a combination of system of OFDM and CDMA technologies. This technique allows the multiple users to access the wireless channel simultaneously by modulating and spreading their input data signals in frequency domain using different spreading sequences. MC-CDMA combines the multipath fading of OFDM with the multi-user access of CDMA.

1. 3.1 System Model of MC-CDMA

The MC-CDMA [4,10] system model for Nu users is shown in Figure 4. The message data are grouped into Nu frames and then each frame is modulated to P symbols. So the symbol matrix for user nu (nu = 1, 2,……..Nu) can be indicated as $dnu = [dnu,1 \quad dnu,2 \ \ldots\ldots\ldots\ldots\ldots \ dnu,P]^T € C^{P*1}$. The symbols of each user are converted firstly serial-to-parallel then spread with the corresponding specific user spreading sequence to form the chip-level transmit matrix i.e.

$snu = [s_{nu},1 \ s_{nu},2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots \ s_{nu},PG]$

$= d_{nu} \otimes c_{nu} \ € \ C^{1*PG}$ ………………..(14)

where $\otimes$ denotes the Kronecker product and the signature sequence of user nu is expressed as

$c_{nu} = [c_{nu,1} \ c_{nu,2} \ \ldots\ldots\ldots \ c_{nu,G}] \ € \ C^{1*G}$ ….(15)

in which C is the spreading code chip alphabet and G is the length of the spreading sequence. Each user is allocated by a distinct spreading code for orthogonality between the users to differentiate. The chips of the frames of each users are then combined and all parallel data sequences are mapped into Ns = P*G subcarriers and transformed into the time domain by the IFFT. The subcarrier is related to the p-th symbol (p = 1, 2,…………, P) and the g-th chip (g = 1,2,...,G) by

$i(p, g) = (p - 1)G + g$………………. (16)

It must be noted that the subcarrier index i, symbol index p, and chip index g are inter-connected together by (16). Therefore the corresponding symbol and chip indexes for i-th subcarrier are

$p(i) = (i - 1)\bmod G + 1$ ………………(17)

and

$g(i) = \lfloor (i-1)/G \rfloor + 1$…………………(18)

respectively where $\lfloor a \rfloor$ denotes the largest integer that is lesser than a. The transmitted i-th multiplexed chip of all users can be determined as

$x_i = \sum_{nu=1}^{N} sn_{u,}i = \sum_{nu=1}^{N} cn_u,g(i)dn_u,p(i)$…..(19)

The output from IFFT is added with CP before transmission over the wireless multipath fading channel. The channel is called as quasi-static frequency selective fading corrupted by AWGN with power spectral density of N0. The duration of CP is greater than the maximum delay spread of the channel to avoid ISI.

On receiving the signal, cyclic prefix is removed and the FFT of size Ns is performed. The received signal model after FFT can be characterized by

$r_i = Hixi + ni$………………………….(20)

The estimates of the transmitted chips of different subcarrier can be obtained by performing Zero Forcing equalization on each subcarrier as shown by

$y_i = H_i^{-1} r_i = H_i^{-1} H_i x_i + H_i^{-1} n_i = x_i + \check{n}_i$……….(21)

The chip estimates are then despreaded by the desired user's spreading sequence can be expressed as

$zn_u,p = \sum_{g=1}^{G} cn_{u,g} y(i) = dn_u,p + \sum_{g=1}^{G} cn_{u,g} \ \check{n}_i$…(22)

The probable p-th symbol detection for the nu-th user is performed by slicing znu,p using the quantization operation Q(.) with respect to the type of constellation in use

$\hat{d}nu,p = Q(znu,p)$ ………………………(23)

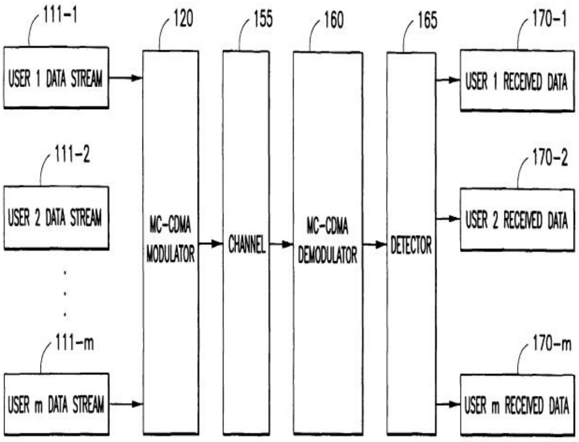

Figure 4: Multiuser MC-CDMA system.

4. MIMO-MC-CDMA Communication System Model

Communication system model of MIMO-MC-CDMA used in this paper is shown in fig.5.

In this communication system we assuming random input provided by user to system model so this data source is considered as random input source using MATLAB. Now due to CDMA system spreading of sequence is done using PN sequence generation so for this spreading of data, spreader is used. Now different modulation scheme is used like *QPSK, 8-PSK, 8-QAM, 16-QAM, 32-QAM and 64-QAM* this is shown by modulator block. Previously described system is MC-CDMA system which is already described in section 3.Multi–Carrier Code Division for Multiple Access (MC-CDMA) is used. Now MIMO encoder half-rate convolutionally encoded STBC block code is used which will be described in section 2.Multiple Input Multiple Output (MIMO). Above process complete transmitter by combination of MIMO and MC-CDMA forms MIMO-MC-CDMA using as shown in fig.5. Now signal is then transmitted through channel, here channel used is Rayleigh Fading Channel [9]. Now reverse process is done on receiver for recovery of transmitted signal and BER calculation is done for analysis of the system. In MIMO system two transmit antenna and two receive antenna is used. Zero-Forcing detection scheme is used at the receiver for detection of signal at the receiver. STBC block code is used at the transmitter as transmit diversity at the transmitter. Now results are compared through different above mentioned multiplexing techniques.

3. Simulation Results and Discussion:

Table 1 shows the simulated model parameters of MIMO-MC-CDMA [11,8,9,4] in 8-QAM and 64-QAM modulation technique.

Fig.6-9. shows performance analysis of MIMO-MC-CDMA in *QPSK*, *8-PSK*, *8-QAM*, *16-QAM*, *32-QAM and 64-QAM* modulation scheme, Table 2 shows the BER and gain comparison with 64-QAM from that we can depict that QPSK have very low BER and high gain as compared to all other modulation technique. This gain comparison is done in 2-dB SNR because at 3-dB BER of QPSK reaches to zero i.e high performance is achieved in QPSK. Fig. 10 shows MIMO-MC-CDMA in different modulation technique. So for 3G and 4G wireless communication if we want to improve system performance we use MIMO-MC-CDMA technique for getting high performance in QPSK modulation technique.

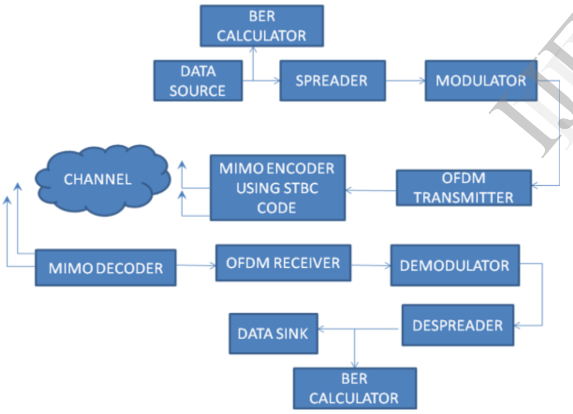

Fig.5. Communication System Model OF MIMO-MC-CDMA

Table:1. Summary of simulated model parameters.

No. of bits transmitted by user	1560
No. of transmitting and receiving antennas	2
Channel Encoder	½ rate convolution encoder
Modulation Schemes	8-QAM and 64 QAM
Signal detection scheme	Zero forcing
Channel	Rayleigh Fading Channel
Signal to Noise Ratio	-10dB to 20 dB
CP Length	1280
OFDM Sub-carriers	6400

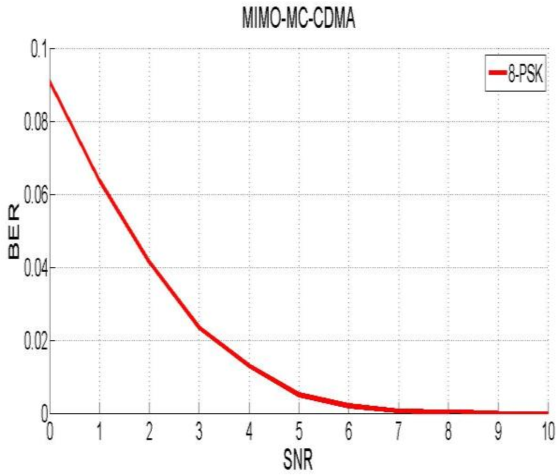

Fig.6. Performance analysis of MIMO-MC-CDMA in 8-PSK.

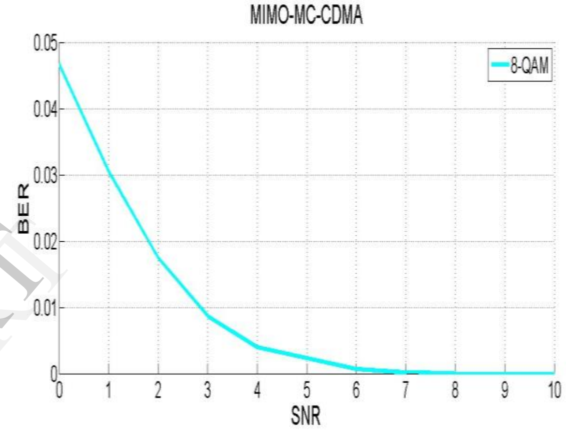

Fig.7. Performance analysis of MIMO-MC-CDMA in 8-QAM.

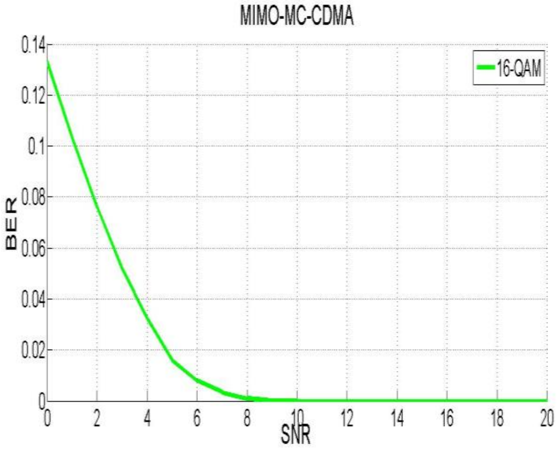

Fig.8. Performance analysis of MIMO-MC-CDMA in 16-QAM.

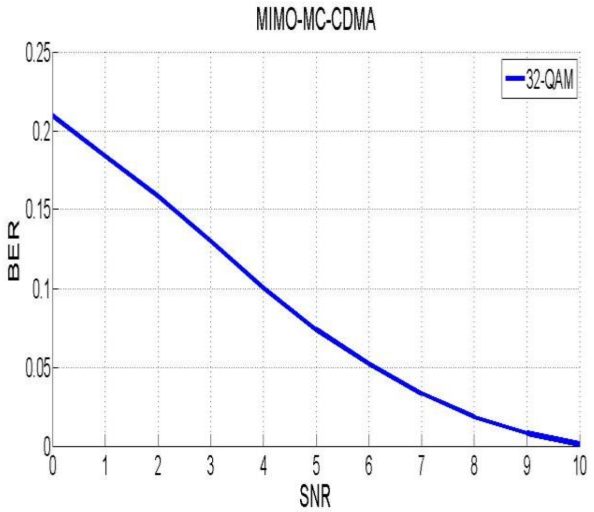

Fig.9. Performance analysis of MIMO-MC-CDMA in 32-QAM.

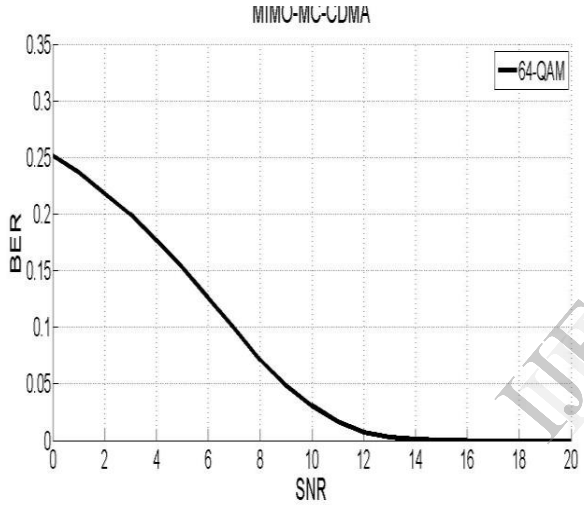

Fig.9. Performance analysis of MIMO-MC-CDMA in 64-QAM.

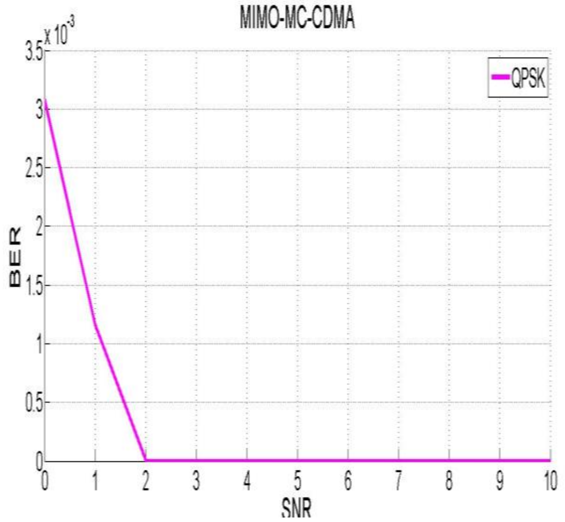

Fig.9. Performance analysis of MIMO-MC-CDMA in QPSK.

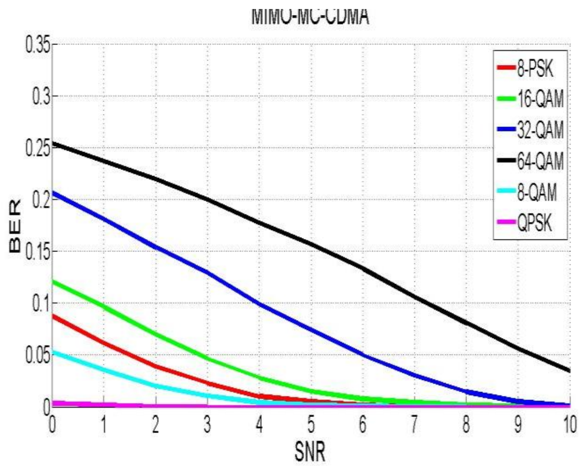

Fig.10. Performance analysis of MIMO-MC-CDMA in *QPSK, 8-PSK, 8-QAM, 16-QAM, 32-QAM and 64-QAM*.

Table 2: Performance analysis of MIMO-MC-CDMA in different modulation technique in terms of gain w.r.t 64-QAM with reference to fig.10 in 2dB SNR:

Modulation	BER	Gain w.r.t 64-QAM
QPSK	0.0003846	27.568dB
8-QAM	0.01987	10.43dB
8-PSK	0.03872	7.538dB
16-QAM	0.06971	4.98dB
32-QAM	0.1538	1.548dB
64-QAM	0.2197	0dB

3. Conclusion

Fig.10 shows the performance comparison of MIMO-MC-CDMA in different modulation technique and Table 2 shows the BER and gain of different modulation techniques w.r.t 64-QAM with SNR of 2dB. From table 2 and Fig.10 we can say that performance of MIMO-MC-CDMA usin QPSK modulation technique outperforms other modulation techniques with very low probability of error and high gain. So for 3G and 4G communication QPSK modulation technique is referred.

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