PAPR Reduction as an Enhancement in OFDM

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Abstract— This paper is engrossed on the critical issue of high PAPR in the most promising high speed communication system using Orthogonal Frequency Division Multiplexing (OFDM). However, OFDM, as an attractive modulation scheme, has shown noteworthy attention across multipath fading channels. It transmits the large amount of data over radio waves but, the summation of data in time domain OFDM signal results in high PAPR which is the major downside of OFDM system. This high PAPR engenders the requirement of PA (Power Amplifier) to be linear in its wide dynamic range and PA's efficiency is a dependent factor of its linear dynamic range which decreases as the range increases.Numerous techniques have been suggested to reduce the PAPR in OFDM. But to reduce high PAPR, there is a hidden cost that has to be paid in terms of payload data rate reduction. This paper sheds light on few reduction techniques (Clipping and Filtering, Selective Mapping) of PAPR, and their comparative study.

Keywords—Orthogonal Frequency Division Multiplexing (OFDM), Peak to Average Power Ratio (PAPR), Clipping and Filtering, Selective Mapping

I. INTRODUCTION

Due to its intrinsic robustness against multipath fading channels, orthogonal frequency division multiplexing (OFDM) has come to the forefront of technology in the field of Wireless communication systems [1]. OFDM is a multicarrier modulation technique transmitting large data over radio waves. While sending high rate DataStream, it splits it into number of lower rate streams which are transmitted over a number of subcarriers in parallel. In a decade, OFDM has emerged as the standard of choice in a number of important high data applications. It finds its application widely being used in Digital Television Broadcasting (such as the digital ATV Terrestrial Broadcasting), European Digital Audio Broadcasting (DAB) and Digital Video Broadcasting Terrestrial (DVB-T), Wireless Asynchronous Transfer Mode (WATM).) [2], [3]

It is based on the principle of transmitting simultaneously many narrow- band orthogonal frequencies, often also called OFDM subcarriers or subcarriers. [1], [4]. The number of subcarriers is often noted by *N*. These frequencies are orthogonal to each other which eliminate the interference between channels. OFDM uses the spectrum much more efficiently by spacing the channels more closely together. The mathematical and diagrammatical representation of OFDM in time–domain model is:

$$x(t)=\frac{1}{\sqrt{N}}\sum_{k=0}^{N-1}X[k]e^{j2\pi kt/T}$$

Where:

X(t) - Continuous time baseband OFDM symbol
N - Number of Subcarriers
f - Subcarrier spacing
T - OFDM symbol period (*T = 1/f*)
X[k] - Digitally modulated data symbol

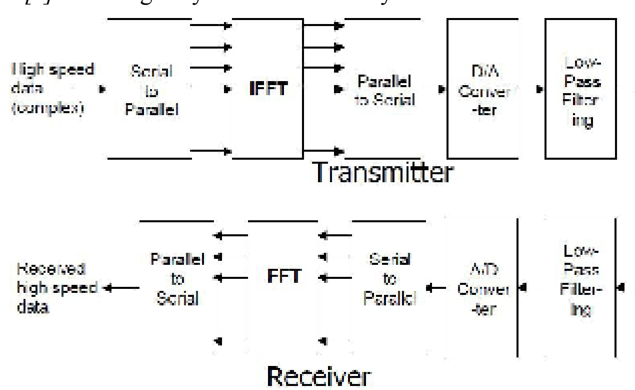

Fig.1. Baseband OFDM System

I. PAPR - PROBLEM AND REDUCTION REQUIREMENT

OFDM is very effective and efficient technique in the field of high speed multi-carrier data transmission. However, OFDM has a drawback too in the sense that it exhibits high PAPR (Peak to Average Power Ratio) due to the time-domain superposition of many data subcarriers, and thus the resulting time domain signal exhibits the Rayleigh-like characteristics and large time–domain amplitude variations [5]. The output in OFDM is superposition of multiple subcarriers which may cause some instantaneous power output to increase and thus become far higher than the mean power of the system. It requires high power amplifiers (HPA) to transmit signals with high PAPR [6]. These types of PA's are low efficiency with high cost and, also can lead to nonlinear power amplifiers, if the peak power is too high.

PAPR: In simple, PAPR can be defined as the ratio between the maximum power and the average power, and is defined by the equation below:

$$PAPR = \frac{P_{peak}}{P_{average}} = MAX\,[\,|X_n|^2] \,/\, E\,[\,|X_n|^2]$$

II. PAPR REDUCTION TECHNIQUES

In the past recent years a variety of techniques have been proposed to reduce PAPR. These techniques are divided mainly into two groups - *signal scrambling techniques* and *signal distortion techniques* which are given below [7]:

A) Signal Scrambling Techniques:

- Block Coding Techniques
- Block Coding Scheme with Error Correction
- Selected Mapping (SLM)
- Partial Transmit Sequence (PTS)
- Interleaving Technique
- Tone Reservation (TR)
- Tone Injection (TI)

B) Signal Distortion Techniques:

- Peak Windowing
- Envelope Scaling
- Peak Reduction Carrier
- Clipping and Filtering

Scrambling techniques scramble the codes to decrease the PAPR. Coding techniques can be used for signal scrambling. Signal scrambling techniques with side information introduces redundancy and thus does not result in effective throughput. On the other hand the signal distortion techniques reduce high peaks directly by distorting the signal prior to amplification. But they introduce both In-band and Out-of-band interference and complexity to the system.

II. CLIPPING AND FILTERING AS A SIGNAL DISTORTION TECHNIQUE FOR REDUCING PAPR IN OFDM

Clipping being the simple and effective PAPR reduction technique, cancels the signal components that exceed some unchanging amplitude called clip level. Clipping is nonlinear process [8] and causes in-band noise distortion, which causes degradation in the performance of bit BER and out-of-band noise, which decreases the spectral efficiency. However, the clipping introduces signal distortion but this undesirable effect can be suppressed by low pass filtering of clipped signal that unfortunately further increases the PAPR.

A method [9] called repeated clipping and filtering that is based on *K*-times repetition of the clipping and filtering process. Therefore both PAPR and adjacent spectral emissions are reduced, although the PAPR reduction is far from simple clipping case. But the major downside of this method is its high complexity. For each frequency domain filtering, two FFT calculations are necessary. A method named simplified clipping and filtering with bounded distortion (SCAFBD) gives almost the same PAPR reduction as repeated clipping and filtering, but the complexity is significantly reduced. Only 3 FFT's are required for the PAPR reduction equivalent to iterative method using arbitrary *K*.

III. METHOD DESCRIPTION

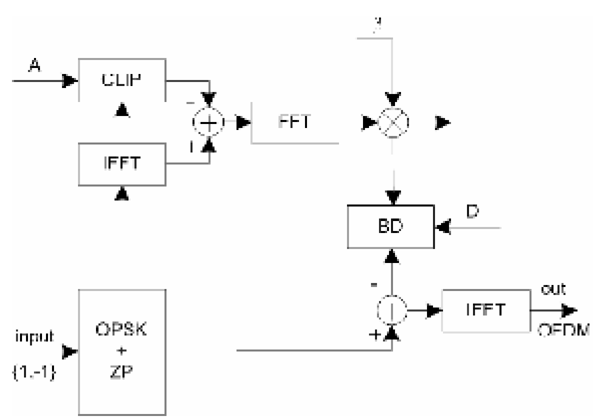

Fig.2. Block diagram for SCAFBD

Firstly the input data are mapped according to the selected constellation (QPSK). Then, Z zero subcarriers are inserted to zero-pad the signal. Resulting data are transformed using IFFT into time domain. Subsequently, the signal is clipped to level *A*. The error signal is computed as the difference between the original and clipped signal. This error signal is transformed back into frequency domain by using FFT and multiplied by the constant β, corresponding chosen number of clipping and filtering stages. The modified error signal in the frequency domain is then passed through the block ensuring the distortion bounding (limitation of I (real) and Q (imaginary) part of the error signal separately to value *D*).

For the simulation [9], the OFDM signal with 64 data subcarriers modulated by the QPSK has been used. The signal is 3-times oversampled by zero-padding, normalized to 0dB in the time domain and clipped to A=3dB. The constant β is set as the equivalent to 3-times repetition of clipping and filtering process. The distortion bound is derived using constant D=10.

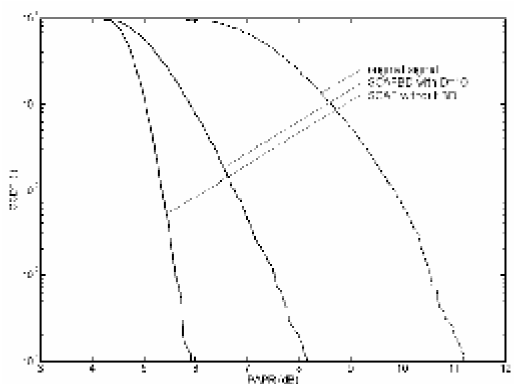

Fig.3. CCDF function for PAPR

III. SELECTIVE MAPPING (SLM) AS A SCRAMBLING TECHNIQUE FOR REDUCING PAPR IN OFDM

In SLM technique [10]-[11], firstly U independent vectors are generated. Each of these containing N random phase symbols in order to improve the PAPR of the symbol block that is to be transmitted. Each of these vectors is used to modify the phases of the complex baseband information symbols in order to randomize the phases in the block around the unit-circle. Therefore, this process produces U new sets of phase-modified symbol $X.S^1, X.S^2, \ldots\ldots X.S^U$. all the new symbols carry the same original information as X, but each with a different phase-mask. After passing each of the U modified symbols through the IFFT process, the symbol with the best PAPR performance will then be selected for transmission. Although PAPR reductions of several dBs can be achieved by using this method but this method invokes the IFFT operation U times per OFDM-block. Due to this, the system complexity significantly increases and hence power consumption and time latency.

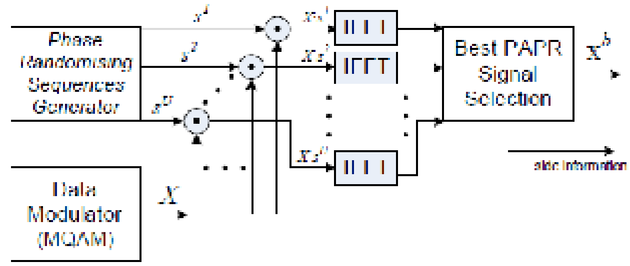

Fig4. Transmitter Scheme for SLM

A novel method *Post-IFFT Amplitude Transforming (PIAT)* have been proposed which applies the randomizing procedure directly in the power spectrum and then generate a corresponding amplitude coefficient sequence for the time domain signal. By doing this, multiple IFFT units and huge amount of searching and computational process can be avoided and thus reducing system complexity.

IV. OVERALL COMPARISON BETWEEN REDUCTION TECHNIQUES

PARAMETERS/ REDUCTION TECHNIQUE	CLIPPING AND FILTERING	SELECTIVE MAPPING
DISTORTION LESS	NO	YES
POWER INCREASE	NO	NO
RATE LOSS	NO	YES
COMPLEXITY	YES	YES
PROMISING METHOD	SCAFBD	PIAT

V. CONCLUSION

Basic requirement of practical PAPR reduction techniques include the compatibility with the family of existing modulation schemes, high spectral efficiency and low complexity. There are many factors to be considered before a specific PAPR reduction technique is chosen. These factors include PAPR reduction capacity, Power increase in transmit signal, BER increase at the receiver, loss in data rate, computational complexity increase and so on. No specific PAPR reduction technique is the best solution for all multi carrier transmission. Rather the PAPR reduction technique should be carefully chosen according to various system requirements. The method for PAPR reduction IN OFDM signal by the time domain clipping with bounded distortion Signal by the time domain clipping with bounded distortion and SLM provides good PAPR reduction and increase signal noise immunity. When compared with the ordinary SLM