ISSN 2395-695X (Print)
ISSN 2395-695X (Online)

International Journal of Advanced Research in Biology Engineering Science and Technology (IJARBEST)

Vol. 2, Special Issue 10, March 2016

REDUCTION OF PAPR IN OFDM USING COMBINATORIAL CLIPPING AND SELECTED MAPPING METHOD

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ABSTRACT

In this project, a technique to handle the problem of high peak to average power ratio (PAPR) in orthogonal frequency-division multiplexing (OFDM) systems. The presented scheme is a combination of two well-known techniques, namely selected mapping (SLM) and clipping. In contrast to other hybrid schemes, where the mentioned techniques are performed consecutively, integrate the clipping procedure in the SLM algorithm. This yields an additional PAPR reduction compared to the serial combination. Further, the clipping strategies are considered with focus on receiver side peak reconstruction using methods provided by the theory of Compressed Sensing. Knowledge on the clipping strategies at the receiver yields an additional gain in peak reconstruction and reduces the bit error probability of the transmission. It provides verification for the performance of the presented scheme.

1. Introduction

Orthogonal frequency division multiplexing (OFDM) is a method of digital modulation in which a signal is split into several narrowband channels at different frequencies.

Orthogonal frequency division multiplexing (OFDM) is a method of encoding digital data on multiple carrier frequencies. OFDM has developed into a popular scheme for wideband digital communication. OFDM is a frequency division multiplexing (FDM) scheme used as a digital multi carrier modulation method. A large number of closely spaced orthogonal sub-carrier signals are used to carry data on several parallel data streams or channels. Each sub-carrier is modulated with a conventional modulation scheme at a low symbol rate, maintaining total data rates similar to conventional single-carrier modulation schemes in the same bandwidth.

In recent years, need for high speed data transmission has increased with the rapid growth in digital wireless communication. Orthogonal Frequency Division Multiplexing (OFDM) is the most popular and widely used method for data transmission in the area of high speed communication systems [1]. But the major disadvantage of OFDM systems is the non-linear distortion caused due to high peak-to-average power ratio (PAPR) of the transmitted signal. OFDM consists of large number of independent subcarriers, as a result of which the amplitude of such a signal can have high peak value A large PAPR ratio brings disadvantages like an increased complexity of the analog to digital (A/D) and digital to analog (D/A) converters and a reduced efficiency of the RF power amplifier.

OFDM is used in many applications owing to its robustness to frequency selective fading or narrowband interference, high bandwidth efficiency and efficient implementation. This

ISSN 2395-695X (Print)
ISSN 2395-695X (Online)

International Journal of Advanced Research in Biology Engineering Science and Technology (IJARBEST)

Vol. 2, Special Issue 10, March 2016

technique has found many applications in digital audio broadcasting (DAB) systems, digital video broadcasting terrestrial TV (DVB-T) systems, wireless local area networks (WLAN), broadband wireless access (BWA) networks and ultra wideband systems. Moreover, it is expected to be the standard for the Fourth Generation (4G) cellular system. The carriers used to transmit the data in OFDM systems are orthogonal to each other. This will provide a lot of advantages over other systems. By dividing the channel into narrowband flat fading sub channels, OFDM is more resistant to frequency selective fading.

2. Related Work

In this section, we first describe studies related to our work and then, we briefly provide background on the EVM calculation required by our system.

Frequency selective fading. There are studies that employ rate adaptation to cope with frequency selective fading. For example, in [2] the authors propose frequency aware rate adaptation (FARA) to improve system performance. They assign subsets of sub-bands to each sender-receiver pair and based on the SNR reported by the receiver on these sub-bands, the sender performs rate adaptation. The authors do not propose a solution to improve the performance of sub carriers experiencing frequency selective fading or low SNR. Bhartia et al. [3] propose a smart mapping of symbols to sub-carriers. This supports partial recovery of symbols if they are lost due to frequency selective fading. They also propose an extra layer of FEC codes on top of Physical layer FEC. One of the main limitations of this work is that the proposed solution is only compatible with block FEC schemes and its not clear how it will work with convolutional or turbo code FECs. A large amount of feedback information is also required for partial symbol recovery. In contrast our scheme is not limited by the choice of FECs and the amount of feedback information is low.

Rate adaptation. There is a large volume of studies on rate adaptation. SampleRate [8], proposed by Bicket et al., probes the performance at a random rate every 10 frames, and selects the rate that minimizes the expected transmission time (including retransmissions). Wong et al. [6] develop robust rate adaptation algorithm (RRAA), which uses short term loss ratios to opportunistically change rate. It further incorporates an adaptive RTS filter to prevent collision losses from lowering data rates. All these (and many similar) existing schemes adapt rate according to frame loss rates. RBAR uses the RTS/CTS exchange to estimate the SNR at a receiver, and picks the transmission bit rate accordingly. OAR further builds on RBAR, by opportunistically transmitting back-to-back frames when the channel quality is good. CHARM [7] leverages the reciprocity of the wireless channel to estimate the average SNR at the receiver using packets overheard from the latter. The overhead of RTS/CTS (present with RBAR and OAR) is thus avoided and implementation on commodity cards is enabled. Sen et al. [4] propose the use of error vector magnitude to perform rate adaptation. Since the above rate adaptation schemes use information such as loss ratio, SNR and EVM averaged over a packet, they fail to capture the effects of frequency selectivity. On the contrary, we try to directly address issues related to frequency selective fading by using per subcarrier EVM measurements.

Multi-user OFDM. There exist a few studies on subcarrier, power and rate assignments in multi-user scenarios. In this case a single channel is shared among multiple users. Kittipiyakul and Javidi propose a scheme to outperform “water filling based multi-user subcarrier assignment” by introducing a subcarrier allocation scheme which takes the queue lengths of different users into account. Adaptive power allocation for a multiuser OFDM environment has

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been proposed in [5]. An OFDM channel is divided into multiple subbands and these subbands are assigned to different users. To alleviate frequency selective fading experienced by different users, redistribution of power and modulation on these subbands is done according to the SNR experienced by the users. The majority of these studies are evaluated only via simulations by making assumptions about channel conditions. Furthermore, power adaptation is done for each user and not on a per OFDM sub-carrier basis.

Error vector magnitude. In this work we use the EVM per subcarrier as the carrier state information (CSI) feedback from the receiver, for the sender to perform power redistribution and rate selection. EVM is a vector measurement taken in terms of peak percentages between the ideal symbol position and the actual measured position in the constellation space for a particular modulation. The error vector is a vector in the I-Q plane between the ideal constellation point and the data interpretation by the receiver. In other words, it is the difference between the actual received symbols and the ideal symbols. The average power of the error vector, normalized to the signal power, is the EVM. It can be expressed as a percentage:

$$EVM(\%) = \sqrt{\frac{P_{error}}{P_{reference}}} * 100,$$

where, Perror is the RMS power of the error vector and Preference is defined as the reference constellation average power. In contrast to SNR, higher EVM values correspond to bad channel conditions, while lower EVM values represent good channel conditions. Note that in JPRA, SNR can be used in lieu of EVM with very minimal changes. It only requires changing of the EVM based rate table to a SNR based rate table and replacing the EVM with SNR in the calibration phase; Specifically, in this phase changes in SNR with changes in transmission powers will be recorded.

3. PEAKS-TO-AVERAGE-POWER RATIO (PAPR)

PAPR can be defined as the relationship between the maximum power of a sample in a transmit OFDM symbol and its average power Where P_{peak} and $P_{average}$ are the peak and average power of a given OFDM symbol. The same definition of PAPR is applied to MIMO-OFDM. The transmit signals in an orthogonal frequency-division multiplexing (OFDM) system can have high peak values in the time domain since many subcarrier components are added via an inverse fast Fourier transformation (IFFT) operation.

As a result, OFDM systems are known to have a high peak-to-average power ratio (PAPR) when compared to single-carrier systems [3]. In fact, the high PAPR is one of the most detrimental aspects in an OFDM system as it decreases the signal to quantization noise ratio (SQNR) of the analog digital convertor (ADC) and digital analog convertor (DAC) while degrading the efficiency of the power amplifier in the transmitter. As a side note, the PAPR problem is more of a concern in the uplink since the efficiency of the power amplifier is critical due to the limited battery power in a mobile terminal.

- Selected Mapping (SLM) and Clipping.
- Integrate the Clipping Procedure in the SLM Algorithm.

3.1 CLIPPING METHOD

A technique that does involve signal distortion is clipping. If the PAPR problem is not handled beforehand, the RF power amplifier of the transmitter automatically clips the peaks when it runs into saturation. This is inefficient, and there are more intelligent ways to generalize

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ISSN 2395-695X (Online)

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this clipping, and to process the peaks in digital baseband domain. In the Following we describe the model and some strategies. The clipping is the easiest technique to reduce the power by setting a maximum level for the transmitted signal. This is the method of clipping the high peaks of the OFDM signal before passing it through the power amplifier (PA). This is done with the help of clipper that limits the signal envelop to the predetermined level known as clipping level (CL).

3.2 SELECTED MAPPING METHOD

Selected Mapping Method is to select the lowest PAPR. SLM exploits the almost-Gaussian random nature of the OFDM signal to reduce the PAPR. Let {a (1)... a (U)} be a set of independent OFDM frames of length N. Then, the probability that the smallest occurring PAPR exceeds a threshold.

3.3 COMBINING METHOD

To improve the PAPR performance further, one can think of combining both methods. Note that this also combines the negative side-effects of both methods, namely signal distortion and the side-information problem. A first idea is to simply concatenate SLM and clipping, as considered for instance in. The block diagram is depicted in and the corresponding CCDF for varying parameters is shown. There is an improvement compared to using either of the methods exclusively, (note the modified scaling for visibility). However, we also observe that the relative gain achieved by increasing either S or U is quite limited.

4. PAPR REDUCTION OF TRANSMITTER SIDE

The SLM technique is developed from the idea of symbol scrambling. In this technique, the signal with lowest PAPR is selected and transmitted.

SLM exploits the almost-Gaussian random nature of the OFDM signal to reduce the PAPR. Let {a (1)... a (U)} be a set of independent OFDM frames of length N. Then, the probability that the smallest occurring PAPR exceeds a threshold γ, is given by

$$P\left(\min_{r}\left(PAPR\left(a^{(r)}\right)\right) > \gamma\right) = ccdf(\gamma)^{u} \qquad (1)$$

To obtain U independent OFDM frames that carry the same information, a transformation of the frequency domain frame s has to be accomplished, that does not change the statistics after IDFT. For instance, this can be achieved by random phase rotations of the data symbols.

$$S(u) = R(u)_{s} \qquad (2)$$

For u = 1. . . U, where each R (u) is a diagonal matrix with diagonal entries on the complex unit circle. In this paper we consider a very basic version, multiplying the with elements from the set {1, j, - 1, -j}, drawn independently at random with equal probability. After multiplying the data vector by different rotation matrices and performing IDFT, the algorithm compares the occurring PAPR values and selects the candidate with the lowest transmission.

A technique that does involve signal distortion is clipping. If the PAPR problem is not handled beforehand, the RF power amplifier of the transmitter automatically clips the peaks when it runs into saturation. This is inefficient, and there are more intelligent ways to generalize this clipping, and to process the peaks in digital baseband domain. In the Following to describe the model and some strategies. Here want to transmit an OFDM frame a, corresponding to a frame a, that contains no entries with a magnitude larger than a given threshold, γ > O.

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- MIN Clipping
- ZERO Clipping
- MAX Clipping
- Suboptimal MINIMAX

MIN CLIPPING

Basically, this is what the amplifier does: clip the largest peaks down to a magnitude of "preserving the phase". That is,

$$\text{Clip}(a_k) = \gamma\, a_k / |a_k| \tag{3}$$

ZERO CLIPPING

Set all peaks to zero, i.e.

$$\text{Clip}(a_k) = 0 \tag{4}$$

MAX CLIPPING

Clip the largest peaks to a magnitude of, and put them on the

opposite side. That is,

$$\text{Clip}(a_k) = -\gamma\, a_k / |a_k| \tag{5}$$

SUBOPTIMAL MINIMAX

Setting, to the (5 + 1) –the largest magnitude has two major drawbacks: the value is data-dependent and changes between different OFDM frames, and it also has to be known to the receiver. Therefore we use a fix, that is sufficiently large and exceeds the remaining (N -5) elements only with small probability. Refer to the appendix for further information on the choice of, and its impact on the PAPR.

5. COMBINING CLIPPING AND SLM

This project presents a technique to handle the problem of high peak-to-average power ratio (PAPR) in orthogonal frequency-division multiplexing (OFDM) systems. The presented scheme is a combination of two well-known techniques, namely selected mapping (SLM) and clipping. In contrast to other hybrid schemes, where the mentioned techniques are performed consecutively, we integrate the clipping procedure in the SLM algorithm. This yields an additional PAPR reduction compared to the serial combination. Further, the clipping strategies are considered with focus on receiver side peak reconstruction using methods provided by the theory of Compressed Sensing. Knowledge on the clipping strategies at the receiver yields an additional gain in peak reconstruction and reduces the bit error probability of the transmission. Simulation results verify the performance of the presented scheme**.**

To improve the PAPR performance, so think of combining both techniques. The clipped SLM is more efficient in both PAPR performance and overall transmit power reduction.

To improve the PAPR performance further, one can think of combining both methods. Note that this also combines the negative side-effects of both methods, namely signal distortion and the side-information problem.

To overcome this limitation and fully benefit from SLM and clipping we propose a hybrid method that integrates the clipping procedure into the SLM algorithm rather than

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concatenating them,

- rotate the input OFDM frame with different R (u),
- perform IDFT and clip each candidate, and
- Select a candidate with lowest PAPR for transmission.

5.1. RECEIVER SIDE

Compressed sensing (also known as compressive sensing, compressive sampling, or sparse sampling) is a signal processing technique for efficiently acquiring and reconstructing a signal, by finding solutions to underdetermined linear systems. This is based on the principle that, through optimization, the sparsity of a signal can be exploited to recover it from far fewer samples than required by the Shannon-Nyquist sampling theorem. There are two conditions under which recovery is possible. The first one is sparsity which requires the signal to be sparse in some domain. The second one is incoherence which is applied through the isometric property which is sufficient for sparse signals.

To avoid losses in system performance due to clipping, it is necessary to estimate the clipping signal at the receiver. In this paper we focus on sparse clipping reconstruction using methods provided by Compressed Sensing theory.

The theory of Compressed Sensing also deals with the noisy measurement model.

$$Y = \Omega x + n \qquad (6)$$

The noise vector n is usually modeled to consist of i.e. complex Gaussian entries. Compressed Sensing theory provides many results that state robustness with respect to these noisy observations. The RI-optimization problem has to be adapted, and greedy algorithms can also be applied.

5.2. PAPR FORMULA

The central limit theorem, the time-domain signal components a_k are almost Gaussian distributed for large N. This implies a high PAPR.

$$PAPR = Max\,(|a_K|^2)/Mean\,(|a_K|^2) \qquad (7)$$

Where,

a_K = Signal Component.

This is expressed by the complementary cumulative distribution function CCDF of the PAPR which is well approximated by,

$1 - (1 - \exp\,(\gamma\text{-,})^{N})$ for, $\gamma > 0$ and sufficiently large N.

Ccdf $(\gamma) = p_r\,(PAPR > \gamma)$ (3.8) Finally here to reduce the peak to average power ratio using the technique selected mapping and clipping in transmitter side and reconstruct the clipped signal in receiver side.

6. Experimental Analysis

The technique of A Hybrid PAPR Reduction Scheme for OFDM using SLM with Clipping at the Transmitter, and Sparse Reconstruction at the Receiver using Mat lab R2014a. Mat lab is appropriate software for analysis the work done evaluation of results for OFDM.

S.NO	SIGNALS	POWER (dB)
1	Original Signal	0.076274 dB
2	Clipped Signal	-0.923726 dB
3	Mapped Signal	-2.473989 dB

ISSN 2395-695X (Print)
ISSN 2395-695X (Online)

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4	Combined Clip-Mapped Signal	-2.545275 dB

Table No 6.1: PAPR Reduction

This tabulation results shows the reducing the peak to average power ratio using selected mapping and clipping method.

7. Conclusion and Future Work

In this project, significantly reduced PAPR has been obtained in OFDM transmission systems with the hybrid method. This PAPR reduction involves clipping and mapping strategy. The strategy has an impact on the ability of a compressed sensing theory to detect the correct clipping distortion signal. With a suitable strategy on CCDF have seen that the PAPR reduction performance. The integration of other clipping strategies can be done without any additional effort.

In future work, extending the recent work with the clipped SLM idea to an adaptive algorithm, which allows an affordable PAPR at the transmitter and reduces the number of, clipped peaks adaptively.

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