THE OPTIMIZATION IN PAPR REDUCTION

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ABSTRACT

This paper describes the idea of PAPR (peak to average power ratio) reduction in M-codification of MC-CDMA (multicarrier code division multiple access). The spreading sequence introduces coherence among subcarriers. This is used to PAPR reduction. The Genetic Algorithm (GA) is used to optimal chip interleaving pattern finding. CCDF (complementary cumulative distribution function) is used for PAPR distribution confrontation.

1 INTRODUCTION

Orthogonal frequency division multiplexing (OFDM) is modulation scheme used in modern communication systems such as Wireless Local Area Network (WLAN) or Digital Video Broadcasting (DVB). OFDM can effectively handle with multipath propagation and has high spectral efficiency. In 1993 some hybrid technics combining OFDM and code division multiple access (CDMA) were proposed [3]. One of that technics is multicarrier code division multiple access (MC-CDMA) witch introduce frequency spreading and multiple access. Both, OFDM and MC-CDMA, have disadvantage in high peak to average power ratio (PAPR). There are many PAPR reduction schemes for OFDM and most of them is useful for MC-CDMA too [4]. The usage of spreading code gives other possibilities to PAPR reduction.

2 SYSTEM MODEL

The basic transmitter structure is similar to OFDM. Different symbols are transmitted on the subcarriers in OFDM, but MC-CDMA (Fig. 1) transmits same symbol in several subcarriers. Each subcarrier transits part of the spreaded symbol (called chip). Spreading code length has not necessarily to be equal to the number of all subcarriers. To complexity reduction and flexible system design some modifications are presented in [1].

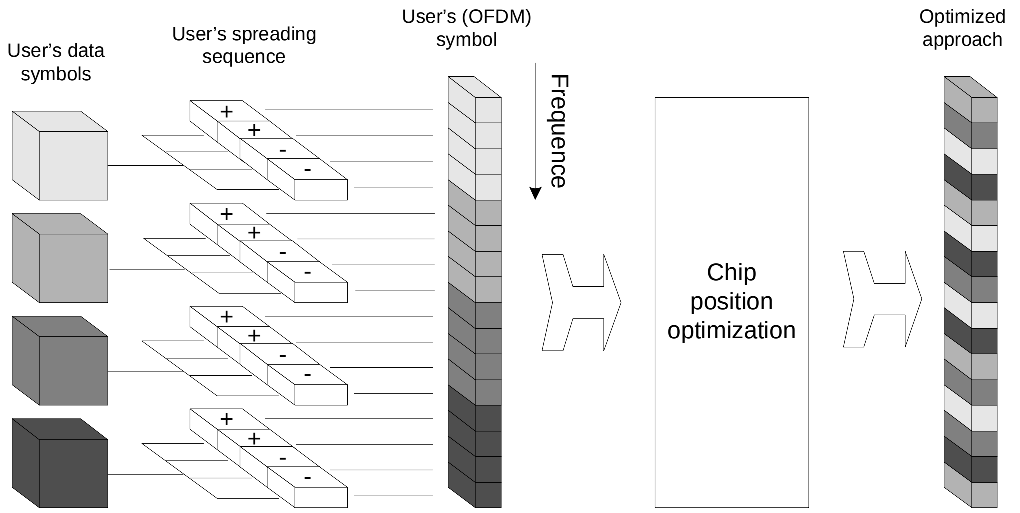

Figure 1: M-modification of MC-CDMA

2.1 M-MODIFICATION

The total number of subcarriers N_c is divided into M groups with L subcarriers in each. For one user (uplink) each group of L subcarriers transmits one symbol spreaded with sequence of the length L. The user transmits M paralel data symbols on all $N_c = M \times L$ cubcarriers. So this M-modification is called Paralel Data Symbols too.

2.2 WALSH SPREADING SEQUENCES

The Walsh sequences are orthogonal sequences used for spreading in MC-CDMA [2]. They can be generated for example from Hadamard matrix. For example Hadamard matrix 4-th order is:

$$H(4) = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 \end{bmatrix}. \tag{1}$$

Each row (or column) is Walsh sequence.

2.3 PEAK TO AVERAGE POWER RATIO

OFDM or MC-CDMA consists of many modulated subcarriers. This leads to problem with peak to average power ratio. If N subcarriers are added up coherently (the same symbols on all subcarriers for OFDM or spreading sequence number 1 for Walsh codes and same data symbols), the peak power is N times average power in a case of the baseband signal. The PAPR of signal x_τ, where τ is used to represent both the continuous-time index t and discrete-time index n, is defined as:

$$PAPR\{x_\tau, \mathcal{T}\} = \frac{\max\limits_{\tau \in \mathcal{T}} |x_\tau|^2}{E\{|x_\tau|^2\}}, \tag{2}$$

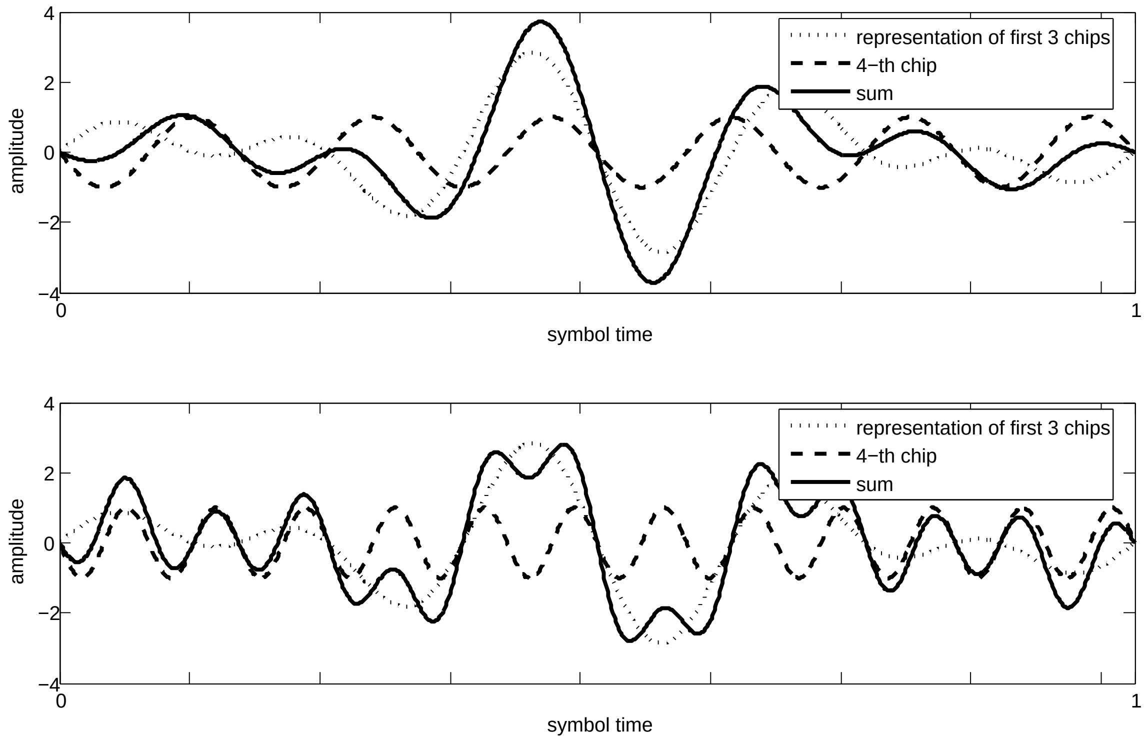

Figure 2: The idea of PAPR reduction. The chip sequence [1 -1 1 -1] is used. First 3 chips are modulated on 3. 4. and 5. subcarrier. 4. chip is modulated on 6. subcarrier in upper figure and on 12. subcarrier in lower.

where $\max_{\tau\in\mathcal{T}} |x_\tau|^2$ denotes the maximum instantaneous power and $E\{|x_\tau|^2\}$ is average power of transmitted symbol interval $\mathcal{T}$.

3 OPTIMIZATION IDEA

There is redundance in Walsh sequence. For example if first 3 chips are 1 -1 1, the last one will be -1 for sure (2. row in (1)). The OFDM subcarriers are represented in time domain by sinusoids. Their sum is OFDM symbol. If we could place that fourth chip on any subcarrier so that time domain representation will have smaller peaks (or et least not higher), we could reduce PAPR. The effect can be seen in Fig. 2. This is simplified idea, which didn't look at other chips (other subcarriers are set to zero). Each subcarrier is modulated by any chip in MC-CDMA system (Fig. 1). The chip allocation can be presented as chip interleaving. The idea become complex problem and optimum searching algorithm must be applied.

The proposal system for testing of PAPR reduction has 48 data subcarriers and 64 IFFT is used according to Fig. 3. MC-CDMA uplink (one user case) with Walsh sequences (length four) spreading is considered. There is factorial of 48 possibilities of chip interleaving.

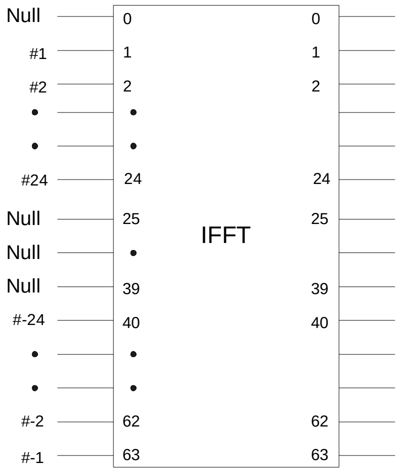

Figure 3: Block of IFFT

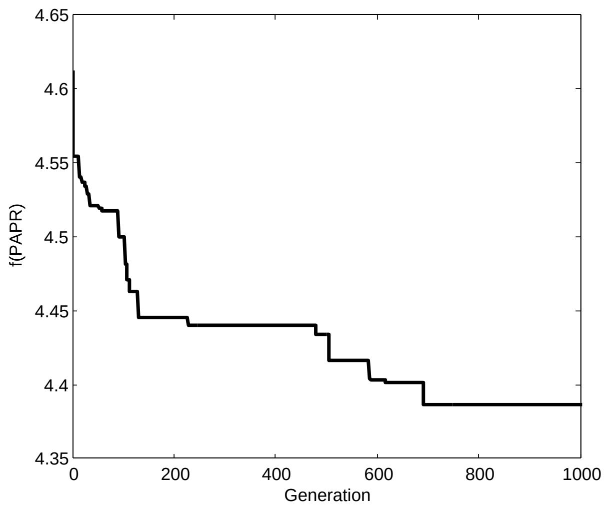

Figure 4: GA optimization process

4 GENETIC ALGORITHM

Genetic algorithm was used to solve this problem. The definition of a problem is to find the best sequence of chips (traveling salesman problem). The GA use combination of previous best solutions to get better one. The algorithm begins with random set of solutions called population. In each step (generation) new population is made from the old one. New individuals are made by crossing old ones (parents). The probability that the individual become the parent depends on its fitness function. The mutation is introduced to prevent falling in a local optimum.

Permutation encoding is used for implementing of chip spreading. In permutation encoding, every individual is presented by string of numbers (1, . . . 48) that represents a position in a sequence. The fitness function (mean PAPR of that sequence) is evaluated for each individual. The parent selection is made by random selection of 3 individuals and the best of them (according to fitness) became parent. Crossover is made by one crossover point selection, the permutation is copied from the first parent till the crossover point and rest is from second parent. After that, the duplications of numbers must be replaced by unused ones. The mutation is made by simple swap of two numbers. The best solution in current generation is called elite and it is replicate in next generation without differences (until better one is founded). The gradual improving illustrates Fig. 4. It describes the value of fitness function in particular generations.

5 RESULTS AND CONCLUSION

The matrix interleavers are compared by CCDF (complementary cumulative distribution function) of PAPR with optimized approach (Fig. 5). The best interleavers (in case of PAPR minimzation) are poor compared to optimized approach. Above mentioned PAPR reduction can be used for uplink in M-modification MC-CDMA. Realization of this approach can be made by chip interleaving, where all users in system have the same inter-

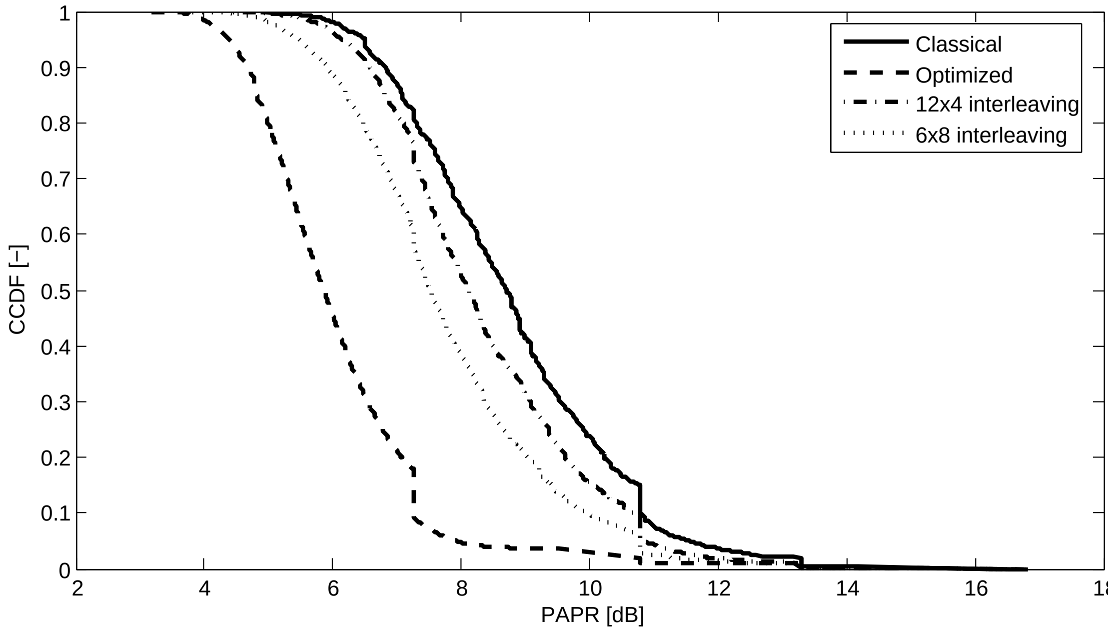

Figure 5: Comparison of optimized sequence and matrix interleavers

leaving pattern to preserve orthogonality among the users. The main advantage of this approach is small complexity (only modified interleaving), no performance degradation and no side information. To full utilization of this scheme clipping can be presented. The optimized approach has smaller clipping probability with the same clipping level.

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