Overview of Peak-to-Average Power Ratio Reduction for MC-CDMA & OFDM systems Using Various Techniques

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Abstract — Orthogonal Frequency Division Multiplex (OFDM) is a promising radio access technique for mobile communication systems due to its high spectrum efficiency and strong immunity against multi path fading with only simple equalization. As a hybrid scheme of OFDM and Code Division Multiple access (CDMA), Multicarrier Code Division Multiple Access (MCCDMA or OFDM-CDMA) intends to exploit the advantages of both OFDM and CDMA. In the downlink of MC-CDMA systems, CDMA coding is applied to provide multiple access ability as well as to spread each user’s data across the entire available frequency band which can greatly reduce the impact of frequency selective fading. And then the spreading code’s chips are modulated on orthogonal sub carriers and spread across the time domain via the OFDM modulation. Therefore MC-CDMA can achieve high data rate transmission with protection against both frequency selective fading and time dispersion while at the same time offer a spectrum efficient multiple access strategy. However MC-CDMA systems suffer from one of the major drawbacks of all multicarrier transmission schemes, a high peak to average power ratio (PAPR). A high dynamic range is required in the linear Power Amplifiers (PA) at the transmitter in order to transmit a signal with large PAPR. The power efficiency performance of such amplifiers decreases as the PAPR increases. And if the dynamic range of PA is insufficient, the signal is distorted from the nonlinearity thus degrade the signal quality. These shortcomings are especially unaffordable for battery powered portable wireless terminals. Various PAPR reduction schemes have been proposed in this paper to reduce peak to average power ratio. In this paper we will see the overview of different PAPR reduction techniques for MC-CDMA system.

Keywords— MC-CDMA, Peak to average power ratio (PAPR), orthogonal frequency division multiplexing (OFDM), Multicarrier code division multiple access (MC-CDMA), Integer Wavelet Packet Transform (IWPT), Non linear companding transform, PTS & SLM.

INTRODUCTION

MC-CDMA Systems

Consider a quasi-synchronous MC-CDMA uplink system with K physical users, where for simplicity the number of sub carriers N is assumed to equal the spreading factor G for each user. No pulse shaping is considered. The MC-CDMA modulator performs the IDFT operation to generate the time domain transmitted signal for user k as follows.

\[
  u_n^k = \frac{1}{N} \sum_{i=0}^{N-1} (a_k c_i n^k) e^{\frac{2\pi i n}{N}}, \quad n = 0, 1, \ldots, N-1
\]

where \(a_k\) is the amplitude, \(c_i\) is the ith chip of normalized spreading code \(c_k\), and \(s_n\) is the data signal for user k. After a sufficient cyclic prefix is inserted between modulated symbols to compensate for the symbol asynchronism and the multipath delay spread, the complete signal is transmitted through a radio channel, where the impulse response vector of the discrete-time multipath channel for user k is given by

\[
  h_k^k = [\alpha_0^k, \alpha_1^k, \ldots, \alpha_{L-1}^k]^T
\]

with \(\alpha_i^k\) being the complex fading gain of the ith path. At the base station, the time-domain received data vector without the cyclic prefix is the sum of the distorted transmitted signal for each user and the additive white Gaussian noise (AWGN) vector \(n\), i.e.,

\[
  X = \sum_{k=1}^{K} u_n^k \otimes \alpha_n^k + n
\]

where the operation \(\otimes\) means the circular convolution. The MC-CDMA demodulator performs the DFT operation of (3) to obtain the frequency-domain received data vector, i.e.

\[
  X = H A s + w, \quad X : N \times 1
\]

In this contribution, a MIMO MC-CDMA system is designed with \(MT=4\) and \(MR=1, 2, 3\) where two coding operations have been...
incorporated, one through the use of orthogonal Walsh-Hadamard (WH) coding, and one in quasiorthogonalSFBC domain (on a per sub carrier basis). The designed system has R=1 at the expense of orthogonality, and with the incorporation of an iterative scheme with low number of iterations a noticeable performance gain is achieved with respect to classical 2xMR scheme, schemes giving a symbol stream d[m] of M symbols. The output symbols are interleaved and spread in frequency domain by a unique(user-specific) spreading vector Ci (WH) of length SF=16( Spreading Factor) enabling 3 spread symbols to be transmitted-CDMA without requiring complex equalizers[5]. By combining the spatial transmission diversity with the space-time block codes for MC CDMA systems, it shows high performance improvement. A code division multiple access system allocates the entire bandwidth to each user. Although the users are separated from each other by a distinctive spreading code in the code domain, different sub channels will be affected by different fading coefficients, and orthogonally between users will be destroyed at the receiver, and as a result, Multi User Interference (MUI) occurs. As the number of users in multiple access environment increases, MUI is increased and performance of the system will be decreased subsequently. In such conditions, proper multi-user detection schemes will be worth. Different single-multi user detection techniques have been investigated so far.

PTS & SLM technique

Scrambling techniques like partial transmit sequence (PTS) and Selected Mapping (SLM), PTS partitions sequence into sub blocks and each sub block is multiplied by a phase weighting factor to produce alternative sequences with low PAPR. Partial Transmit Sequence (PTS) technique is an efficient approach and a distortionless scheme for reducing PAPR. Due to its flexibility, the PTS technique works with an arbitrary number of subcarriers[19]. In addition, it works without restriction on the type of modulation scheme. Thus, the investigation of PAPR in MC-CDMA system combined with PTS technique is very attractive. SLM pseudo randomly modifies the phases of the original information symbols in each OFDM block several times and selects the phase-modified OFDM block with the best PAPR performance for transmission. But they all require independent multiple IFFT computation process for PAPR reduction for every symbol with which the non-negligible side information must be transmitted along. Although these OFDM based schemes are applicable to the MC-CDMA systems, more efficient MC-CDMA specific algorithm can be developed by exploiting the characteristics of the OFDM–CDMA that distinguish it from the conventional OFDM. Since MC-CDMA system provides an efficient method of frequency diversity, it is suitable to a frequency selective Rayleigh fading environment. This technique becomes a potential technique or future wireless networks[17].

Clipping & Filtering technique

Clipping & Filtering techniques are mostly effective techniques to reduce high PAPR in OFDM system. Here clipping is Non linear process which increase the base band noise distortion, increase bit error rate & decrease spectral efficiency. Filtering after clipping will reduce the PAPR without spectrum expansion. Here, if the OFDM signal is over sampled then the scheme of correction is suitable with the clipping so that each sub carrier generated with the interference. So for this scheme each signal must be oversampled by factor of four. This scheme is more compatible with the PSK modulation scheme[17].

Peak Windowing technique

Here, peak windowing technique is very similar to the clipping but it will give better performance with adding some self interference and increasing the BER. Due to this out band radiation is also increased, in this method we multiply different windows with large signal peaks like Gaussian shaped window, cosine, Kaiser & Hamming windows, the resulting spectrum is a convolution of the original OFDM spectrum with the spectrum of the applied window. Means window should be as narrow as possible. By using this technique PAPR can be reduced up to 4 db for each sub carrier & SNR is limited to 0.3 db due to signal distortion[17].

Dynamic Code-allocation Based PAPR reduction technique

In this technique a new optimized spreading codes redistribution scheme which utilizes the characteristics of MC-CDMA systems to avoid the use of extra randomizers. Rather than randomizing the transmitted symbols or creating a set of new spreading codes, we strategically redistribute spreading codes between users for each MC-CDMA symbol, therefore a set of new MC-CDMA symbols can be generated with high possibility that low PAPR value can be obtain[19]. This method mainly focuses on Walsh-Hadamard (WH) and Complementary Golay(CP) codes. In a lightly loaded MC-CDMA system, WH codes tend to have much larger PAPR than fully loaded system. With our optimized sequence modification it is shown that stable performance can be achieved for both lightly and fully loaded systems. Here, this reduction technique takes place in two distinct stages. The first is to determine an optimizing sequence if the system is lightly loaded and then perform the dynamic code redistribution[17].

Non-linear companding techniques

Nonlinear companding transforms are one the most attractive schemes due to their good system performance, the simplicity of implementation, without restriction on the number of subcarriers, the type of constellation and any bandwidth expansion. Unlike the μ-law companding scheme, which mainly focuses on enlarging small signals, nonlinear companding schemes adjust both small and large signals without bias so that it is able to offer better performance in terms of PAPR reduction, Bit-Error-Rate (BER)
and phase error for OFDM and MC-CDMA systems. Fig shows the block diagram of typical MC-CDMA system using non-linear companding technique. Various non-linear companding techniques like C1(.), C2(.) & exponential companding C(.) are available. These techniques effectively transform the original Gaussian-distributed OFDM signals into uniform distributed(companded) signals without changing average power level[18].

![Fig 2: OFDM system using non linear companding technique](image)

**Integer wavelet packet transform technique**

Obtain IWT from given wavelet functions; omitting details, it has been proven that rounding off the output of each filter right before adding or subtracting yields a couple of perfect reconstruction forward and inverse IWT. It is straightforward to understand that the same procedure which leads to IWT from wavelet transform can be applied to the wavelet packets transform, yielding the IWPT.

The implementation follows the same scheme used for the IWT. The IWPT tree can be built iterating the single wavelet decomposition step on both the low-pass and high-pass branches, with rounding off in order to achieve the integer transforms. IWPT yields a representation which can be lossless, as it maps an integer valued sequence onto integer valued coefficients in the transformed domain; moreover, it allows for the selection of an adaptive representation, which can match the variable characteristics better than the IWT. However IWPT is one of the best technique to reduce PAPR.

![Fig 3: IWPT Block Diagram](image)

**CONCLUSION**

Here, In this paper we have represented the overview of different PAPR reduction techniques for MC-CDMA systems. To reduce PAPR any method can be used according to our convenience. But in recent days Non linear companding technique & Integer Wavelet packet transform techniques are most popular due to it’s good performance in terms of BER. These two methods will reduce PAPR of MC-CDMA system up to good extent than any other method represented in this paper.

**REFERENCES**