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PEAK-TO-AVERAGE-POWER REDUCTION TECHNIQUES IN OFDM SYSTEM

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ABSTRACT:

Orthogonal frequency division multiplexing (OFDM) is an appealing technique for achieving high bit-rate data transmission, due to its robustness against the multipath fading and Inters Symbol Interference (ISI). One of the main problems of OFDM technique, high peak-to-average-power ratio of transmitted signal is due to the superposition of many subcarriers. In this paper, we described the popular methods for PAPR reduction.

Keywords- Orthogonal Frequency Division Multiplexing (OFDM), Peak to Average Power Ratio (PAPR), PTS, SLM, TR, TI.

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is very attractive multi-carrier modulation (MCM) scheme technique used for 4th Generation (4G) wireless communication. OFDM has been very popular technique due to many advantages such as [1] [2].

Computationally efficient: because of using FFT techniques to implement the modulation and demodulation process.

Fading resistant: because of the parting the channel into narrowband flat-fading sub channels.

Symbol recovery: because of the use of adequate channel coding and interleaving.

Power efficient: due to use power allocation algorithms.

Bandwidth efficient: because of having the advantages of mitigating ISI in frequency selective fading channels

Noise resistant: because of protection against co-channel interference and impulsive parasitic noise.

ISI elimination: because of use of cyclic prefix.

Due to these merits OFDM is chosen as high data rate communication systems such as Mobile Communication, Digital Audio Broadcasting (DAB), Digital Video Broadcasting terrestrial (DVB-T) and based Worldwide Interoperability for Microwave Access (Wi-MAX) [3].

IEEE 802.11, IEEE 802.16, IEEE 802.20 European Telecommunications Standards Institute (ETSI) & Broadcast Radio Access committees established international standards making use of OFDM for high speed wireless communications [4, 5].

II. OFDM MODEL

In OFDM modulation technique, a block of N data symbols, $X_k = (X_0, X_1 \dots X_{N-1})$ is formed with each symbol modulating the corresponding subcarrier from a set of subcarriers. In OFDM, the incoming data is first modulated by using QPSK modulation. An OFDM carrier signal is the sum of a number of orthogonal subcarriers, with baseband data on each subcarrier being independently modulated commonly using some type of quadrature amplitude modulation (QAM) or phase shift keying (PSK). While it is promising to transmit more bits per symbol, if the energy of the constellation is to remain the same, the points on the constellation must be closer together and the transmission becomes more susceptible to noise. This results in a higher bit error rate than for the lower order QAM variants. In this mode there is a balance between achieving higher data rates and maintaining a satisfactory bit error rate for any radio communications system. The N subcarriers are chosen to be orthogonal. [6]

The complex baseband OFDM signal for *N* subcarriers can
be written as

$$x(t) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k e^{j2\pi k f_0 t} \qquad 0 \le t \le T \quad (1)$$

Replacing t = nT_b where T_b = T/N, gives the discrete time version denoted by

$$x(n) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k \; e^{\frac{j2\pi kn}{LN}} \qquad n = 0, 1 \dots, NL-1 \quad (2)$$

Where *L* is the oversampling factor.

III. PAPR

A well-known drawback of OFDM is that the amplitude of the time domain signal varies strongly with the transmitted symbols modulated on the subcarriers in the frequency domain, resulting in a ‘peaky’ signal. If the maximum amplitude of the time domain signal is too large, it pushes the transmit amplifier into a non-linear region which distorts the signal resulting in a substantial increase in the error rate at the receiver[7].

The PAPR of OFDM signal sequence is defined as the ratio between the maximum instantaneous power and its average power, which can be written for the oversampled OFDM signal symbol

$$PAPR = \frac{\max 0 \le t \le T \; |x(t)|^2}{E \; [\; |x(t)|^2]} \qquad (3)$$

where E is the expectation operator.

The above power characteristics can also be described in terms of their magnitudes (not power) by defining the crest factor (CF) as:

$$CF = \sqrt{PAPR} \qquad (4)$$

IV. PAPR REDUCTION TECHNIQUES

4.1 Block Coding Technque

Block coding is the simple technique to diminish PAPR. The basic principle of block coding technique is to select code words with low peak power after coding from all probable symbols. With N sub-carrier QPSK modulation provides 2N bits and thus 2^{2N} messages [8].

If k bit data block is encoded by (n, k) block code with generation matrix G at transmitter and a phase rotator vector b is used to produce encoded output. By separating large information sequence into different sub-blocks and encode these sub-blocks with system on programmable chips (SOPC) large PAPR reduction can be achieved [8].

4.2 Partial Transmit Sequences

Partial Transmit Sequences (PTS) generates a signal with a low PAPR through the addition of appropriately phase rotated signal parts. Fig shows the block diagram of the partial transmit sequence (PTS) technique. The signal

$X = [X_0, X_1, \ldots \ldots X_{Nc-1}]^T$ to be transmitted is partitioned into disjoint sub-blocks X^v of length N_c/V which is represented by the vector $X = [X^1, X^2, \ldots \ldots X^v]^T$ as $X = \sum_{v=1}^{V} X^v$. Where $N_c$the number of subcarriers and V is is the number of sub-blocks. Complex phase factors

$b^v = e^{j\varphi_v}, \varphi^v \in [0, 2\pi)$ and v = 1, 2,....,V are introduced to combine the PTS's in the block diagram.

The phase vectors are selected in such a way that the PAPR of the combined signal get minimize.

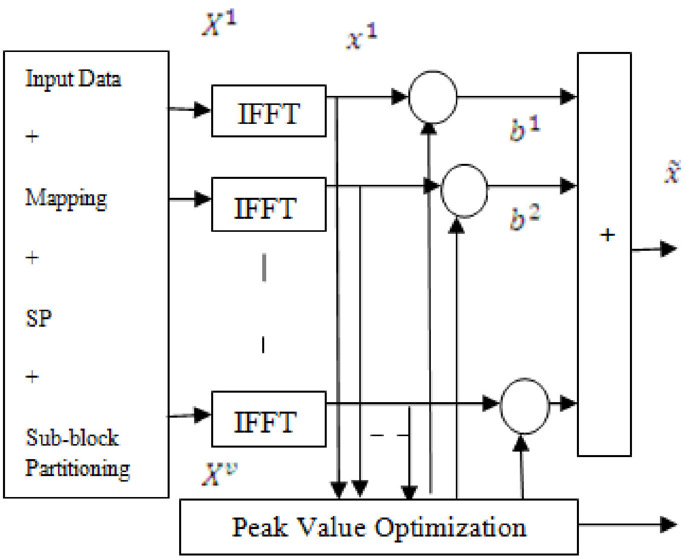

Fig 1: Block diagram of PTS technique

Each

sub-block vector is given by $\hat{X} = \sum_{v-1}^{V} b^v X^v$. Time domain signal X is obtained by applying IFFT operation on $\hat{X}$ that is

$$\mathbf{x} = IFFT\ (\hat{X}) = \sum_{v=1}^{V} b^v\ IFFT\ (X^v) = \sum_{v=1}^{V} b^v\ \mathrm{x}^v$$

Select one suitable factor combination $b = (b^1, b^2, \ldots, b^v)$ which makes the result optimum. The combination can be given by:

$$b = (b^1, b^2, \ldots, b^v) = argmin_{(b^1, b^2, \ldots, b^v)}(\max(n = 0,1, \ldots, N_c - 1) \mid \sum_{v=1}^{V} b^v X^v |^2)$$

In such a way we can find the best **b** to optimize the PAPR performance. The additional cost is to be paid for extra V-1 times IFFTs operations [10].

4.3 Selected Mapping

This technique works on the principle of choosing a copy of signal with lowest PAPR among multiple copies generated from original signal through some series of codes. In this mapping, side information is required at the destination side to match the sent signal. SLM has been considered with the drawback of high computational complexity [5].

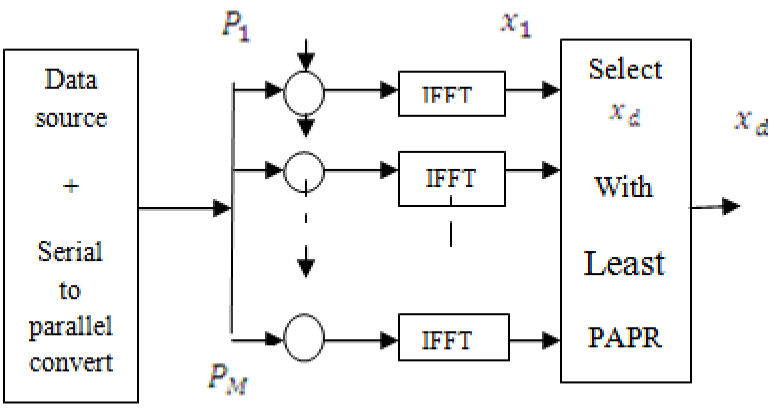

Fig 2: Block diagram of SLM technique

4.3.1 Comparison of PTS and SLM

Both are probabilistic methods for PAPR reduction. In concept of OFDM signals generation, SLM produce multiple time domain asymptotically independent signals while PTS generates alternative signals. When we compare the complexity of both, PTS is more advantageous as frequency vector in PTS is divided into many sub-blocks before phase transformation. Although PTS performs better than SLM but necessary bits for side information is larger than required in SLM.

4.4 Clipping And Filtering

This PAPR reduction technique is used mostly where some part of the signals is to be clipped which is outside the specified region. Usually clipping is done at transmitter side and receiver is to recover the OFDM signal by the estimation of clipping's location and size. Thus clipping method diminishes the BER and spectral efficiency by introducing both in band distortion and out of band radiation into OFDM signals [11].

Filtering method is used to reduce out of band radiation after clipping. A repeating combined method of clipping and filtering is used to degrade the peak re-growth generated by clipping method at the cost of computational complexity.

4.5 TR And TI

In the PAPR reduction techniques of TR and TI, both transmitter and receiver reserve a part of tones which are not used for data transmission [10].

In TR, PAPR reduction signal in time domain $\boldsymbol{c}$ is to be added to the original time domain signal x. After TR processing, we would get the new modulated OFDM signals

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$$\tilde{X} = IFFT\ (\mathbf{x} + \mathbf{c}) = \mathbf{X} + \mathbf{C}$$

Where **C** = *IFFT* (**c**)

and $\{\mathbf{c} = c_n | n = 0,1,\ldots,N-1\}$

Our objective in TR is to find the suitable value of **c** by convex optimization in the form of linear programming.

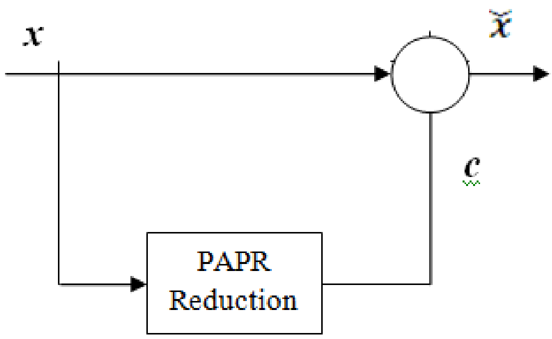

Fig 3: Block diagram of TR/TI

In the same way, TI uses an extra correction to optimize **C.** The basic idea used in this technique is to increase the constellation size so that each symbol in the data block can be mapped into one of the several equivalent constellation points, these extra degrees of freedom can be exploited for PAPR reduction. Here the transmitted power increases.

V. CONCLUSION

In this paper, most popular techniques for PAPR reduction have been analyzed. These techniques are capable to significant reduction in PAPR at the cost of data rate, more power transmitted, lacking BER performance, increased computational complexity.

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