A Literature Review on Low Complexity Orthogonal Frequency Division Multiplexing Systems for Reduction of PAPR

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Abstract - Most multicarrier modulation schemes (such as OFDM) have high PAPR compared with single carrier systems. Since there are enough subcarriers with the same phase, the instantaneous amplitude caused by those overlapped signals will be much larger than the mean power of the sub-carriers, which causes high PAPR. The high PAPR requires radio frequency (RF) amplifiers to have a large dynamic range, which wastes the resources of amplifiers and decreases the corresponding efficiency. Moreover, if the instantaneous power exceeds the linear region, those signals will be distorted, which causes out-of-band radiation and BER degradation. In order to use the OFDM technique in practice, these drawbacks need to be restrained.

Keywords – Orthogonal frequency division multiplexing (OFDM), peak-to-average power ratio (PAPR), selective mapping (SLM).

I. INTRODUCTION

Traditional single carrier modulation techniques can achieve only limited data rates due to the restrictions imposed by the multipath effect of wireless channel and the receiver complexity. High data-rate is desirable in many recent wireless multimedia applications [1]. However, as the data-rate in communication system increases, the symbol duration gets reduced. Therefore, the communication systems using single carrier modulation suffer from severe inter-symbol interference (ISI) caused by dispersive channel impulse response, thereby needing a complex equalization mechanism. Orthogonal Frequency Division Multiplexing is a special form of multicarrier modulation scheme, which divides the entire frequency selective fading channel into many orthogonal narrow band flat fading sub channels. In OFDM system high-bit-rate data stream is transmitted in parallel over a number of lower data rate subcarriers and do not undergo ISI due to the long symbol duration[2].

High PAPR has become a critical problem that needs to be solved in an OFDM system. The envelope of a an OFDM is not constant. Occasionally, a large signal peak can occur when many subcarriers are added in phase. OFDM signals with high PAPR when transmitted through a nonlinear device, such as a high power amplifier (HPA), can suffer inter-modulation distortion and out-of-band emission (spectral re-growth). The first effect degrades the BER performance of the system while the latter effect causes interference to other users and thus decreases the cellular capacity of the system.

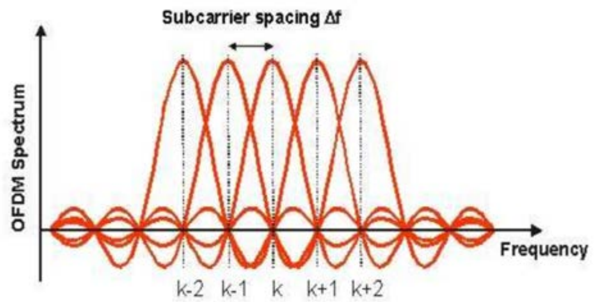

Figure 1.1 Orthogonal Frequency Division Multiplexing Spectrum

Developing an algorithm to reduce PAPR has become a popular field since the 1990s, and is becoming much more popular with the 4G applications. Many institutions and universities make this problem the focus of their research.

Currently, the on-going approaches for reducing PAPR can be generally divided into three categories limiting class, signal scrambling, and encoding approaches. The limiting class approach is the most straightforward method for PAPR reduction. At the transmitter, those signals whose peak are larger than a threshold are clipped before being sent into the digital-to-analog coveter (DAC) or the radio - frequency (RF) power amplifier. The scrambling approach is different from the limiting one, since it does not clip signals, but it decreases the probability that high PAPR signals can occur. The scrambling technologies try to represent a data sequence by different sequences. In this way, the systems can pick one sequence that has the lowest PAPR for transmission. The encoding approach encodes a signal by confining the code sets and select those that are less than a threshold for transmission. However, the evaluation criteria for a PAPR reduction algorithm are not limited to PAPR reduction performance. There are many factors that must be considered. Some PAPR reduction techniques can effectively reduce PAPR but they are too complex to be realized; this confines the use of them in practice. A technique can be simple and easy to implement; however, its PAPR reduction performance may not be as good as that of other techniques. Hence, both PAPR reduction performance and computational complexity need to be considered and a trade-off between them need to be made.

II. SYSTEM MODEL

The discrete time baseband OFDM system with N subcarriers is shown in figure 2.1. It consists of transmitter, channel and receiver blocks.

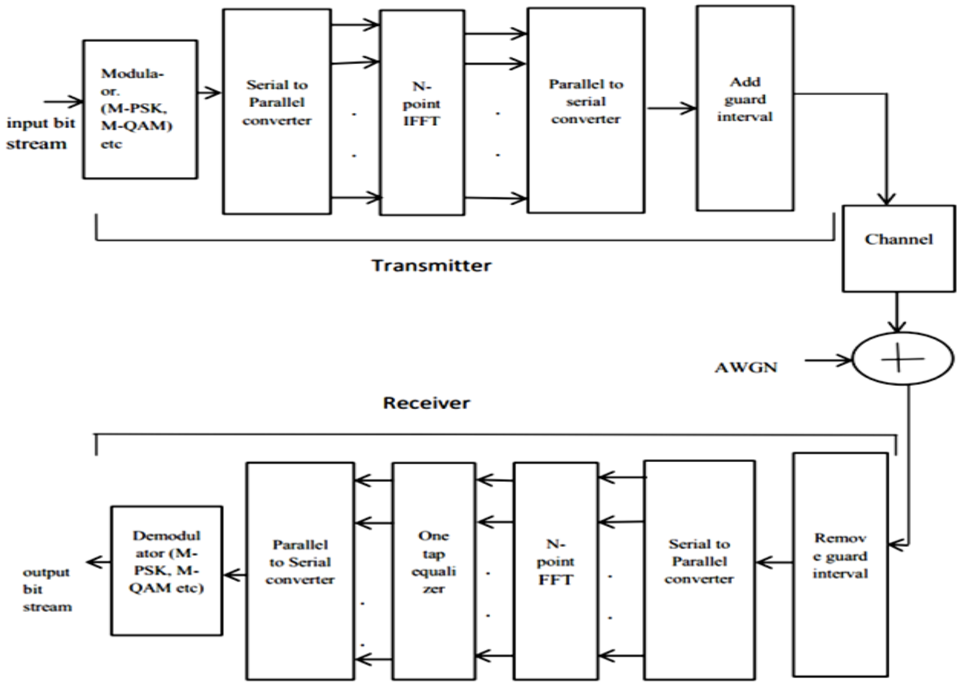

Figure 2.1 OFDM system model

Transmitter

In this model, a block of input bits (symbols) are modulated by M-ary data modulators and then, such symbols are transferred by the serial to parallel converter. Different types of data modulator can be used depending upon system requirement (e.g. M-PSK, M-QAM etc.). The complex parallel data symbols (X_k) obtained by using modulation techniques are given to N point IFFT block as shown in figure 2.1

Channel Model

The phenomenon of noise and multipath environment can be predicted by using channel model. Generation of noise can be done by adding few random data to the OFDM symbol and multipath environment can be generated by adding attenuated and delayed copies of the OFDM signal.

Receiver

At the receiver, inverse of the transmitter is done. Here, first the guard interval of OFDM symbol is removed. Then, these unguarded OFDM symbol is converted from serial to parallel which are passed through FFT block. The FFT converts these parallel OFDM data streams into frequency domain

III. PEAK TO AVERAGE POWER RATIO

It is defined as the ratio between the maximum power and the average power for the envelope of a baseband complex signal $\tilde{S}(t)$ i.e.

$$PAPR\{\tilde{s}(t)\} = \frac{\max|\tilde{s}(t)|^2}{E|\tilde{s}(t)|^2}$$

Also we can write this PAPR equation for the complex pass-band signal s(t) as

$$PAPR\{s(t)\} = \frac{\max|s(t)|^2}{E\left\{|s(t)|^2\right\}}$$

Effect of High PAPR

The linear power amplifiers are being used in the transmitter so the Q-point must be in the linear region. Due to the high PAPR the Q-point moves to the saturation region hence the clipping of signal peaks takes place which generates in-band and out-of band distortion. So to keep the Q-point in the linear region the dynamic range of the power amplifier should be increased which again reduces its efficiency and enhances the cost. Hence a trade-off exists between nonlinearity and efficiency [1]. And also with the increasing of this dynamic range the cost of power amplifier increases. As a Communication field the objective should be to reduce this PAPR.

PAPR Reduction Techniques

A lot of techniques presents for the reduction of this PAPR [1]. About some of the reduction techniques like Clipping and Filtering, Coding, Partial Transmit Sequence, Selected Mapping, Tone Reservation, Tone Injection, Active Constellation Extension are briefly described here.

Clipping and Filtering

This is a simplest technique used for PAPR reduction. Clipping means the amplitude clipping which limits the peak envelope of the input signal to a predetermined value

Active Constellation Extension (ACE) Technique

This technique for PAPR reduction is similar to Tone Injection technique. According to this technique , some of the outer signal constellation points in the data block are dynamically extended towards the outside of the original constellation such that PAPR of the data block is reduced. In this case also there will be increase of transmitted power take place.

Selected Mapping (SLM) Technique

The basic idea of this technique is first generate a number of alternative OFDM signals from the original data block and then transmit the OFDM signal having minimum PAPR. But data rate loss and complexity at the transmitter side are two basic disadvantages for this technique

IV. RELATED WORK

S. Katam and P. Muthuchidambaranathan [1] Orthogonal frequency division multiplexing (OFDM) is an attractive current technology for wireless communication systems due to its high spectral efficiency. One major disadvantage associated with OFDM is high peak to average power ratio (PAPR). It needs a large back-off high power amplifier (HPA) else degradation of bit error rate (BER) occurred. Selective mapping (SLM) is an effective technique used to reduce PAPR. It has a large computational complexity caused by bank of inverse fast Fourier transforms (IFFTs). This paper, have been proposed low complexity SLM-PTS method uses a conversion sequence and the concept of partial transmit sequence (PTS) to replaces the bank of IFFTs in the conventional SLM. The simulation results show that the proposed method PAPR performance is same as the conventional SLM method

Y. Rahmatallah and S. Mohan [2] The objective of this survey is to provide the readers and practitioners in the industry with a broader understanding of the high peak-to-average power ratio (PAPR) problem in orthogonal frequency division multiplexing (OFDM) systems and generate a taxonomy of the available solutions to mitigate the problem. Beginning with a description of OFDM systems, the survey describes the most commonly encountered impediment of OFDM systems, the PAPR problem and consequent impact on power amplifiers leading to nonlinear distortion. The survey clearly defines the metrics based on which the performance of PAPR reduction schemes can be evaluated. A taxonomy of PAPR reduction schemes classifies them into signal distortion, multiple signaling and probabilistic, and coding techniques with further classification within each category. Authors provide complexity analyses for a few PAPR reduction methods to demonstrate the differences in complexity requirements between different methods. Moreover, the research provides insights into the transmitted power constraint by showing the possibility of satisfying the constraint without added complexity by the use of companding transforms with suitably chosen companding parameters. The rapid growth in multimedia-based applications has triggered an insatiable thirst for high data rates and hence increased demand on OFDM-based wireless systems that can support high data rates and high mobility. As the data rates and mobility supported by the OFDM system increase, the number of subcarriers also increases, which in turn leads to high PAPR. As future OFDM-based systems may push the number of subcarriers up to meet the higher data rates and mobility demands, there will be also a need to mitigate the high PAPR that arises, which will likely spur new research activities. The authors believe that this survey will serve as a valuable pedagogical resource for understanding the current research contributions in the area of PAPR reduction in OFDM systems, the different techniques that are available for designers and their trade-offs towards developing more efficient and practical solutions, especially for future research in PAPR reduction schemes for high data rate OFDM systems.

X. Zhu, W. Pan, H. Li and Y. Tang [3] Iterative clipping and filtering (ICF) is a well-known technique to reduce the peak-to-average power ratio (PAPR) of orthogonal frequency division multiplexing (OFDM) signals. Recently, Wang and Luo investigated the clipped signal and proposed a modified algorithm called optimized ICF (OICF). This is an optimal algorithm since it can achieve the required PAPR reduction with minimum in-band distortion and far fewer iterations. However, OICF needs to solve a convex optimization problem with {O}(N^3) complexity, where N represents the number of subcarriers. In this paper, instead of analyzing the clipped signal, authors study the clipping noise and propose a simplified OICF algorithm. In the new algorithm, solving the convex optimization problem is approximated by some simple algebraic operations and the computational complexity reduces to {O}(N). Simulation results show that after three iterations, the original OICF algorithm can achieve the desired PAPR while the simplified one exhibits almost the same performance: for a 128-subcarrier and quadrature phase shift keying (QPSK) modulated OFDM system, the PAPR-reduction performance difference between the two algorithms are 5x10^{-3}dB at a 10^{-4} clipping probability and the bit-error-rate performance difference is 6x10^{-3}dB at a 10^{-7} error probability.

S. H. Muller and J. B. Huber [4] Two powerful and distortion less peak power reduction schemes for orthogonal frequency division multiplexing (OFDM) are compared. One investigated technique is selected mapping (SLM) where the actual transmit signal is selected from a set of signals and the second scheme utilizes phase rotated partial transmit sequences (PTS) to construct the transmit signal. Both approaches are very flexible as they do not impose any restriction on the modulation applied in the subcarriers or on their number. They both introduce some additional system complexity but nearly vanishing redundancy to achieve markedly improved statistics of the multicarrier transmit signal. The schemes are compared by simulation results with respect to the required system complexity and transmit signal redundancy

L. J. Cimini and N. R. Sollenberger [5] Orthogonal frequency division multiplexing (OFDM) is an attractive technique for achieving high-bit-rate wireless data transmission. However, the potentially large peak-to-average power ratio (PAP) of a multicarrier signal has limited its application. Two promising techniques for improving the statistics of the PAP of an OFDM signal have previously been proposed: the selective mapping and partial transmit sequence approaches. Here, authors summarize these techniques and present suboptimal strategies for combining partial transmit sequences that achieve similar performance but with reduced complexity.

V. CONCLUSION

This review paper basically concentrates on PAPR reduction schemes. Numerous analysts have studied an assortment of PAPR reduction schemes; notwithstanding, the proposition for the most part concentrate on the selective mapping (SLM) conspire, which has effective PAPR execution. The fundamental research course is the means by which to diminish the computational intricacy of the SLM conspire while keeping a similarly compelling PAPR decrease. In this theory, three PAPR reduction schemes are analyzed that can be considered as low-complex modified versions of the conventional SLM scheme.

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