GLOBAL SEARCH ALGORITHM BASED MULTIUSER DETECTORS FOR MC-CDMA SYSTEM UNDER CLIPPING NOISE AND RAYLEIGH FADING CHANNELS

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ABSTRACT

Multi Carrier Code Division Multiple Access (MC-CDMA), a promising technology for the 4G communication systems is considered in this paper. The foremost limitation of such system is the Multiple Access Interference (MAI) which is due to frequency-selective fading, near-far effect, frequency offset, and nonlinear power amplification. The performance of MC-CDMA under such scenario is poor and optimal detection is one of the solutions with a high complexity tag attached. Use of global optimization for such detectors, especially using Global Search algorithm is considered in this paper. The Bit Error Rate (BER) performance analysis is performed for frequency fading channels with and without non linear distortion.

Keywords: *MC-CDMA system, Multi User Detectors, Clipping Noise, Rayleigh fading channel, Global search algorithm*

1. INTRODUCTION

CDMA achieves soft capacity limit by using the same bandwidth all time by assigning different spreading codes to each user. The only limitation is the self interference and multi-user interference [1,2]. One of the reasons for this impairment is contributed by the channel. Orthogonal Frequency Division Multiple Access (OFDM) is another technology adopted by the digital broadcasting society to counter the Inter Symbol Interference (ISI) problem. The fusion of OFDM and CDMA has yielded MC-CDMA which applies the spreading sequences in the frequency domain. MC-CDMA uses spreading in frequency domain. It is opted for the downlink where the spectral efficiency is important and the high data rate is required [2,3]. The MC-CDMA in presence of non linear distortion and Multiple Access Interference (MAI) is dealt with various detectors [4, 5] using Lattice decoding and Genetic Algorithms [6]. Other global optimization technique like Global Search (GS) which can be implemented in a parallel processor is discussed in this paper.

This paper is organized as follows: Section 2 describes the system description; Section 3 discusses the optimum receiver; Section 4 describes clipping noise effects; Section 5 describes the Global Search algorithm based optimum detector; Section 6 gives the simulation results and Section 7 draws the conclusion.

2. SYSTEM DESCRIPTION

In the transmitter for the MC-CDMA, data from k users are spread using different spreading sequences of length *L* and they are combined. This is explained by the following equations [3].

U_k is the k^{th} user with data rate $1/T_d$. The spreading code is Ck_0, Ck_2, ...Ck_{L-1}. After spreading of each user and combining, the signal is Sk_0, Sk_1,...Sk_{L-1}

$$S = \sum_{k=0}^{k-1} s_k = \left(s_0, s_1, ..., s_{L-1}\right)^T \qquad (1)$$

Where,

$$S = CU \qquad (2)$$

$$U = (U_0, U_1, ...U_{k-1})^T \qquad (3)$$

$$C = (C_0, C_1, ...C_{k-1})^T \qquad (4)$$

The combined signal is send to serial to parallel converter and each data element is given a particular frequency slot using IFFT. Then the output is combined to form a OFDM symbol.

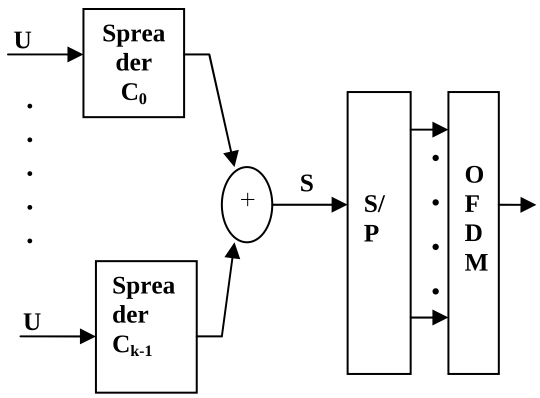

Figure 1. Transmitter configuration of a MC-CDMA system

Now the received OFDM symbol will be given as

$$r = \sum_{k=0}^{k-1} H_k S_k + \eta = (R_0, R_1, ...R_{L-1}) \quad (5)$$

$$r = HS + \eta \quad (6)$$

The '**r**' is the received OFDM symbol but a signal element from the user. It is also to be noted that '**r**' will have all '**k**' users data and each spreading code assigned to each user in the transmitter will be used again in the receiver to get the single signal element from '**r**'. The number of spreading codes are equal to number of users. But the OFDM symbol length is the size of the spreading code.

$$r = XS + \eta = (R_0, R_1, ..., R_{L-1}) \quad (7)$$

$$X = HC \quad (8)$$

X is called as system matrix.

3. OPTIMUM RECEIVER

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.

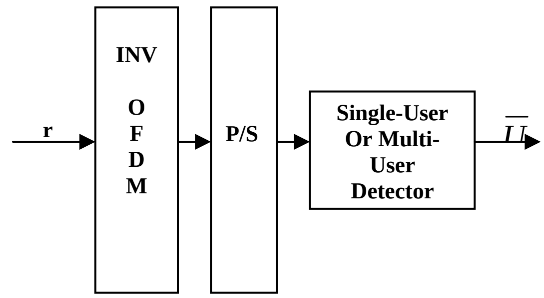

Figure 2. Receiver configuration of a MC-CDMA system

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

$$\overline{U^{'}} = Er \quad (9)$$

Where

$$E_{l,l} = \frac{H_{l,l}^{*}}{|H_{l,l}|^2} \quad (10)$$

$$\overline{U} = quantize(\overline{U^{'}}) \quad (11)$$

The Multi-User detection can be of optimal or suboptimal [7]. In this research 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.

$$E_{se} = \| r - XU_L \|^2 \quad (12)$$

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 [9,10] and models to generate clipping noise effects has also been proposed. The performance of MC-CDMA system under such impairments is discussed in detail and BER performance analysis for a Zero Forcing equalizer aided detectors are shown [11].

4.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 [10] 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 easily verified by the *Bussgang Theorem* and shown in[10].

$$X_{clip}(k) = \alpha X(k) + n_d(k) \qquad (13)$$

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

$$X_{clip}(k) = \{X(k)\} when \mid X(k) < A \mid (14)$$

$$X_{clip}(k) = A^{\arg(X(k))} when \mid X(k) \geq A \mid (15)$$

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

$$IBO = \frac{A^2}{P_x} \qquad (16)$$

This IBO is given usually in decibels and variation of the IBO changes the performance analysis in terms of BER [10].

5.GLOBAL SEARCH AS AN OPTIMAL DETECTOR

In Section 3, it is clearly shown that 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 Decoding and Genetic Algorithms are proposed [5, 6]. Another approach of using Particle Swarm Optimization is also proposed to assist the Multi User Detection (MUD) procedure [13]. In this paper a new global optimization technique called Global Search (GS) algorithm is deployed [9].

The main idea behind Global Search (GS) algorithm is to find starting points for gradient based local NLP solvers. OptQuest is a scatter search developed by OptTek® Systems 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 $f(x,y)$ (17)

subject to the nonlinear constraints

$gl \leq G(x, y) \leq gu$ (18)

the linear constraints

$l \leq A\, x + A\, y \leq u$ 1 2 (19)

$x \in S\,, y \in Y$ (20)

where *x* is an *n*-dimensional vector of continuous decision variables, *y* is 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 $S \times Y$. This is necessary so that a gradient-based local NLP solver can be applied to the relaxed NLP sub-problems formed from (17) - (20) by allowing the *y* variables to be continuous

6. SIMULATION RESULT- MULTI USER DETECTION

The MC-CDMA system as proposed in [5,6] is taken into study for our simulation . This serves as a tool to compare the performance analysis of GS algorithm when compared to the available optimal detectors.

6.1 BER PERFORMANCE UNDER ETSI INDOOR CHANNEL

The scenario similar to reference [5] is taken into consideration in this part of analysis. The received symbol power is equal to the transmitted symbol power. Each user symbol is spread over *L* = 64 sub-carriers, 32 users with a real Walsh-Hadamard sequence and the guard interval is 25% of the OFDM symbol period employing QPSK is taken into consideration. The system is simulated in MATLAB® environment and 10^8 symbols are transmitted and received.

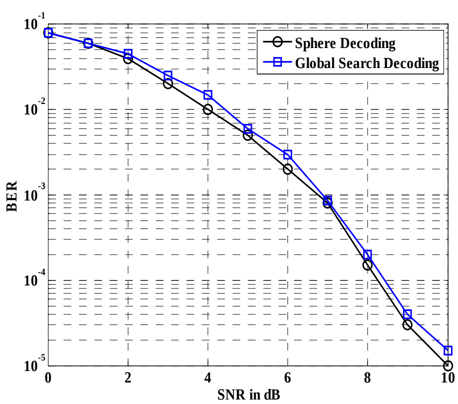

Figure 3. BER performance of Global Search Algorithm when compared with Sphere decoding algorithm

In Figure 3, the comparison between the Sphere Decoding algorithm and GS algorithm is done. The performance of GS algorithm is comparable with the Sphere Decoding algorithm based MUD.

6.2BER PERFORMANCE UNDER RAYLEIGH FADING AND CLIPPING NOISE EFFECT.

Using BPSK modulation, randomly varying Rayleigh fading channel, Walsh spreading code, number of sub carriers 4, number of users 15 and other parameters same as [6]. The results for the GA assisted MUD is also taken from [6] and clipping noise model and addition are similar to the reference [11].

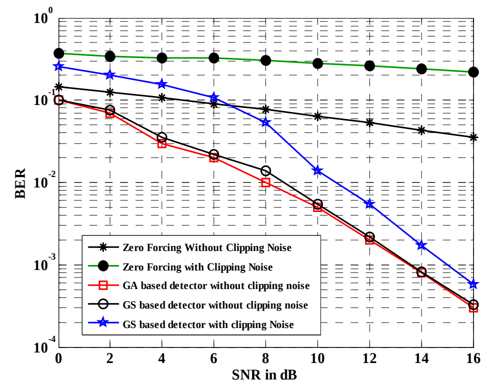

Figure 4. Performance analysis of a MC-CDMA under clipping noise for GA and GS based detectors.

In Figure 4, the MC-CDMA BER performance under Rayleigh fading and clipping noise is shown. Zero Forcing (ZF) equalizer based detection is also shown for the comparison. The figure also clearly indicates the necessity of MUD for the MC-CDMA system affected by the clipping noise.

7. CONCLUSION

In this paper 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 with respect to the literature found. 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. However the parallel processing capability of the GS algorithm is definitely a positive approach to use this technology in the detection.

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