Interference cancellation in MC-CDMA by adopting Blind Equalization for wireless communication systems

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Abstract— The increasing demand for wireless services has created the need for cost effective transmission techniques that can exploit scarce spectral resources efficiently .In order to achieve the high bit rates needed to meet the quality of service requirements of future multimedia applications, MC-CDMA has been considered as good air-interface candidate. However, the user capacity of MC-CDMA system is essentially limited by interference. This interference can be mitigated by employing precoding techniques; Blind Equalization based receivers and efficient interference suppression techniques. In the proposed system, combined Iterative IA precoding at the transmitter with Blind Equalization based processing at the receiver is suggested for MC-CDMA systems. Conventional equalizations minimizing mean square error generally require a training sequence accompanying the data sequence. Considering the fact that blind equalizers do not require pilot signals to recover the transmitted data.The constant modulus algorithm (CMA) is one widely used algorithm for blind equalization of QAM signals.Our scheme achieves the maximum degree of freedom provided by the IA precoding,with performance close to matched filter bound (MFB).

Index Terms— Blind Equalization, CMA, Interference alignment, MC-CDMA systems.

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1 INTRODUCTION

Multiple access techniques allow large number of mobile users to share the allocated spectrum in the most efficient manner [5]. As the spectrum is limited, the sharing is required the increase the capacity of a cell or over a geographical area by allowing the available bandwidth to be used at the same time by different users and this must be done in such a way that quality of service doesn't degrade within the existing users. Spread Spectrum Multiple Access (SSMA) uses signals which have transmission bandwidth whose magnitude is greater than the minimum required bandwidth. A Pseudo Noise (PN) sequence converts a narrow band signal to a wide band noise like signal before transmission.

Code division multiple access (CDMA) is a channel access method used by various radio communication technologies [6], [9]. CDMA is a multiple access scheme, where several transmitters can send information simultaneously over a single communication channel. This allows several users to share a band of frequencies. For avoiding undue interference between the users, CDMA employs spread-spectrum technology and a special coding scheme where each transmitter is assigned a code.

In OFDM a large number of closely spaced orthogonal sub-carrier signals are used to carry data on several parallel data streams or channels. Each sub-carrier is modulated with a conventional modulation scheme such as Quadrature Amplitude Modulation (QAM) or Phase-Shift Keying (PSK) at a low symbol rate, maintaining total data rates similar to conventional single-carrier modulation schemes in the same bandwidth [11].

In order to achieve the high bit rates needed to meet the quality of service requirements of future multimedia applications, Multi-Carrier Code Division Multiple Access (MC-CDMA) has been considered as good air-interface candidate. This scheme combines efficiently OFDM and CDMA [14]. MC-CDMA spreads each user symbol in the frequency domain. Each user symbol is carried over multiple parallel subcarriers, and it is phase shifted according to a code value. The code values differ per subcarrier and per user. The receiver combines all subcarrier signals, by weighing these to compensate varying signal strengths and undo the code shift. The receiver can separate signals of different users, because these have different code values. In the downlink, that is one base station transmitting to one or more terminals, the MC-CDMA typically reduces to Multi-Carrier Code Division Multiplexing [11]. All user signals can easily be synchronized, and all signals on one subcarrier experience the same radio channel properties.

The equalizer is the most expensive component of a data demodulator and can consume over 80% of the total computations needed to demodulate a given signal [2]. In the blind method of equalization, where the desired signal or training sequence is not available, some statistical property (mean, varience, Kurtosis) of the signal is used for the determination of the instantaneous error. This instantaneous error is then used for updating the adaptive filter coefficient vector.

The most commonly used adaptive algorithm for blind-channel equalization is the Constant Modulus Algorithm (CMA), which uses the constant modularity of the signal as the desired property. CMA assumes that the input to the channel is a modulated signal that has constant amplitude at every instant in time [2]. Any deviation of the received signal amplitude from the constant value is considered a distortion introduced by the channel. The distortion is mainly caused by band-limiting or multi-path effects in the channel. Both these

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effects result in inter-symbol interference (ISI) and thus distort the received signal. The objective of equalization is to remove the effect of the channel from the received signal. CMA attempts to accomplish this objective by forcing the output of the adaptive filter (equalizer) to be of constant amplitude. CMA can also be used for QAM signals where the amplitude of the modulated signal is not the same at every instant.

2 PROPOSED WORK

MIMO MC-CDMA systems with iterative IA precoding at transmitter and iterative frequency domain receivers based on the blind equalization concept is considered. IA based techniques achieve the maximum DoF in MIMO interference channels. However, they cannot efficiently exploit the space-frequency diversity.

Many algorithms have been proposed during the past few decades however due to its simplicity, good performance and robustness the constant-modulus algorithm (CMA) is most often used in practice. Maybe the most prominent disadvantage of CMA is its slow convergence [2]. The traditional LMS algorithm also suffers from slow convergence as well. Although in practice the improved Normalized LMS (NLMS) is used, which usually converges many times faster than the LMS algorithm at the cost of only a few extra computations per update.

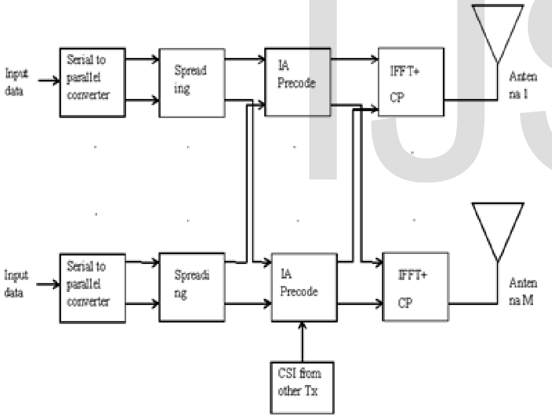

Fig.1.Block Diagram of Proposed MC-CDMA transmitter.

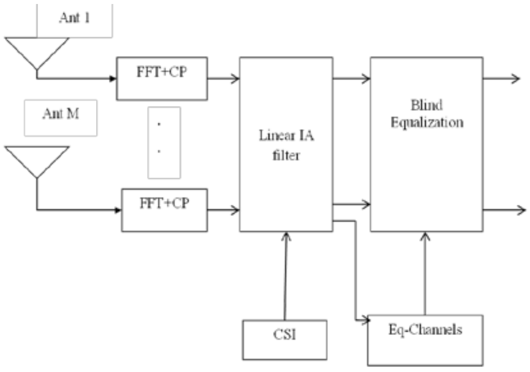

Fig.2.Block Diagram of Proposed MC-CDMA receiver.

2.1 System Model

A K-user MIMO interference channel with constant coefficients on a per-subcarrier basis is considered. It comprises K transmitter -receiver pairs sharing the same physical channel, where a given transmitter only intends to have its P_k spatial data symbols on each subcarrier decoded by a single receiver. Consider a symmetric case where all transmitters and receivers have M antennas, and $P_k = P \forall k,$ which is denoted by an (M, M, K) interference channel with P data symbols per subcarrier. It has been shown that for $K \leq 3,$ the number of spatial DoF achievable in an(M, M, K) interference channel is $KM/2$, while for$K > 3$, the overall spatial DoF achievable is only $,P_t = \sum_{k=1}^{K} P_k > 2M - 1$. As can be seen, each one of the *P* *L*-length data symbols blocks$\{s_{k,p,l}; p = 1,..P, l = 0, ...L-1\}$, where the constellation symbol $d_{k,p,l}$ is selected from the data according to given mapping rule, is spread into *L* chips using orthogonal Walsh-Hadamard codes, leading to the block $\{s_{k,p,l}; p = 1,..P, l = 0, ...L-1\}$. Then, a set of *P* chips (one of each block) is weighted by an IA-precoding matrix. Note that here the IA-precoding is applied on a chip level instead of data level as in the conventional IA systems. The signal after the IA precoding at the *k*th transmitter subcarrier *l* can be written as

$$X_{k,l} = W_{k,l}s_{k,l} \qquad (1)$$

Where $W_{k,l} \in C^{M \times P}$ is the linear precoding matrix computed at the *k*th transmitter on subcarrier *l*, constrained to $\|W_{k,l}\|_F^2 \leq T_p$ and T_p is the transmit power .The received frequency-domain signal (i.e., after cyclic prefix removal and FFT operation) for the kth receiver and the *l*th subcarrier is given by,

$$y_{k,l} = H_{k,k,l}W_{k,l}s_{k,l} + \sum_{i=1}^{K} H_{k,i,l}W_{i,l}s_{i,l} + n_{k,l} \qquad (2)$$

The size $M \times M$ matrix

$$H_{k,i,l} = \sqrt{\alpha_{k,i}}H_{k,i,l}^{(iid)} \qquad (3)$$

denotes the overall channel between the transmitter *j* and receiver *k* on subcarrier *l*, where $H_{k,i,l}^{(iid)}$ contains the fast fading coefficients which is assumed to have i.i.d *CN* (0, 1) entries independent, identically distributed complex normal random variables. $\alpha_{k,i}$ is the long term channel power on the same link.$n_{k,l}$ is the additive white Gaussian noise (AWGN) vector at receiver *k* on subcarrier *l*.

2.2 Interference Leakage IA precoding Algorithm

The subspace, with orthonormal basis $\Phi_{k,l}$ and precoders are jointly designed to optimize an appropriate cost function. The global function to optimize is

$$s_{IL} = \sum_{k=1}^{K} \sum_{i=1}^{K} \|\Phi_{k,l}^{H} H_{k,i,l} W_{k,i,l}\|_F^2 \qquad (4)$$

This is usually denoted by IL.

A simple approach to solve this problem is to use an alternating minimization procedure. This algorithm takes the following iterative form:

1) Define an arbitrary orthogonal basis $\Phi_{k,l}$ or each receiver subspace on each subcarrier.

2) Find the precoder matrix $W_{i,l}$ such that each node has maximum squared Euclidean distance between it and the subspace spanned by the columns of each $\Phi_{k,l}$ by using

$$W_{i,l} = \mathcal{V}^{P}_{min}(H^{H}_{k,i,l}\Phi^{H}_{k,l}H_{k,i,l}) \quad (5)$$

3) Update the receiver orthonormal subspaces according to

$$\Phi_{k,l} = \mathcal{V}^{P}_{min}(H_{k,i,l}\Phi_{i,l}W^{H}_{i,l}H^{H}_{k,i,l}) \quad (6)$$

4) Repeat steps 2 and 3 until convergence. This can be carried out until $\Im_{IL}(t) < \varepsilon$ if feasibility conditions are met, or $\Im_{IL}(t-1) - \Im_{IL}(t) < \varepsilon$.Otherwise, for an arbitrary threshold ε.

2.3 Constant Modulous Algorithm

CMA is a stochastic gradient algorithm that minimizes the dispersion of the equalizer output around a circular contour. The CMA algorithm adapts filter coefficients at each time n in order to minimize the modulus error. This algorithm was developed to perform the interference reduction functions on constant-envelope signals. The constant envelope signals, information is contained purely in the phasor angle, while the modulus or instantaneous amplitude is fixed.CMA seeks to minimize the cost function. The channel out put is defined as x(k), depends on input a(k), noise n(k),

$$x(k)=\sum_{i=0}^{L-1} h(i)a(k-i)+n(k) \quad (7)$$

The equalizer out put is $y(k) = W^{H}(k)x(k)'$ (8)

$$W(k) = [w_0(k)w_1(k)\ldots w_{N-1}(k)]^{T}] \quad (9)$$

$$X(k) = x(k), x(k-1) \ldots, x(k-N+1)^{T} \quad (10)$$

The cost function of CMA is defined as

$$J(k) = E[(|y(k)|^2 - R_2)^2] \quad (11)$$

The error signal is given by,

$$e(k) = y(k)(|y(k)|^2 - R_2) \quad (12)$$

The update of tap weights vector can be written as

$$W(k+1) = W(k) - \mu.e(k).X^{*}(k) \quad (13)$$

Where μ is step size parameter.

2.4 The LMS Algorithm

The LMS Algorithm is a developed form of steepest descent adaptive filter, in the family of stochastic gradient algorithms, which has a weight vector update equation given by,

$$w_{n+1} = w_n + \mu e(n)x^{*}(n) \quad (14)$$

The update equation fot the kth coefficient is given by,

$$w_{n+1}(k) = w_n(k) + \mu e(n)x^{*}(n-k) \quad (15)$$

2.5 Proposed CMA

A combination of blind equalization and LMS algorithm is proposed. The strengths of blind equalization i.e, equalization without training sequence and effective utilization of the bandwidth and the strengths of LMS algorithm i.e., good convergence of data are used together to get better results. The CMA module is designed to work in blind mode and the LMS works in the Decision-Directed mode (DD mode). Initially, the received signal is fed to the blind equalizer and cost function is monitored.When the cost function or the error function reduces below a threshold value, the input is connected to the Decision-Directed mode. The combination is shown in the following figure

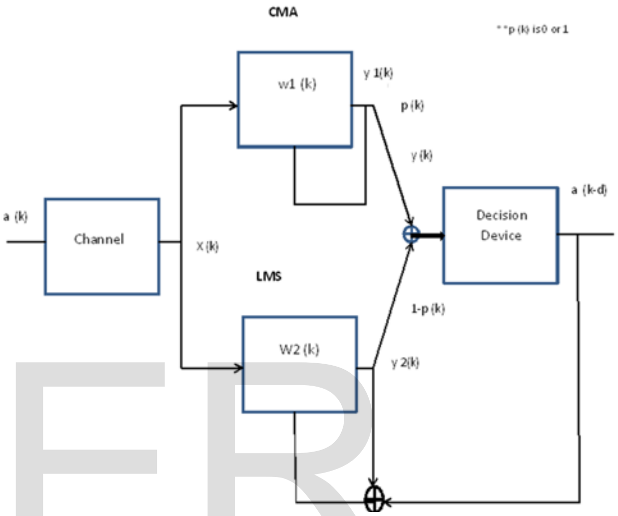

Fig.3.Block diagram of Proposed CMA.

TABLE 1

SPECIFICATIONS FOR PROPOSED SYSTEM

Parameters	specification
Number of users	2
Number of transmitter receiver pairs	3
FFT length	1000
Number of antennas at receiver side	2
Number of antennas at transmitter side	2

3 SIMULATION RESULTS

Performance results are analyzed for the proposed receiver structure that is for IA precoding with blind equalizer.The specifications for the proposed system are shown in Table 1.

Input data were generated for user 1 and user 2. The number of bits for user1 is N=100, the number of bits considered for user 2 is M=100.The input data generated are shown in figure 4 and figure 5. Spreading is done for the generated data. Here spreading is done in the frequency domain. For the purpose of spreading Walsh Hadamard codes are used. The spread data for user 1 and user 2 are shown in figure 6 and figure 7.For converting spread data into OFDM signals, Inverse Fourier Transform (IFFT) need to be performed .Signals generated by IFFT for user1 and user 2 are shown in figure 8 and figure 9.

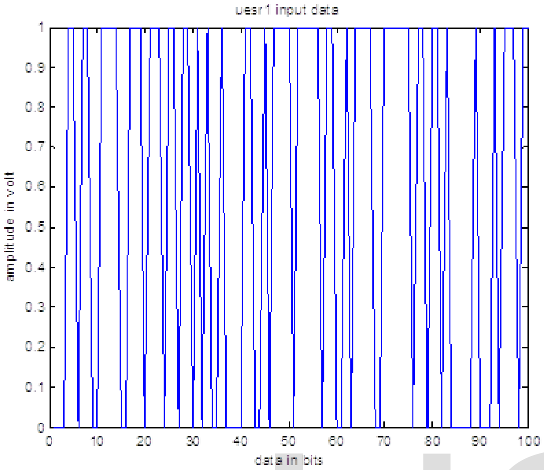

Fig. 4.Input data for user 1.

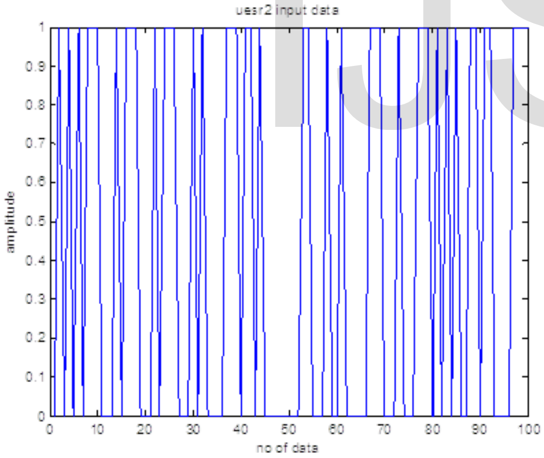

Fig. 5.Input data for user 2.

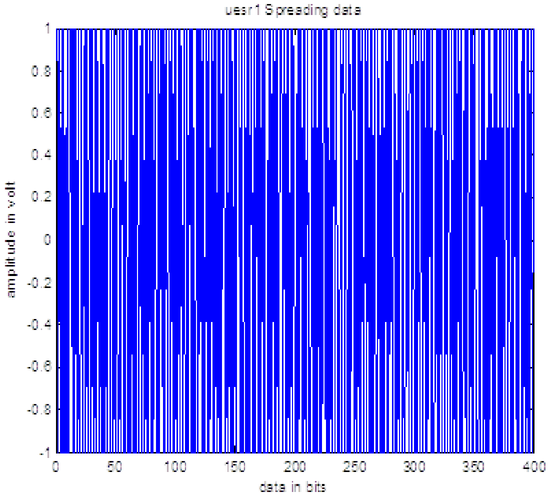

Fig. 6.Spread Data for user 1.

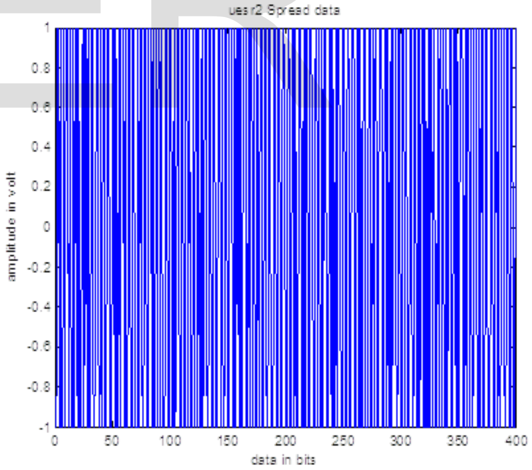

Fig. 7.Spread data for user 2.

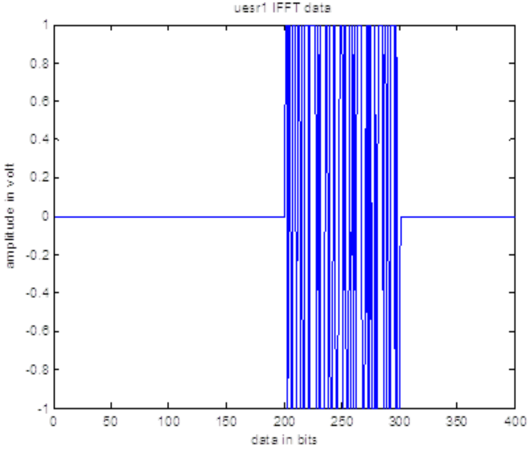

Fig. 8.IFFT on user 1.

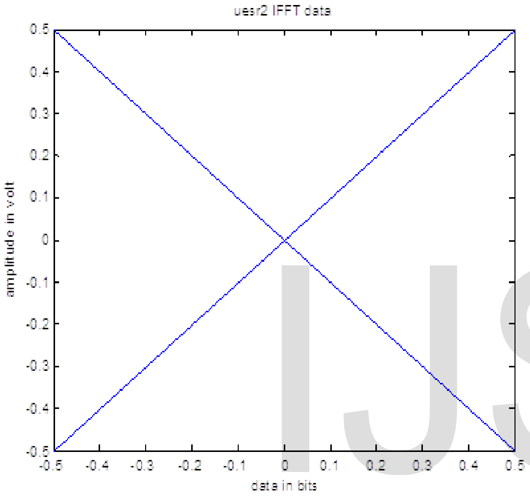

Fig. 9.IFFT on user 2.

The generated signals are combined and transmitted through the Additive White Gaussian Noise (AWGN) channel. The data transmission is shown in figure 10.

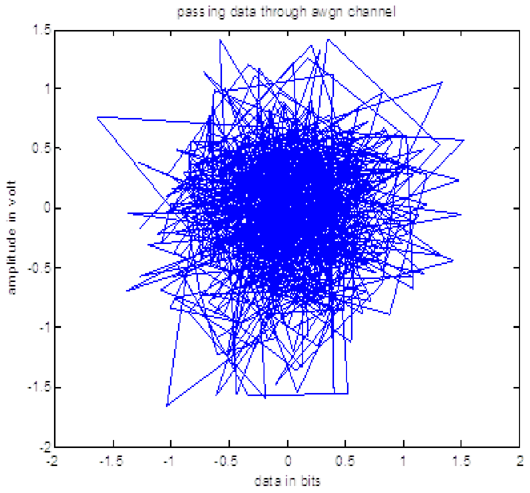

Fig. 10.Data transmission over AWGN

3.1 Performance Results for IA precoded MC-CDMA

The performance results are presented in terms of the average bit error rate (BER) as a function of E_b/N_0 with E_b denoting the average bit energy and N_0 denoting the one-sided noise power spectral density.

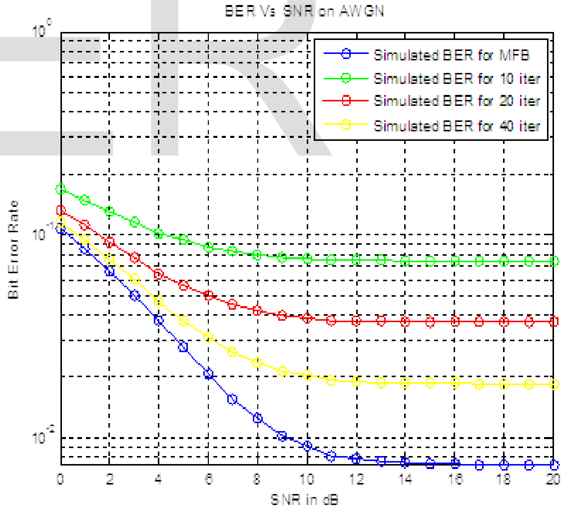

Fig. 11.Bit Error Rate verses SNR

It observes that the BER performance approaches the MFB after a few iterations (typically 10, 20 or 40 iterations). In this scenario the equalizer must deal with inter block interference, since 1000-length blocks are transmitted simultaneously by each transmitter. Therefore, the proposed scheme is quite efficient to separate the spatial streams with only a few iterations.

The performance of CMA compared with different iteration rates (10, 20, and 40) and also with MFB is depicted in figure 12 and figure 13.

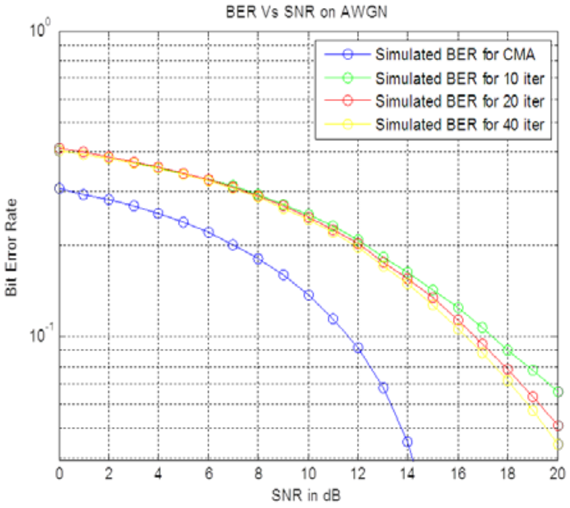

Fig. 12.Bit Error Rate verses SNR.

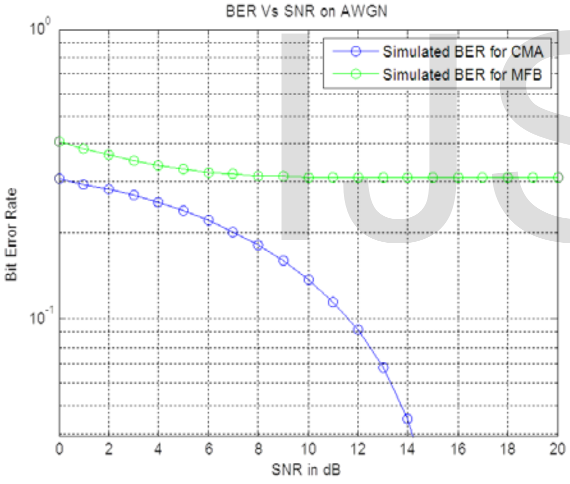

Fig. 13.Bit Error Rate verses SNR.

From the output plots it is well derived that the performance of CMA is much better than 10, 20, 40 iterations.Moreover the performance of CMA even overwhelms MFB.

4 APPLICATIONS

Blind equalizers are used in Micro-wave radio. They were realized in very large scale integration (VLSI) for high definition television (HDTV) set-top cable demodulators.The blind processing applications are emerging in wireless communication technology.

5 CONCLUSION

In the proposed system IA precoding is considered on a per subcarrier basis, at the transmitter with blind equalization based processing at the receiver for MIMO MC-CDMA systems. The proposed receiver structure was considered to mitigate the inter-user aligned interference, and then a blind equalizer was designed to efficiently separate the spatial streams.

Blind equalization is an emerging equalization techniquewhich helps in utilizing the bandwidth efficiently. But the challenges faced are slow convergence rate and stability.

Since efficient usage of bandwidth is very critical these days, researchers are coming up with new ways to overcome these challenges. By implementing the convex combination of adaptive algorithms and also by using the variable step-size, the performance of the equalizer is improved.

The performance analysis in terms of BER and SNR was obtained and was concluded that performance could be much enhanced by increasing the number of iterations and also by using CMA.

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