Analysis of PAPR based OFDM Signal by using Iterative Companding Transform & Filtering Technique: A Review

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Abstract— OFDM (Orthogonal Frequency Division Multiplexing) systems suffer through a critical drawback: The approximately Gaussian-distributed output samples produce high Peak-to-Average Power Ratio (PAPR), which leads to the inter-modulation among sub carrier. It is observe that companding transform is an excessive operation after modulating the OFDM signals, thus companding schemes reduce PAPR at the expense of generating companding Transform.

Key words: OFDM, PAPR

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is an excellent technology for 4th generation (4G) cellular networks. In OFDM parallel transmission scheme which splits high data rate to serial data stream into low-rate sub stream; each one is modulated on a separate SC. OFDM is one of the many multicarrier modulation techniques, which provides high spectral efficiency, low implementation complexity, less vulnerability to echoes and non – linear distortion. Due to such advantages of the OFDM system, it is extensively used in various communication systems. But the major problem is faced, while implementing OFDM system is the high peak –to – average power ratio of this system.

However, OFDM systems suffer from a serious drawback: The approximately Gaussian-distributed output samples produce high Peak-to-Average Power Ratio (PAPR), which leads to the inter-modulation among sub carriers and undesired Out-of-Band Interference (OBI). As a result, the Digital-to-Analog (D/A) converter and High Power Amplifier (HPA) with an extremely wide dynamic range are used to avoid the nonlinear distortion by reducing the power efficiency of HPAs. So there are various techniques have been proposed to reduce the PAPR of OFDM signals, such as Clipping and Filtering (CF), Selective Mapping (SLM), Partial Transmit Sequence (PTS), Tone Reservation (TR), and Companding Transform (CT). Out of these techniques, CF is the simplest solution. However, clipping is a highly nonlinear processing, and causes significant OBI and in band distortion, which degrades the Bit Error Rate (BER) performance of OFDM system. Note that, compare to the in-band distortion, OBI is more critical as it interferes with the radio communications in adjacent channels.

Companding transforms has low computational complexity and simple implementation but it consist of increased error rate. In selective mapping (SLM) technique, it generates a set of adequate different OFDM symbols, all represents the same information as the original OFDM symbol, then transmitted the one with the lowest PAPR. Information of selected symbol is transmitted to the receiver as side information which reduces the data rate. In tone injection (TI) technique, the constellation size is increased so that each of the points in the original basic constellation is mapped into several other points in the expanded constellation which helps to reduce PAPR but with increased power and complexity. In tone reservation (TR) technique, a subset of tones is reserved which carries no information data.

The ratio of peak power and the average power is referred to as peak-to-average power ratio (PAPR). The high PAPR requires transmitter's power amplifier with a large linear range capable of accommodating the signal, but practically power amplifier has a limited linear region beyond which it saturates to a maximum output level.

II. LITERATURE REVIEW

Orthogonal frequency-division multiplexing (OFDM) effectively suffers intersymbol interference (ISI) occures by the delay spread of wireless channels. Therefore, it has been used in many wireless systems and adopted by various standards. In this paper, we present a comprehensive survey on OFDM for wireless communications. We go through basic OFDM and related modulations, and various techniques to improve the performance of OFDM for wireless communications, including channel estimation and signal detection, time- and frequency-offset estimation and correction, peak-to-average power ratio reduction, and multiple-input-multiple-output (MIMO) techniques. the PAPR problem and consequent impact on power amplifiers leading to nonlinear distortion. A taxonomy of PAPR reduction schemes classifies them into signal distortion, multiple signaling and probabilistic, and coding techniques with further classification within each category. 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. 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.

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.

A simple but effective companding technique to reduce the peak-to-average power ratio of OFDM signal is evaluated in this paper. The idea comes from the use of companding in speech processing. Since OFDM signal is similar to speech signal in the sense that large signals only occur very infrequently, the same companding technique might be used to improve OFDM transmission performance. The target of ICTF strategy is to get a critical PAPR reduction, yet to the detriment of a less measure of in band distortion and out-of-band spectral regrowth. Initially, the

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peaks of original symbol are compacted subject to a predetermined signal weakening level (attenuation) created by the companding distortion, which is straightforwardly identified with the BER degradation. Second, a frequency-domain filtering is embraced for minimizing the OBI. Recently, an optimized ICF method based on convex optimization was proposed to dramatically. Decrease the number of required iterations. But unfortunately, its benefits come at the price of an increased complexity. Further motivated by the observation above, two immediate questions arise from the previous works on CT technique. The first one is how to obtain an effective trade-off between the PAPR reduction and BER performance. The next is how to minimize the undesired out-of-band interference. In the paper, enlightened by the iterative filtering approach in ICF method, an Iterative CT and Filtering (ICTF) technique is proposed for reducing the PAPR of OFDM signal.

By using an iterative procedure, ICTF can obtain a significant PAPR reduction as well as an improved BER performance simultaneously. A survey of PAPR reduction techniques reveals that perhaps the most widely known methods are signal clipping, block coding , selected mapping SLM and partial transmit sequence (PTS) Of them, clipping is a very simple method to reduce PAPR . This can lower the PAPR easily by cutting away the signal above the assigned clip level. But it results in out-of-band radiation and in-band distortion causing poor signal quality.

III. Reduction Techniques

There are multiple techniques to improve the PAPR reduction. Several reduction techniques are reviewed in the following sections.

A. *Clipping & Filtering*

This method employs a clipper that limits the signal envelope to a predetermined clipping level (CL) if the signal exceeds that level; otherwise, the clipper passes the signal without change, as defined by:

$$T(x[n]) = \begin{cases} x[n] & \text{if } \; |x[n] < CL| \\ CL\, e^{j< x[n]} & \text{if } \; |x[n] > CL| \end{cases}$$

Where x[n] is the OFDM signal, CL is the clipping level and, is the angle of x[n]. Clipping is a non-linear process that leads to both in-band and out-of-band distortions. The out-of-band distortion causes spectral spreading and can be eliminated by filtering the signal after clipping but the in-band distortion can degrade the BER performance and cannot be reduced by filtering. However, oversampling by taking longer IFFT can reduce the in-band distortion effect as portion of the noise is reshaped outside of the signal band that can be removed later by filtering.

B. *Selective Mapping (SLM)*

The basic idea in SLM technique is to generate a set of sufficiently different candidate data blocks by the transmitter where all the data blocks represents the same information as the original data block and select the favorable having the least PAPR for transmission. The block diagram of the SLM technique is shown in Figure

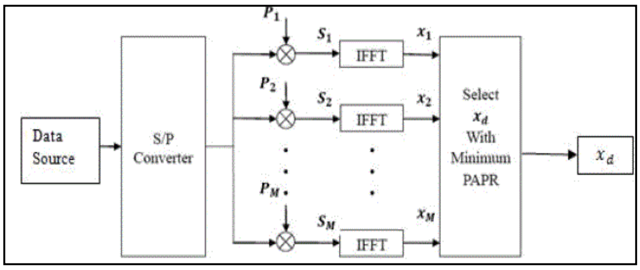

Fig. 1: Selective Mapping Scheme (SLM)

The basic idea of SLM is to produce U alternative transmit sequences from the same data source and then to select the transmit signal exhibiting the lowest PAPR. The idea stems from the fact that as the PAPR is determined by the sequence of the transmit data vectors; X m multiplying the data vectors by some random phase will change the PAPR properties after the IFFT. Mathematically, a set of U markedly different, pseudo random fixed vectors are generated Both the input data and phase sequences have the same length After multiplication, inverse fast Fourier transform (IFFT) will be applied on each sequence to convert the signal from frequency domain to the time domain. The result from multiplication will generate the data block of an OFDM system that has different time domain signals The last step is comparing the PAPR among the independent data blocks and the candidate with the lowest PAPR will be selected for transmission.

C. *Partial Transmit Sequence (PTS)*

In PTS, an input data block of length N is partitioned into a number of disjoint sub-blocks. Then each of these sub-blocks are padded with zeros and weighted by a phase factor. The schematic is shown in Figure

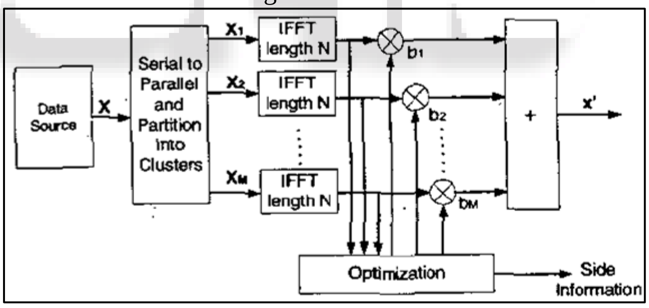

Fig. 3: Partial Transmit Sequence Technique

The fundamental idea of this technique is sub-dividing the original OFDM symbol data into sub-data which is transmitted through the sub-blocks which are then multiplied by the weighing value which were differed by the phase rotation factor until choosing the optimum value which has low PAPR. The block diagram for PTS technique implementation is shown in figure. The data sequence X in frequency domain is sub-divided into v sub-sequence which were transmitted in sub-blocks without overlapping and having equal size of N which contains N/V non-zero values in each sub-blocks. With the assumption that the sub-blocks have equal size without having any gap between them. for an optimum result, one of the factor is selected such that it gives minimum output value

D. *Tone Injection (TI)*

This technique increases the constellation size so that each of the point in the original basic constellation can be mapped

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into several equivalent points in the expanded constellation [33]. Since substituting a point in the basic constellation for a new point in the larger constellation is equivalent to injecting a tone of the appropriate frequency and phase in the multicarrier signal, therefore, this technique is called tone injection. The extra degrees of freedom, which is generated as each symbol in the data block can be mapped into one of the several equivalent constellation points, can be utilized for PAPR reduction. The extended constellation of a constellation point in QPSK/4-QAM is shown in Figure

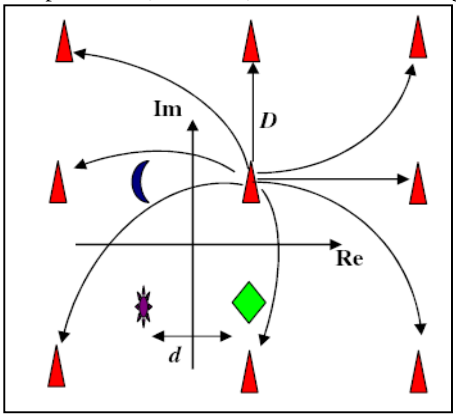

Fig. 3: Extended Constellation in QPSK

E. Companding Transform

Figure shows the block diagram of a typical OFDM system using the companding technique for PAPR reduction. Let N denote the number of sub-carriers used for parallel information transmission and let SK (0 < k < N-1) denote the K^{th} complex modulated symbol in a block of N information symbols. The outputs Sn the N-point In-verse Fast Fourier Transform (IFFT) of SK are the OFDM signal samples over one symbol interval.

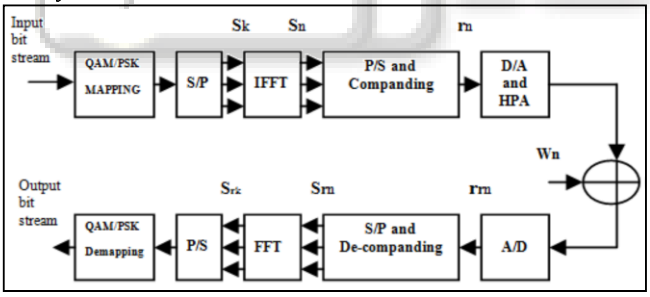

Fig. 4:

The input information symbols are assumed to be statistically independent and identically distributed. So when N is large(e.g.N≥64),the real and imaginary parts of Sn, denoted by Re {Sn} and Im {Sn}, are Independent and identically distributed Gaussian random variables with zero mean and a common variance σ2=E[|Sk|2]/2,according to the central limit theorem.

The amplitude, or modulus, of OFDM signal Sn is given by,

$$|Sn|=\sqrt{Re^2\{sn\}+im^2\{Sn\}}$$

The peak power occurs when N modulated symbols are added with the same phase

By using the nonlinear companding technique, the OFDM signals sn are companded before they are converted into analog wave-forms and amplified by the high power Amplifiers (HPAs).

The companded signal tn (0≤n≤N–1) is given by

$$t_{n=h(Sn)}$$

IV. CONCLUSION

This paper has reviewed the mainly latest research trends for reduction of Peak to Average Power ratio (PAPR). In this paper many different methods are studied for PAPR reduction. All of proposed schemes have the potential to reduce PAPR substantially but at the cost of loss in data rate, transmit signal power increase, BER increase, computational complexity increase and so on. Thus, the PAPR reduction technique should be carefully chosen according to various system requirements

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