Performance Estimation of 2*2 MIMO-MC-CDMA Using Convolution Code in Different Modulation Technique

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ABSTRACT

*In this paper we estimate the performance of 2*2 MIMO-MC-CDMA system using convolution code in MATLAB which highly optimizes 3G and 4G wireless communication system by reducing BER. CDMA (Code Division for Multiple Access) is a multi-user system or spread spectrum system for which spreading of sequence is done by PN(Pseudo-random Noise) sequence generator at the transmitter and convolution encoding scheme is used in encoder of CDMA as FEC (Forward Error Correction) code to reduce BER (Bit Error Rate). Now this system is 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. This combination of system called 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 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 [3] ZF equalizer at transmitter is not required because MIMO-OFDM combination remove the probability of ISI at the transmitter. Resultant system with the combination of OFDM-CDMA and MIMO-OFDM forms MIMO-MC-CDMA which is highly optimized system for 3G and 4G wireless communication system. Now after forming MIMO-MC-CDMA using convolution code in MATLAB [1] we analyze system performance in different modulation schemes like, QPSK, 8-PSK, 8-QAM, 16-QAM, 32-QAM and 64-QAM in Rayleigh fading channel.*

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

1. Introduction

Due to increased demand of high data rate and low probability of error in this paper we utilizes the technique of MIMO, CDMA and OFDM results enhanced technique for minimum error rate. MC-CDMA is combination of CDMA and OFDM. 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 results improved efficiency of the wireless communication system which results high speed and low probability of error.

This experience is further improved by combination of MIMO with MCCDMA by which throughput of the wireless system is increased. MIMO is multiple antenna system in which multiple receive diversity and multiple transmit diversity is used for synchronization of system to reduce ISI. To minimize mean square error ZF equalizer is used. And for transmit diversity half-rate convolutionally encoded Alamouti STBC code is used. And finally combined MIMO-MC-CDMA [5] is formed by all above operations using MATLAB and this MIMO-MC-CDMA is then encoded using convolution code as encoder in MC-CDMA. This MIMO-MC-CDMA using convolution code then analyzed using QPSK, 8-QAM and 64-QAM modulation techniques.

1.1. OFDM System Model

Figure 1 represents the transceiver block diagram for the OFDM system[8]. In transmitter, the information bits are modulated by P symbols. Hence the symbol vector can be represented as,
$d = [d1\ d2\ \_\ \_\ \_\ dP\ ]^T \in C^{P*1}$ …………..…(1)
where C designate a set of complex numbers. The symbols are serial-to-parallel (S/P) converted and then mapped into Ns parallel orthogonal sub-carriers and transformed into the time domain by the inverse Fast Fourier transform (IFFT). Then the output of samples of the IFFT are parallel-to-serial (P/S) converted to form the baseband signal then cyclic prefix (CP) is added before transmission over the multipath radio channel.
Cyclic prefix is added to the transmitted signal in order to reduce ISI which arises between OFDM symbols from large multipath delay spreads. Cyclic Prefix is nothing but a cyclically extended guard interval, where each OFDM symbol is precede by a periodic extension. The total symbol duration is
$Ttotal = Tg + Td$…………………………(2)
where Tg is the guard interval and Td is the symbol duration. If the guard interval is longer than the multipath delay then ISI can be avoided. Cyclic prefix converts the linear convolution into a cyclic convolution. That is the multipath fading effect on the transmitted symbols is reduced to an element-wise multiplication between the transmitted data constellations d with the channel frequency response H.
The frequency response of the channel is known by the Fourier Transform (FT) of the channel impulse response h. As a result, the orthogonality of the Sub-carriers is improved. The channel is considered to be frequency selective fading corrupted by additive white Gaussian noise (AWGN).
The received signal model after the FFT at i-th subcarrier, can be characterised as
$ri = Hidi + ni$ ……………………………...(3)
where Hi represents fading coefficient of the channel and ni noise signal at the i-th subcarrier.
Frequency response at the i-th subcarrier (i =1, 2, ……..Ns) is calculated by
$Hi = \sum_{l=0}^{L-1} (h(l) \exp(-j2\pi i r1 / Ns))$……….(4)
where r1 is the path arrival time normalized to the OFDM sub-carrier spacing, such that r1Td is the delay and 1/Td is the OFDM subcarrier spacing. Equation (4) represents the path arrival time can be any positive real number. This shows the realistic channel environments.

Figure 1: OFDM system block diagram.

On receiving the signal, the CP is removed and the Fast Fourier transform of Ns size is performed.
The estimates of the transmitted symbol are obtained by performing zero forcing (ZF) equalization on each subcarrier and which is given by
$yi = H_i^{-1} r_i$
$= H_i^{-1} h_i d_i + H_i^{-1} n_i = d_i + \check{n}_i$………………(5)
where H_i^{-1} denotes the inverse of Hi. In general, equalization techniques are used to reduce ISI created in frequency selective channels.

1.2.Direct Sequence Code Division Multiple Access (DS-CDMA)

Direct sequence code division multiple access (DS-CDMA) employ direct sequence spread spectrum (DSSS) technique to permit multiple users sharing the same bandwidth at the same time. DSSS spreads the arriving data stream with a pseudo-random (PN) code over a bandwidth much larger than the signal bandwidth. So, the transmit power remains constant and the bandwidth of the spreading signal is large, the power spectral density of the transmitted signal below the noise power spectral density.
The user to detect own transmitted data to ensure secure communications. The transceiver of a DS-CDMA system for a single user is shown in Fig.2.
Consider P no. of BPSK modulated symbols with a symbol rate of $Rd = 1/T_d$ represented by
$d = [d1\ d2$ ………… $dP]^T \in C^{P*1}$ ……….(6)
In transmitter, the symbols are spreaded by wideband PN spreading code to figure the transmitted baseband signal as
$x = dc$ …………………………………..(7)
where $c = [c1\ c2$ ………… $cG] \in C^{1*G}$ is the PN spreading sequence with chip rate $Rc = 1/Tc$ and G is the length of the spreading code. The bandwidth

of the spreading sequence, $Bc \approx 1/Tc$, is approximately Td/Tc times greater than the bandwidth of the input symbols Bd. The spreading factor of the system is given by SF=Bc/Bd = Td/Tc which is equal to G. The baseband signal now transmitted over the AWGN channel and the received baseband signal after demodulation is given by

$r = dc + n$ ………………………………...(8)

where n is the noise vector. The symbol decision statistic is generated by despreading the received signal with the PN spreading sequence. This is given by

$D= rc^T$ ……………………………..……..(9)

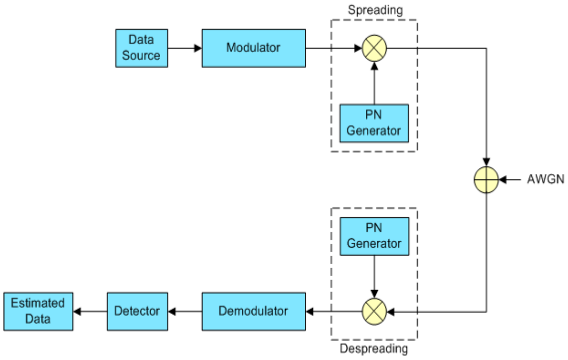

Figure 2: Block diagram of DS-CDMA system.

1.3 Multi Carrier Code Division Multiple Access (MC-CDMA)

MC-CDMA [2,6,7] 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 3. 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 $dnu =[dnu,1\ \ dnu,2\ \ldots\ldots\ldots\ldots\ dnu,P]^T € C^{P*1}$. 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.

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

$= d_{nu} \otimes c_{nu}\ € C^{1*PG}$ ……………………..(10)

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

$c_{nu} =[c_{nu,1}\ c_{nu,2} \ldots\ldots\ c_{nu,G}] € C^{1*G}$ ……..(11)

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

$i(p, g) = (p - 1)G + g$……………………. (12)

It must be noted that the subcarrier index i, symbol index p, and chip index g are inter-connected together by (12). Therefore the corresponding symbol and chip indexes for i-th subcarrier are

$p(i) = (i - 1)\mathrm{mod}G + 1$ …………………(13)

and

$g(i) =\lfloor (i-1)/G \rfloor+1$……………………(14)

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

$x_i =\sum_{nu=1}^{N} sn_u,i=\sum_{nu=1}^{N} cn_u,g(i)dn_u,p(i)$…(15)

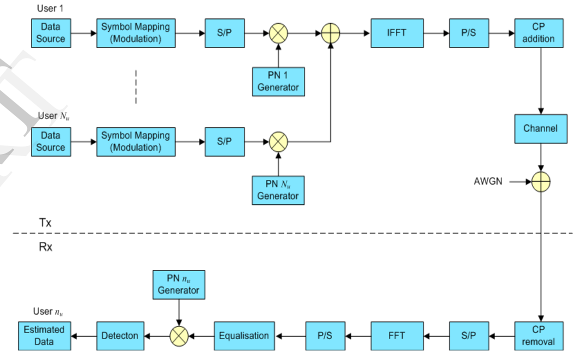

Figure 3: Multiuser MC-CDMA system.

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

$r_i= Hixi + ni$…………………….. ….(16)

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

$y_i=H_i^{-1}r_i=H_i^{-1}H_ix_i+H_i^{-1}n_i=x_i+\check{n}_i$…………..(17)

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

$zn_u,p = \sum_{g=1}^{G} cn_{u,g}y(i)=dn_u,p+ \sum_{g=1}^{G} cn_{u,g}\ \check{n}_i$..(18)

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

$d^{\wedge}nu,p = Q(znu,p)$ …………………….. (19)

1.4. 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 four transmit (Nt = 4) and four receive (Nr = 4) antennas is shown in Figure 4.

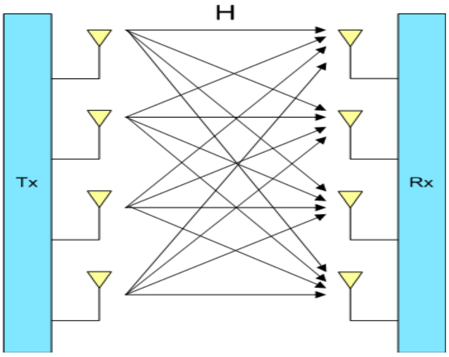

Figure 4: 4x4 MIMO channel.

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} …………………….…………..(20)

The channel model in (20) can be simplified to equation can be represented as

$r = Hd + n$ ……………………….……..(21)

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.

1.4.1 Spatial Multiplexing

Figure 5 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

$d = [d1\ d2$ ………….. $dNt]^T$ € C^{Nr*1} ………..(22)

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.

1.4.1.1 Linear Detection (Nulling)

Spatial interference can be suppressed by Linear filtering (or nulling) which arises when multiple antennas transmit multiple sub streams 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

$GZF = H^+ = (H^HH)^{-1}H^H$ ………………...(23)

$GMMSE =[H^HH + N0INt]^{-1} H^H$ ………..(24)

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

$y = Gr = Gd + Gn$ ……………………….…...(25)

where G represents the ZF or MMSE spatial suppression matrix given by (23) or (24) respectively.

1.4.2 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 Fig.6.

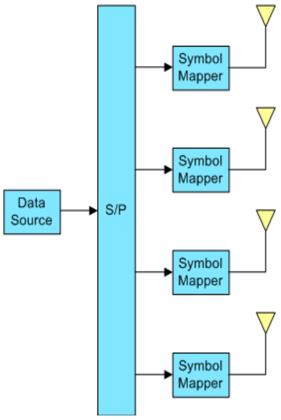

Figure 5: Spatial multiplexing architecture.

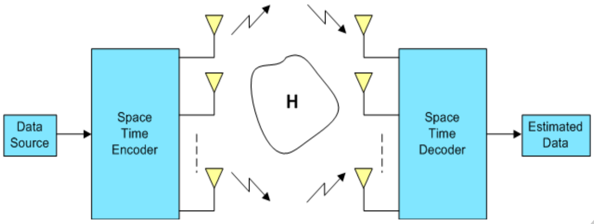

Figure 6: Space-time coding (STC).

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.

1.4.2.1 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

$$D = \begin{bmatrix} d0 & d1 \\ -d1* & d0* \end{bmatrix} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(26)$$

The transmission matrix is orthogonal i.e.

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

$$=(|d0|^2+|d1|^2)I \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(27)$$

The first and second received signals are given by

$r(1) = h1d0 + h2d1 + n(1)$……..….. ……(28)

$r(2) = -h1d1^* + h2d0^* + n(2)$…….........(29)

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

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

$$= \begin{bmatrix} h1 & h2 \\ h2* & -h1* \end{bmatrix} + \begin{bmatrix} n(1) \\ n(2)* \end{bmatrix} = Hd+n \ldots\ldots(30)$$

Similar to (27), the orthogonal channel matrix H is such that

$$H^H H$$

$$= \begin{bmatrix} \lfloor h1 \rfloor^2 + \lfloor h2 \rfloor^2 & 0 \\ 0 & \lfloor h1 \rfloor^2 + \lfloor h2 \rfloor^2 \end{bmatrix} \ldots\ldots(31)$$

The transmitted signal can be separated by pre-multiplying the received signal in (30) with H^H as given by

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

$$=(|h1^2| + |h2^2| d + \check{n} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(32)$$

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

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.

2. MIMO-MC-CDMA Communication System Model

Communication system model of MIMO-MC-CDMA using convolution code used in this paper is shown in fig.7.

In this communication system we assuming random input provided by user to system model so this data source is considered as random input source through MATLAB. Now convolution encoding is done as FEC (Forward Error Correction) technique to reduce error probability. 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-QAM and 64-QAM this is shown by modulator block. Previously described system is CDMA system which is already described in section 1.2 Direct Sequence Code Division Multiple Access (DS-CDMA) now OFDM transmitter is used which is described in detail on section 1.1.OFDM System Model. Now MIMO encoder half- rate convolutionally encoded STBC block code is used which will be described in section 1.4 Multiple Input Multiple Output (MIMO). Above process complete transmitter of MIMO-MC-CDMA using convolution code as shown in fig.7. 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.

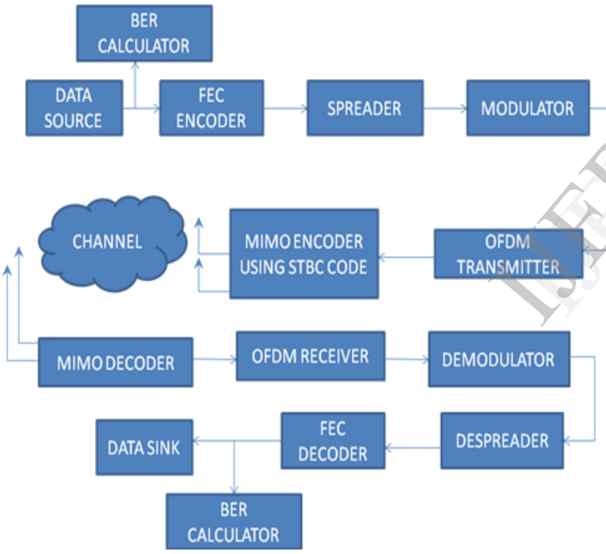

Fig.7. Communication System Model OF MIMO-MC-CDMA using convolution code

3. Simulation Results and Discussion:

Table 1 shows the simulated model parameters of MIMO-MC-CDMA [11-14] using convolution code in QPSK, 8-PSK, 8-QAM, 16-QAM, 32-QAM and 64 QAM modulation technique.

Performance analysis of MIMO-MC-CDMA using convolution code in above described modulation scheme is shown in fig.8-13.

Fig. 14 shows the comparative analysis of all above modulation schemes in MIMO-MC-CDMA using convolution code.

Table 2 shows the performance analysis of all modulation schemes in terms of BER and gain.

From table.2 and Fig.14 we can say that QPSK shows high gain (18.28dB) with respect to other modulation schemes and also have very low bit error rate w.r.t other modulation techniques. This is possible by using convolution code as encoding scheme in MIMO-MC-CDMA.

Table:1. Summary of simulated model parameters.

No. of bits transmitted by user	1560
No. of transmitting and receiving antennas	2*2
FEC Encoder	Convolution encoder
Channel Encoder	½ rate convolution encoder
Modulation Schemes	QPSK, 8-PSK, 8-QAM, 16-QAM, 32-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

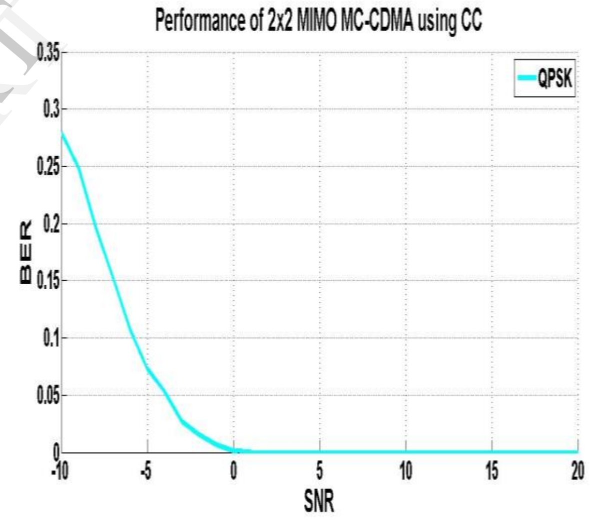

Fig.8. Performance analysis of MIMO-MC-CDMA using convolution code in QPSK modulation scheme.

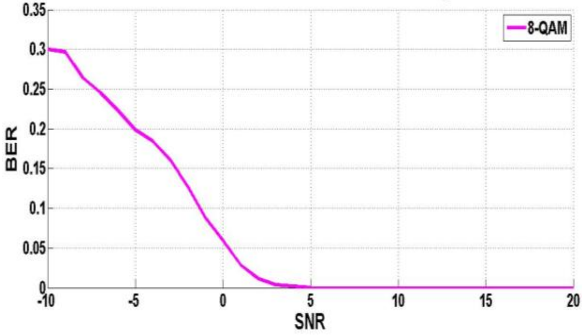

Fig.9. Performance analysis of MIMO-MC-CDMA using convolution code in 8-QAM modulation scheme.

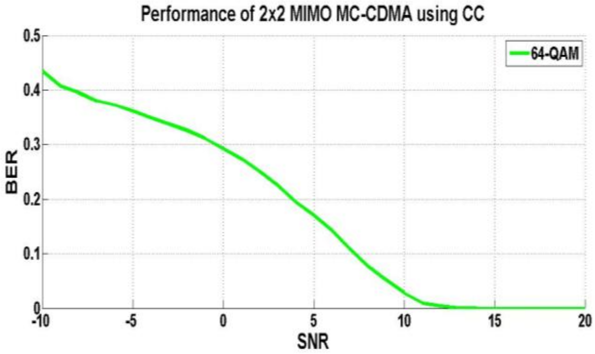

Fig.10. Performance analysis of MIMO-MC-CDMA using convolution code in 64-QAM modulation scheme.

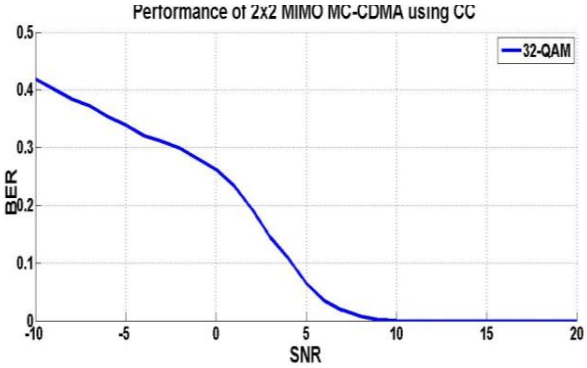

Fig.11. Performance analysis of MIMO-MC-CDMA using convolution code in 32-QAM modulation

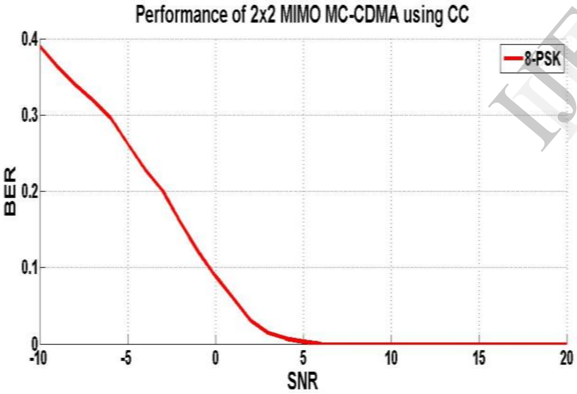

Fig.12. Performance analysis of MIMO-MC-CDMA using convolution code in 8-PSK modulation

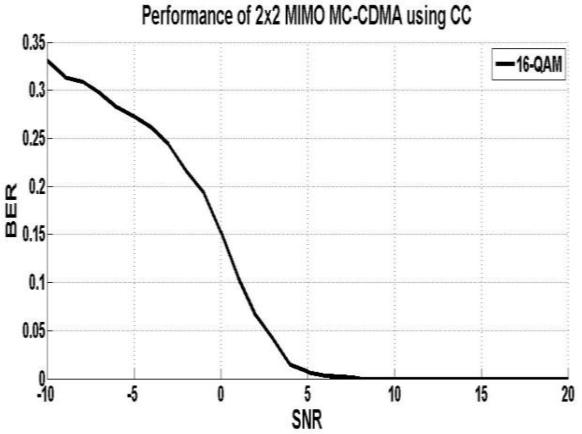

Fig.13. Performance analysis of MIMO-MC-CDMA using convolution code in 16-QAM modulation

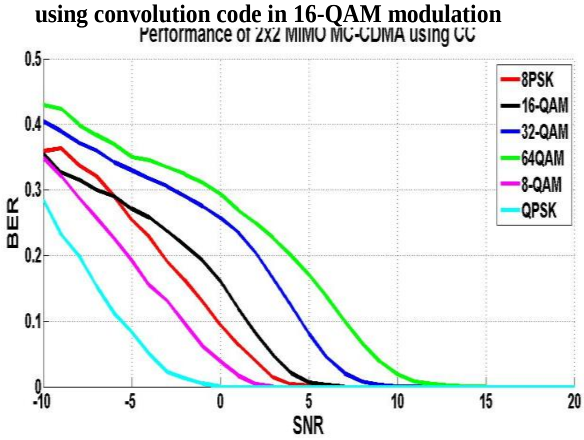

Fig.14. Performance analysis of MIMO-MC-CDMA using convolution code in 8-QAM, 16-QAM, 32-QAM, 64-QAM, 8-PSK and QPSK modulation scheme.

Table: 2. Performance analysis at -1dB SNR with respect to 64-QAM modulation technique as shown in fig.14:

Modulation	BER at -1dB	Gain w.r.t 64-QAM
QPSK	0.004615	18.28 dB
8-QAM	0.06128	7.05 dB
8-PSK	0.1292	3.812 dB
16-QAM	0.1917	2.09 dB
32-QAM	0.2749	0.533 dB
64-QAM	0.3108	0 dB

3. Conclusion

Fig. 14 shows the comparative analysis of MIMO-MC-CDMA using convolution code in QPSK, 8-PSK, 8-QAM, 16-QAM, 32-QAM and 64 QAM modulation schemes. Table 2 shows the comparative analysis of different modulation schemes by which we can say that as modulation scheme order is lower results increase in BER. This paper aims to reduce bit error rate as reduced effectively in QPSK modulation scheme with gain of 18.28 dB with respect to 64-QAM which shows the gain of QPSK is higher as compared to other modulation technique with very low probability of error because errors were removed at 0dB in QPSK.

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