Performance Analysis of Global Search Algorithm Based Multiuser Detector for Multi Carrier Code Division Multiple Access System under Clipping Noise

[1]S. Sivanesskumar and [2]R. Sukanesh
[1]Department of Information Technology,
Anjalai Ammal Mahalingam Engineering College, Kovilvenni, Tamilnadu, India
[2]Department of Electronics and Communication Engineering,
Thiagarajar College of Engineering, Madurai, Tamil Nadu, India

Abstract: Problem statement: Multi Carrier Code Division Multiple Access (MC-CDMA), a promising technology for the 4G communication systems. The major limitation of MC-CDMA system is the Multiple Access Interference (MAI) which is due to near-far effect, frequency offset and nonlinear power amplification due to clipping noise. **Approach:** The performance of MC-CDMA under clipping noise using Global search algorithm based Multiuser detector in AWGN, Rayleigh and Rician channel is analyzed in this study. **Results:** The proposed method is simulated using BPSK modulation, Walsh spreading code, number of subcarriers 64 and number of users 16 and clipping noise. **Conclusion:** By simulation result, BER in AWGN channel outperforms other channels as SNR is increased. The performance of Rician fading channel is better than that of Rayleigh fading channel, because of the LOS path.

Key words: MC-CDMA system, clipping noise, Rayleigh fading channel, Rician channel, global search algorithm, Orthogonal Frequency Division Multiplexing (OFDM), Inter Symbol Interference (ISI), Partial Transmit Sequences (PTS), Bit Error Rate (BER), High Power Amplifiers (HPA)

INTRODUCTION

Wireless communications is an emerging field, which has seen enormous growth in the last several years. The spectacular growth of video, voice and data communication over the Internet and the equally rapid pervasion of mobile telephony, justifies great expectations for mobile multimedia. Due to this growth of multimedia communication, the users demanded high date rate communication systems in wireless environment where the spectral resource is scarce. To fulfill the requirements new technologies like Code Division Multiple Access and Orthogonal Frequency Division Multiplexing (OFDM) are few promising systems for the 4G communication standards (Yee and Linnartz, 1993; Sayadi *et al.*, 2009)

OFDM is a highly efficient method of data transmission which has very strong ability Against Multipath Interference (MAI) and Inter Symbol Interference (ISI). CDMA is one of multiple access method with large capacity and spreading gain.MC-CDMA is the combined technique of OFDM and CDMA exploits the advantages (Hara and Prasad, 1997).

One of the major disadvantages of MC-CDMA system based on OFDM is the high sensitivity to nonlinear amplification which requires large back-off in the transmitter amplifier makes it inefficient. On the other hand using low back-off leads to signal distortion which results performance degradation. When spread spectrum techniques are used with OFDM, the nonlinear amplification of the signal destroys the properties of spreading sequences (Costa *et al.*, 1999; Ochiai and Imai, 2002)

The simplest methods to reduce high Peak to Average Power Ratio (PAPR) of Multicarrier signals are signal cilpping and filtering before signal transmission. The effects of cilpping and filtering has been considered in (Li and Cimini, 1998).

In addition to clipping method, other methods like Successive clipping and filtering, Precoding, Partial Transmit Sequences (PTS) for PAPR reduction in MC-CDMA system are analyzed in (Ginige *et al.*, 2001; Kang *et al.*, 2005)

Corresponding Author: S. Sivanesskumar, Department of Information Technology, Anjalai Ammal Mahalingam Engineering College, Kovilvenni, Tamilnadu, India

In PTS method, parallel inputs to IFFT/FFT block are portioned into smaller parts and multiplied by sequences which are selected to reduce PAPR which produces multicarrier signal with low PAPR after IFFT/FFT process and transmitted.

In SLM method, before IFFT/FFT, the symbols are multiplied by random sequences and then one of the sequences with lowest PAPR value is chosen and transmitted. These two methods need side information in receiver to decode the received signal.

In the receiver side, iterative decoding and multiuser detection are combined to reduce clipping noise and multiple access interference. Silva and Dinis (2006) a MUD that performs joint detection, estimation and cancellation of nonlinear effects has been introduced.

The MC-CDMA system in presence of nonlinear distortion and MAI is dealt with MUD using Genetic algorithm has been considered in (Wei and Hanzo, 2004). In this study, Global search algorithm based MUD in AWGN, Rayleigh and Rician channels is implemented and Bit Error Rate (BER) is analyzed with respect to Signal to Noise Ratio (SNR).

MATERIALS AND METHODS

MC-CDMA system: The block diagram of the MC-CDMA system is shown in the Fig. 1.The serial data stream is mapped to data symbols with phase and amplitude modulation scheme and the resulting symbol is divided into a vector of N data symbols resulting parallel data symbols. The IFFT of the data symbols are computed and cyclic prefix is introduced as a guard interval whose length should exceed the maximum excess delay of the multipath radio channel. Due to the cyclic prefix the transmitted signal becomes periodic and the effect of time dispersive multipath channel becomes equivalent to a cyclic convolution discarding the guard interval at the receiver. Due to the properties of the cyclic convolution, the channel is limited to the multiplication of the transfer function, the Fourier transform of the channel impulse response. At the receiver side the reverse operation of the transmitter has been performed. The guard period is removed and then FFT of each symbol has been determined to find the original transmitted spectrum. By using the code sequences used at the spreading block of transmitter has been used at the despreading block of the receiver to obtain the original signal which was transmitted. The transmitted signal is given by:

$$S(t) = \sum_{m=-\infty}^{\infty} \sum_{n=0}^{N-1} D_m C_n e^{j2\Pi(f_c+F/T_b)t} p(t-nT_s) \qquad (1)$$

Where:

n = The time index
D_m = The spreading code of the mth user
T_s = The symbol duration
C_m = The transmitted data symbol of the nth subchannel
p = The no. of input symbol of one MCCDMA symbol for each user

In the MCCDMA receiver, after down conversion and removal of guard interval, the received data is converted in to a parallel symbol stream using a serial to parallel converter. Also the m-subcarrier component corresponding to the received data are detected with FFT and then multiplexed with the gain to combine the energy of the received signal scattered in the frequency domain. Finally after interleaving and dispreading the received data can be recovered. The received signal can be written as:

$$r(t) = \rho_n \sum_{m=-\infty}^{\infty} \sum_{n=0}^{N-1} D_m C_n e^{j2\Pi(f_c+F/T_b)t} p(t-nT_s) \qquad (2)$$

The detector for the MC-CDMA can be of two types, namely Single-User detector and Multi-User detector. The Single-User detector is usually an suboptimal detector having an equalizer and quantizer combination.

The equalizer of Single Tap zero forcing for example will lead to:

$$\overline{U}' = Er \qquad (3)$$

Where:

$$E_{l,l} = \frac{H_{l,l}^*}{|H_{l,l}|^2} \qquad (4)$$

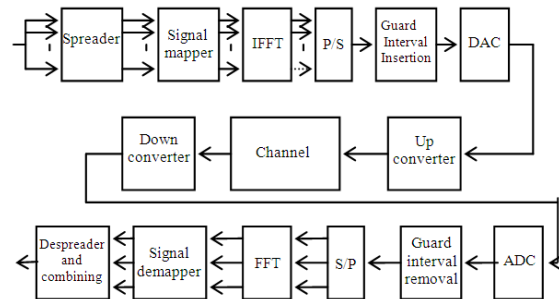$$\overline{U} = quantize(\overline{U}') \qquad (5)$$

Fig. 1: Block diagram of MC-CDMA transceiver

The Multi-User detection can be of optimal or suboptimal. In this study optimal detectors are considered and MLSE version of the optimal detector is formulated as below.

In MLSE, the received symbol is compared with all possible symbols from all users. The comparison is a Euclidean metric and the symbol which gives minimum value is considered as the transmitted one. For a symbol of size L and users K, the number of Euclidean distance calculation is L^K:

$$E_{se} = \| r - XU_L \|^2 \tag{6}$$

The optimal detectors are mandatory when there is a severe MAI due to the fading channel characteristics and clipping noise. The clipping noise effects has been studied in detail in (Hathi *et al*., 2002) and models to generate clipping noise effects has also been proposed.

Clipping noise effects: The OFDM uses High Power Amplifiers (HPA) which are usually non linear for achieving high efficiency. This amplifiers however does not have equal gain throughout the frequency range. This leads to clipping of few symbols and usually called as clipping noise . This makes OFDM to suffer from spectral spreading and In-Band distortion. This clipping noise reduces spectral efficiency and BER performance. One of the solution is using Golay Sequences for small number of users and Walsh Hadamard sequences for high number of users.

The modeling of the clipping effect on the OFDM signal is shown in (Fazel and Kaiser, 1998) for a distorting system with characteristics denoted as f(x). Let x(k) be the discrete OFDM signal in time domain which follows the complex Normal distribution with equal variance Px/2.. When this signal is passed through a clipping amplifier, the resultant will be of two components. One component will be the signal itself and the other is the distorted component. This can be shown in:

$$X_{clip}(k) = \alpha X(k) + n_d(k) \tag{7}$$

Alpha depends on the P_x and f(x). The clipped signal is:

$$X_{clip}(k) = \{X(k)\} \text{ when } |X(k) < A | \tag{8}$$

$$X_{clip}(k) = A^{\arg(X(k))} \text{ when } |X(k) \geq A | \tag{9}$$

The Input power BackOff (IBO) for such systems is given by:

$$IBO = \frac{A^2}{P_x} \tag{10}$$

This IBO is given usually in decibels and variation of the IBO changes the performance analysis in terms of BER.

Global Search algorithm multi user detector: MC-CDMA system performance is poor when there is a non linear distortion like clipping noise or when the channel characteristic are time dispersive. Under such situation optimum detection using Exhaustive Search method is only solution. However, Exhaustive Search method is computationally expensive and alternatives like Sphere In this study a new global optimization technique called Global Search (GS) algorithm is deployed (Ugray *et al*., 2007).

The main idea behind Global Search (GS) algorithm is to find starting points for gradient based local NLP solvers. OptQuest is a scatter search which is used to find the starting point for such gradient search algorithm. The combination of global optimization along with powerful local search makes this algorithm very effective. In this reference it has been proved that this algorithm is capable of solving complex optimization problem with linear and non linear constraints easily. The Scatter Search is an augmentation of GA where new population is generated in a deterministic way rather than the random way.

The most general problem this algorithm can solve has the form:

minimize f(x,y) (11)

Subject to the nonlinear constraints:

$$gl \leq G(x, y) \leq gu \tag{12}$$

the linear constraints:

$$l \leq A x + A y \leq u \, 1 \, 2 \tag{13}$$

$$x \in S , y \in Y \tag{14}$$

Where:
x = An n-dimensional vector of continuous decision variables
y = A p-dimensional vector of discrete decision variables and the vectors gl, gu, l and u contain upper and lower bounds for the nonlinear and linear constraints respectively

The matrices 1 A and 2 A are 2 m by n and 2 m by p respectively and contain the coefficients of any linear constraints. The set S is defined by simple bounds on x

and assume that it is closed and bounded, i.e., that each component of x has a finite upper and lower bound. This is required by the OptQuest scatter search procedure.

The set Y is assumed to be finite and is often the set of all p-dimensional binary or integer vectors y which satisfy finite bounds. The objective function f and the 1 m -dimensional vector of constraint functions G are assumed to have continuous first partial derivatives at all points in S×Y. This is necessary so that a gradient-based local NLP solver can be applied to the relaxed NLP sub-problems formed from (11-14) by allowing the y variables to be continuous

System performance: To analyze the system performance, we consider three channel models, such as AWGN, Rayleigh fading and Rician fading channel.

AWGN channel: This channel is assumed to corrupt the signal by the addition of white Gaussian noise n(t) which denotes a sample function of the Additive White Gaussian Noise (AWGN) process with zero mean and two sided power spectral density:

$$\Phi_n(f) = 0.5 \, N_0 \, \text{W/Hz} \tag{15}$$

Rayleigh fading channel: Depending on the surrounding environment, a transmitted radio signal usually, propagates through several different paths before it reaches the receiver. If there is no line-of-sight between the transmitter and the receiver the attenuation coefficients corresponding to different paths are often assumed to be independent and identically distributed in which path gain has uniformly distributed phase and Rayleigh distributed magnitude. In this channel, the transfer function assumed for the mth user can be represented as:

$$H_m(f_c + F/T_b) = \rho_{m,i} e^{j\theta_{m,i}} \tag{16}$$

where, $\rho_{m,i}$ and $\theta_{m,i}$ represents the random magnitude and phase of the channel of the user at the frequency f_c.

The random magnitude is assumed to be independent and identically distributed (iid) Rayleigh random variables in the interval for all users and subcarriers where the Rayleigh distribution is:

$$f(\rho_{m,i}) = \frac{\rho_{m,i}}{\sigma_{m,i}^2} e^{\frac{-\rho_{m,i}^2}{2\sigma_{m,i}^2}} \tag{17}$$

Table 1: Parameters of the simulated MC-CDMA system

Modulation scheme	BPSK
Spreading code	Walsh Hadamard
Number of Subcarriers	64
Number of users	16
Nonlinear Amplifier	Saleh, IBO= 0 dB
Equalization	Zero forcing

Rician fading channel: The model behind the Rician fading is same as Rayleigh fading except that in Rician fading a strong dominant component is present. This dominant component can be for instance LOS.

Refined Rician models also consider:

- That the dominant wave can be a phasor sum of two or more dominant signals, e.g., the line-of-sight, plus ground reflection. This combined signal is then mostly treated as a deterministic process
- That the dominant wave can also be subject to shadow attenuation. This is a popular assumption in the modeling of satellite channels

Besides the dominant component, the mobile antenna receives a large number of reflected and scattered waves. As there is line of sight component, the magnitude factor $\rho_{m,I}$ for i = 0,1,2…N-1 assume to have the following Rician distribution which is given by:

$$f(\rho_{m,i}) = \frac{\rho_{m,i}}{\sigma_{m,i}^2} e^{\frac{\rho_{m,i}^2 + b_0^2}{2\sigma_{m,i}^2}} \quad I_0(\frac{b_0 \rho_{m,i}}{\sigma_{m,i}^2}) \tag{18}$$

Where:
b = The line of sight component
I_0 = The ordered modified Bessel function which is given by:

$$I_0(x) = \sum_{k=0}^{\infty} \frac{(x/2)^{2k}}{kt\Gamma(k+1)} \quad \text{for} \, x \ge 0 \tag{19}$$

RESULTS

Table 1 shows the simulation parameters using MATLAB for the performance of the multicarrier code division multiple access system in a variety of channels, such as AWGN, Rayleigh fading and Rician fading channel, as a function of signal-to-noise ratio (SNR = T_b/N_0).

DISCUSSION

In Fig. 2, the MC-CDMA BER performance under AWGN. Rayleigh and Rician channels under clipping noise is shown and without clipping noise in AWGN channel is also shown for the comparison.
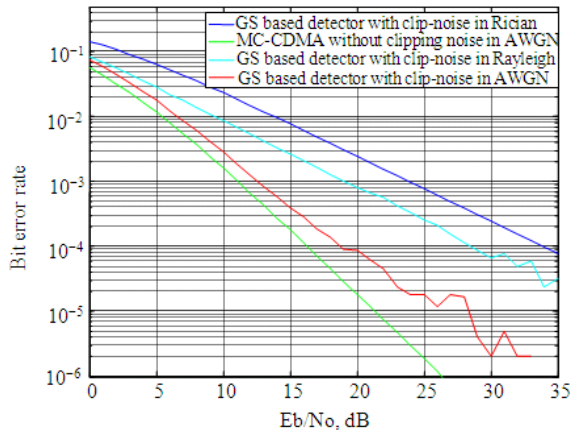
Fig. 2: Analysis of BER fora MC-CDMA under clipping noise for GS based detectors

The performance of MC-CDMA system would be affected by clipping noise introduced from the High power amplifier. The clipping noise causes significant spectral leakage(out of band interference) and degraded Bit error rate performance.

The operating point of HPA is defined by input backoff(IBO) parameter which corresponds to the ratio of saturated output power(Po) and the average input power(Pav) which is given by:

$$IBO = 10 \log_{10} (Po/Pav) \text{ dB} \qquad (20)$$

The normalized minimal signal to noise ratio is given by:

$$(SNR)o = 10 \log_{10} (Po \; Tb/ \; No) \text{ dB} \qquad (21)$$

which is needed to achieve the required BER. Tb is the equivalent duration of one information bit, No is the two sided spectral noise density and Po is the given reference power of HPA. The SNR can be minimized by optimization of HPA backoff.

The Fig. 2 also clearly indicates the necessity of MUD for the MC-CDMA system affected by the clipping noise and the proposed method considerably improves the BER performance of the clipped MC-CDMA system.

CONCLUSION

In this study the Global Search algorithm is used to assist Multi User Detection in MC-CDMA affected by fading and clipping noise. The simulations are done using MATLAB. It has been shown that the Global Search procedure is a suitable candidate for the MUD problem. The main limitation is lack of tuning the

algorithm and computational complexity comparison between existing algorithms.

The performance of MC-CDMA system under clipping noise using Global Search algorithm MUD in AWGN, Rayleigh fading and Rician fading channel is analyzed. By simulation result, BER in AWGN channel outperforms other channels as SNR is increased. The performance of Rician fading channel is better than that of Rayleigh fading channel, because of the LOS path. BER depends on the number of users and sub-carriers in Rayleigh fading and Rician fading channel.

REFERENCES

Costa, E., M. Midrio and S. Pupolin, 1999. Impact of amplifier nonlinearities on OFDM transmission system performance. IEEE Commun. Lett., 3: 37-39. DOI: 10.1109/4234.749355

Fazel, K. and S. Kaiser, 1998. Analysis of non-linear distortions on MC-CDMA. Proceedings of IEEE International Conference on Communications, Jun. 7-11, Atlanta, GA, USA., pp: 1028-1034. DOI: 10.1109/ICC.1998.685168

Ginige, T., N. Rajatheva and K.M. Ahmed, 2001. Dynamic spreading code selection method for papr reduction in ofdm-cdma systems with 4-qam modulation. IEEE Commun. Lett., 5: 408-410. DOI: 10.1109/4234.957377

Hara, S. and R. Prasad, 1997. Overview of multicarrier CDMA. IEEE Commun. Mag., 126-133. DOI: 10.1109/35.642841

Hathi, N., M. Rodrigues, I. Darwazeh and J. O'Reilly, 2002. Performance assessment of MC-CDMA and MC-DS-CDMA in the presence of High Power Amplifier Non-linearities. Proceedings of IEEE 55th Vehicular Technology Conference, (VTC'02), Electr. Eng., Univ. Coll. London, pp: 1467-1471. DOI: 10.1109/VTC.2002.1002860

Kang, K., S. Kim, D. Ahn and H.J. Lee, 2005. Efficient papr reduction scheme for satellite mc-cdma systems. IEE Proc. Commun., 152: 697-703. DOI: 10.1049/ip-com:20045159

Li, X. and L.J.J. Cimini, 1998. Effects of clipping and filtering on the performance of OFDM. IEEE Commun. Lett., 2: 131-133. DOI: 10.1109/4234.673657

Ochiai, H. and H. Imai, 2002. Performance analysis of deliberately clipped OFDM signals. IEEE Trans. Commun., 50: 89-101. DOI: 10.1109/26.975762

Sayadi, F., M. Ismail, N. Misran, K. Jumari and M. Abdullah, 2009. Efficient detection algorithm for a multiple-input and multiple-output multiuser multi-carrier code division multiple access in time-varying channels. Am. J. Eng. Applied Sci., 2: 635-642. DOI: 10.3844/ajeassp.2009.635.642

Silva, P. and R. Dinis, 2006. Joint multiuser detection and cancelation of nonlinear distortion effects for the uplink of MC-CDMA systems. Proceedings of the 17th Annual IEEE International symposium on Personal Indoor and Mobile Radio Communications, Sept. 11-14, IEEE Xplore, Helsinki, pp: 1-5. DOI: 10.1109/PIMRC.2006.254328

Ugray, Z., L. Lasdon, J. Plummer, F. Glover and J. Kelly *et al*., 2007. Scatter search and local NLP solvers: A multistart framework for global optimization. INFORMS J. Comput., 19: 328-340. DOI: 10.1287/ijoc.1060.0175

Wei, H. and L. Hanzo, 2004. Genetic algorithm assisted multiuser detection for asynchronous multicarrier CDMA IEEE VTC'04 (Fall). Los Angeles, USA., 3: 1914-1918. DOI: 10.1109/VETECF.2004.140037

Yee, N. and J.P. Linnartz, 1993. BER of multi-carrier CDMA in an indoor rician fading channel. Proceedings of the 27th Asilomar Conference on Signals, Systems and Computers, Nov. 1-3, IEEE Xplore, USA., pp: 426-430. DOI: 10.1109/ACSSC.1993.342548