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Performance Evaluation of Hybrid PAPR Reduction Methods

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Abstract - Orthogonal frequency division multiplexing (OFDM) is an efficient multicarrier modulation technique for wireless communication. However, one of the main drawbacks encountered in implementing OFDM is its resultant high peak-to-average power ratio (PAPR). Many techniques have been proposed in the literature to substantially decrease the peaks in the OFDM signal. The problem with these, however, is that their effects on other parameters are not always positive. These effects include a decrease in the bit error rate (BER), an increase in complexity, or a reduction in the bit rate. The objective of this paper is to describe the PAPR problem in a bid to reduce the peaks in the OFDM signal. The paper proposes performance evaluation and optimization of hybrid PAPR reduction techniques for commercial, public safety, and tactical applications. Furthermore, the principal characteristics are compared through a complementary cumulative distribution function and efficiency evaluation.

Keywords —Cyclic prefix (CP), Orthogonal Frequency Division Multiplexing (OFDM), Partial Transmit Sequence(PTS), Peak To Average Power Ratio (PAPR), Selective Mapping (SLM), zero padding (ZP)

I. INTRODUCTION

OFDM, which is a multicarrier modulation technique, is widely employed in broadband wireless communication standards such as IEEE 802.11 (Wi-Fi). In OFDM [1],[2] the entire frequency band is divided into a number of orthogonal sub bands. The data stream is also divided into several parallel data streams of lower rate and the individual subcarriers are modulated by individual low rate data streams and the resultant signals are added up and transmitted. OFDM eliminates intersymbol interference (ISI) with a guard band, which is zero padding (ZP) or cyclic prefix (CP).

II. PAPR ISSUE IN OFDM

The transmitted signals in an OFDM system can have high peak values in time domain because of IFFT operation. Data symbols across subcarriers add up to produce a high peak value OFDM symbol resulting in high peak-to-average power ratio (PAPR) [3]. PAPR of a signal x is the ratio of the maximum power to the average power of the signal and can be defined as in equation (1).

$$PAPR = \frac{max|x(t)|^2}{E[|x(t)|^2]} \quad (1)$$

The maximum possible value of PAPR is N, the number of subcarriers, which occurs when all the subcarriers add up constructively at a single point. The largest PAPR rarely occurs and hence it is a common practice to find the probability that the PAPR of a symbol exceeds a given threshold $PAPR_0$. Hence, for representing PAPR, complementary cumulative distribution function (CCDF) is used, which can be defined as in equation (2).

$$CCDF = P(PAPR > PAPR_0) \quad (2)$$

Large PAPR means that the OFDM signal has a large variation between the average signal power and the maximum signal power.

Different PAPR reduction techniques like clipping, interleaving, tone injection, tone reservation, coding, companding, selected mapping (SLM), partial transmit sequence (PTS), etc. are available in literature. In this paper, performance of different hybrid PAPR reduction techniques are compared in terms of PAPR reduction capability. Efficiency of the proposed new hybrid methods are calculated in terms of its ability to reduce PAPR levels in the system and CCDF graphs are plotted.

III. CONVENTIONAL METHODS

The major conventional PAPR reduction methods [4] are clipping, companding, selected mapping (SLM) and partial transmit sequence (PTS). One simplest approach of reducing the PAPR is to clip the amplitude of the signal to a fixed level. The clipping technique employs clipping or nonlinear saturation around the peaks to reduce the PAPR. It is simple to implement, but it may cause in-band and out-of-band interferences while destroying the orthogonality among the subcarriers. Hence, clipping is followed by

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filtering.

Any invertible function with compression feature can be used for companding. Here one can apply the invertible transformation so as to recover the signal back at the receiver. The major drawback is its out-of-band interference.

In selected mapping method, the input data structure is multiplied by random series and resultant series with the lowest PAPR is chosen for transmission. This allows the receiver to recover the original data with the multiplying sequence which can be sent as coded information.

Partial transmit sequence method is based on the phase shifting of sub-blocks of data and multiplication of data structure by random vectors. This method is flexible and effective for OFDM system. The main purpose of this method is that the input data frame is divided into non-overlapping sub blocks and each sub block is phase shifted by a constant factor to reduce PAPR.

IV. COMBINATIONAL METHODS PROPOSED

Considering the conventional methods, it is proposed to combine them and to evaluate the performances of the combination in PAPR reduction. This section proposes the combination of SLM as well as PTS with companding as well as with clipping.

A. SLM WITH COMPANDING

The block diagram of SLM with companding method is shown in Fig.1 and is achieved by adding a companding block at the beginning of the SLM section of the OFDM.

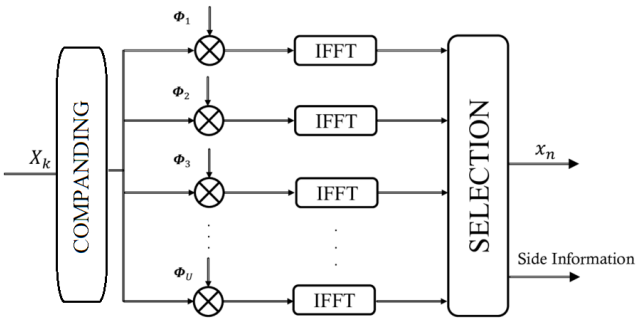

Fig.1 : Block schematic of SLM with companding

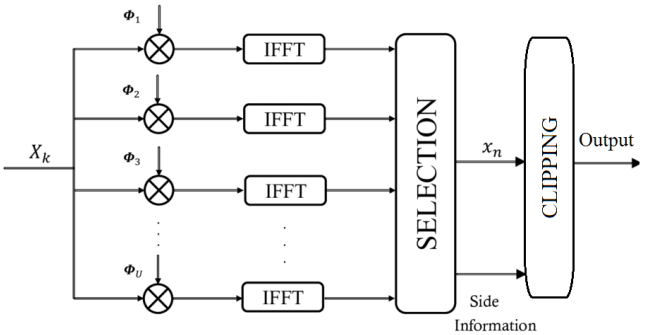

Fig. 2: Block schematic of SLM with clipping

B. SLM WITH CLIPPING

The block diagram of SLM with clipping method is shown in Fig. 2 and is achieved by adding a clipping block at the end of the SLM section of the OFDM.

C. PTS WITH COMPANDING

The block diagram of PTS with companding method is shown in Fig 3 and is achieved by adding a companding block at the end of the PTS section of the OFDM.

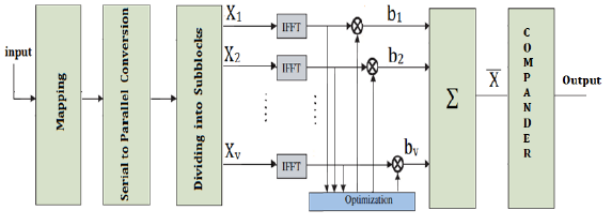

Fig. 3 : Block schematic of PTS with companding

D. PTS WITH CLIPPING

The block diagram of PTS with Clipping method is shown in Fig. 4 and is achieved by adding a clipping block at the end of the PTS section of the OFDM.

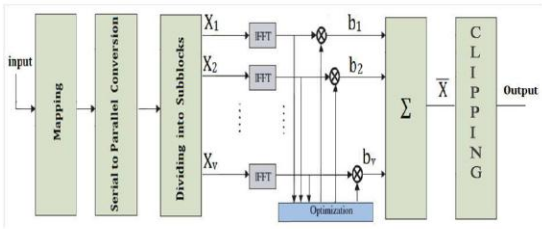

Fig. 4 : Block schematic of PTS with clipping

V. SIMULATION RESULTS

This section discusses the simulation results of the different hybrid PAPR reduction methods proposed.

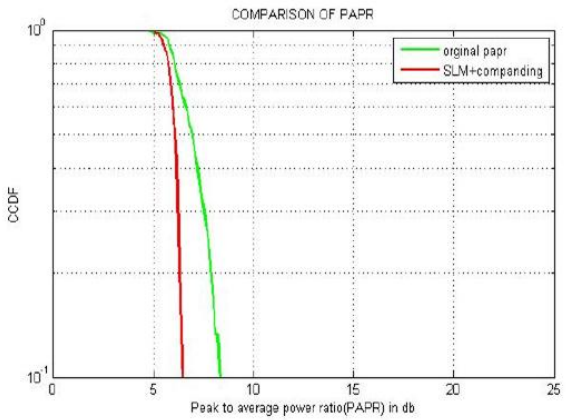

Fig. 5 : Performance of hybrid combination of SLM and companding

Fig. 5 shows the performance of hybrid combination of SLM and companding. It is seen that the CCDF curve shifts to the left when SLM and companding are combined for PAPR reduction, when compared with normal OFDM when no PAPR reduction method has been adopted. At CCDF value of 0.1, PAPR of original input OFDM signal is at 8.169dB, whereas PAPR of hybrid combination i.e., SLM with companding technique is reduced to 6.344dB.

Fig. 6 shows the performance of hybrid combination of

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SLM and clipping. It is seen that the CCDF curve shifts to the left when SLM and clipping are combined for PAPR reduction, when compared with normal OFDM when no PAPR reduction method has been adopted as well as with SLM alone, for PAPR reduction. At CCDF value of 0.1, PAPR of original input OFDM signal is at 8.169dB, whereas PAPR of SLM method alone is 6.5dB and that of hybrid combination i.e., SLM with clipping technique is 5.407dB.

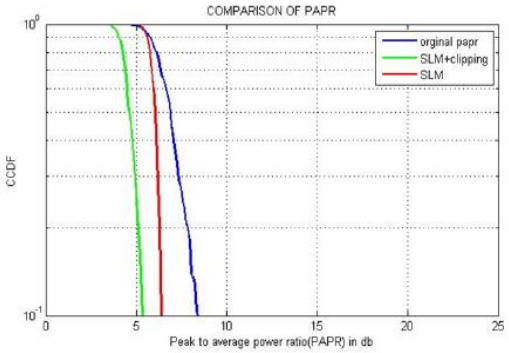

Fig. 6 : Performance of hybrid combination of SLM and clipping

Fig. 7 shows the performance of hybrid combination of PTS and companding. It is seen that the CCDF curve shifts to the left when PTS and companding are combined for PAPR reduction, when compared with normal OFDM when no PAPR reduction method has been adopted as well as when PTS alone has been used for PAPR reduction. At CCDF value of 0.1, PAPR of original input OFDM signal is at 8.169dB, whereas PAPR of PTS alone is 6.792dB and that of hybrid combination i.e., PTS with companding technique is 3.768dB.

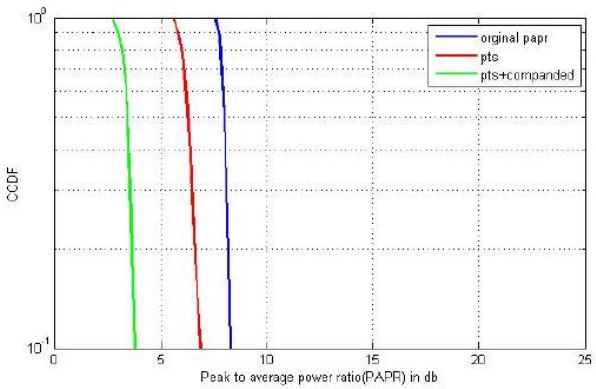

Fig. 7 : Performance of hybrid combination of PTS and companding

Fig. 8 shows the performance of hybrid combination of PTS and clipping. Compared to Fig. 7, it can be seen that at CCDF value of 0.1, PAPR of hybrid method of PTS and companding is at 3.768dB, whereas PAPR of hybrid method of PTS and clipping is 6.2dB. Hence, out of the four hybrid schemes compared, it has been noticed that hybrid combination of PTS and companding is the best scheme for PAPR reduction.

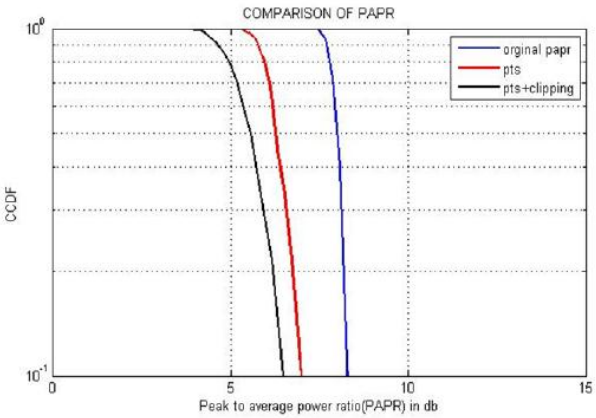

Fig. 8 : Performance of hybrid combination of PTS and clipping

VI. Conclusion

OFDM, which is a multicarrier modulation technique employed in various broadband wireless communication standards suffers from high PAPR. Different PAPR reduction techniques like clipping, interleaving, tone injection, tone reservation, coding, companding, selected mapping (SLM), partial transmit sequence (PTS), etc. are available in literature. This paper proposed performance evaluation of hybrid PAPR reduction techniques i.e. combination of SLM as well as PTS with companding as well as with clipping. From the observations and results obtained, it is clear that the combination of PTS and companding method is highly efficient for maximum PAPR reduction.

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