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PAPR Reduction in OFDM system by Modified DFT spreading technique with Pulse shaping

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Abstract:. OFDM has earned much popularity during recent years due to its high speed, high spectral efficiency, and robustness to multipath fading, robustness to Inter-Symbol Interference (ISI). But high Peak to Average Power Ratio (PAPR) is one of the major problems associated with OFDM system. In this paper we give emphasis on the PAPR reduction of OFDM system using clipping and filtering, PTS, DFT spreading. These techniques are very effective in reducing the PAPR of OFDM system and are distortion less. We proposed a modified DFT Spreading technique combined with the effect of pulse shaping to improve the overall performance of DFT Spreading technique.
Keywords: OFDM, PAPR, inter symbol interference, FFT, IFFT.

Introduction:

One of the prime advantages of OFDM system is that it is highly immune to Inter-Symbol Interference (ISI). This immunity is achieved in OFDM simply by inserting a guard band between successive OFDM symbols. There are three methods by which guard band can be inserted which are cyclic prefix, cyclic suffix and zero padding. The addition of guard band basically transforms the wideband frequency selective channel into a group of narrow parallel narrowband flat fading channel. OFDM has become an absolute solution for various high data rate broad band mobile and wireless communication system because of features like high immunity to multipath fading high speed data transmission rate and requirement of less complex equalizers [1],[2].

Clipping and Filtering Technique

Clipping is one of the simplest and efficient PAPR reduction techniques. It involves cancelling of signal components that exceed some unchanging amplitude level. This unchanging amplitude level is called as clip level. However clipping produce distortion power known as clipping noise which expand the transmitted signal bandwidth. The expanded spectrum of the transmitted signal causes the interference between the subcarriers [13].. Clipping and filtering is the best solution to the problem of expanded spectrum of the transmitted signal. Although filtering can decrease the spectral growth, filtering after clipping can help in minimizing the out-of-band radiation. It may also produce some peak re-growth due to which the peak signal exceed the clip level [15].

The amplitude clipping can be represented by the following equation [27]:

$$y(t) = \begin{cases} -A & if \quad x(t) < -A \\ x(t) & if \quad -A \le x(t) \le A \\ A & if \quad x(t) > A \end{cases}$$

Where, y(t) is passband clipped signal A is pre-specified clipping level & x(t) is passband signal. Clipping is always performed at the transmitter side.. These two problems will degrade the system performance including the BER and spectrum efficiency [5].

Partial Transmit Sequence (PTS) Technique

Partial transmit sequence technique was first proposed by Muller and Hubber in 1997 [21] for reducing high PAPR in OFDM systems.. The fundamental principle of this technique is that the input data block is partitioned into non overlapping sub blocks and each sub block is phase shifted by a constant factor to reduce PAPR of the transmitted data. PTS belongs to the class of probabilistic method for PAPR reduction. It can be said that PTS technique is modified version of SLM technique. A comprehensive block diagram of PTS has been depicted in figure 4.2.

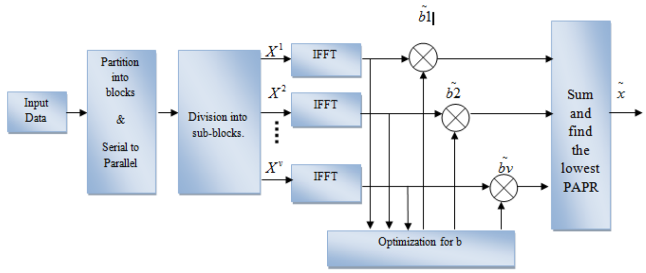

Figure 4.2: Block diagram of PTS technique.

Here the input data block of N symbols is divided into V disjoint sub blocks [12]. The V disjoint sub blocks can be expressed as:

$$X = [X^0, X^1, X^2, ..., X^{V-1}]^T$$

Where, X^i are sub blocks that are successively located and also are of equal size. In SLM [8] the scrambling is applied to all the subcarriers together but in case of PTS scrambling is applied to each sub block independently. Then each partitioned sub block is multiplied by corresponding complex phase factor $b^v = e^{j\phi v}, v = 1,2,...,V$, subsequently taking the IFFT of these partitioned sub blocks yields:

$$x = IFFT\left\{\sum_{v=1}^{V} b^v X^v\right\} = \sum_{v=1}^{V} b^v.IFFT\{X^v\} = \sum_{v=1}^{V} b^v x^v$$

Where, $\{x^v\}$ is referred to as Partial Transmit Sequence

DFT Spreading Technique

DFT spreading technique belongs to the class of pre-distortion method of PAPR reduction in OFDM system. This is used to reduce the high PAPR value of OFDM signals using DFT extension to frequency domain signal [9]. It spread the input signal using the operation of DFT which can be subsequently taken for IFFT operation. DFT spreading technique is also known as Single Carrier FDMA (SC-FDMA). Suppose that DFT of same size as that of IFFT is used as spreading code as depicted in figure 4.3, then the OFDMA system becomes equivalent to SC-FDMA. This is because the DFT and IDFT operation cancels each other. In this case the transmitted signal will have same PAPR as in a single carrier system [5].

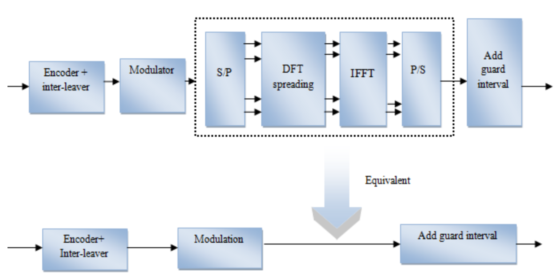

Figure 4.3: Block diagram of DFT spreading Technique.

Modified DFT spreading with pulse shaping technique

The PAPR reduction capability of DFT spreading method can be enhanced by using the concept of pulse shaping. The concept of pulse shaping is to find an efficient transmitter and corresponding receiver wave with minimum peak power ratio for the channel condition. The raised cosine filter is used for pulse shaping because it is able to reduce the ISI [27].

Pulse shaping is a linear filtering operation which is used to reduce the out of band signal energy. The pulse shaping operation can be performed in transmitter through convolution between the modulated subcarrier and filter impulse response [24, 25].

The response of baseband pulse amplitude modulation (PAM) is given by the following equation:

$$S_{PAM}(t) = \sum_{n=-\infty}^{\infty} C_n h(t - nT)$$

Here, S_{PAM} (t) is the output of PAM, C_n is the transmitted symbol, h (t) is impulse response of the pulse shaping filter.

It is to be noted that the impulse response of the filter has to be selected in such a way that it should have zero ISI and should have minimum bandwidth occupancy [12].

For distortion less transmission the impulse response of the filter is mathematically given as:

$$h(nT) = \begin{cases} 1 & for \quad n = 0 \\ 0 & for\ n = \pm 1, \pm 2, .. \end{cases}$$

The pulse shaping filter can be represented as:

$$S(t) = \sin c\left(\frac{t}{T}\right) \frac{\cos\left(\frac{\pi \beta t}{T}\right)}{1 - 4\beta^2 t^2 / T^2}$$

Where T is the symbol period & β is the roll off factor. The roll-off factor, β is used to determine the excess bandwidth of Nyquist ISI free pulse. The PAPR performance of DFT spreading can be significantly improved by varying the roll factor after IFFT.

Partial Transmit Sequence

We observe from the above discussion that in PTS [6-9&10-11] approach, number of sub-blocks (V) and the number of possible phase values (w) are some of the parameters that impact the PAPR reduction performance

In our simulation, two parameters will be considered. They are sub-block sizes V and different sub-block partition proposals.

The number of computations for equations in this suboptimal combination algorithm is V, which is much fewer than that required by the original PTS technique (i.e. $V \ll W^{V}$). Figure 5.1 shows the CCDF of PAPR for a 32-QAM/OFDM system using PTS technique as the number of subblock varies. It is seen that the PAPR performance Improves as the number of subblocks increases with V =1, 2,4, 8, 16 and 32.

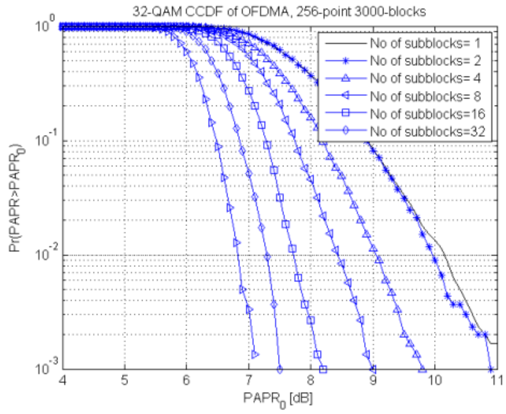

Fig.5.1: PAPR performance of a 32-QAM/OFDM system with PTS

Clipping and Filtering

Figure 5.2(a) shows the CCDFs of crest factor (CF) for the clipped and filtered OFDM signals [34]. The CCDF of CF can be considered as the distribution of PAPR since CF is the square root of PAPR. It can be seen from this figure 5.2 that the PAPR of the OFDM signal decreases significantly after clipping and increases a little after filtering. It has been observed from the figure 5.2 that the smaller the clipping ratio (CR) is, the greater the PAPR reduction effect is. Figure 5.2(b) shows the BER performance when clipping and filtering technique is used [27]. It has been observed from this figure 5.2 that the BER performance becomes worse as the CR decreases.

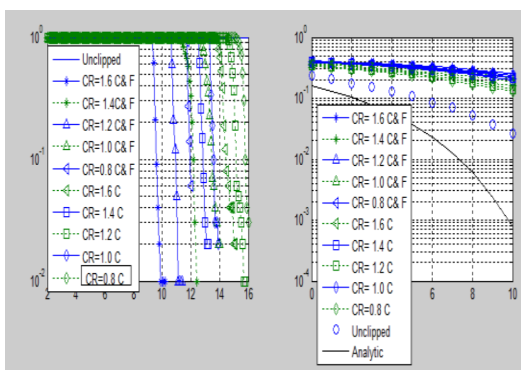

Figure 5.2 PAPR Distribution and BER performance with clipping and filtering [27].

DFT Spreading

Figure 5.3 shows a comparison of PAPR performances when the DFT-spreading technique is applied to the IFDMA, LFDMA, and OFDMA [27]. We have taken QPSK, 16-QAM, and 64-QAM for an SC-FDMA system with N=256, M=64 and S=4. It can be seen from Figure 5.3 that the PAPR performance of the DFT-spreading technique varies Depending on the subcarrier allocation method. In the case of 16-QAM, the values of PAPRs with IFDMA, LFDMA, and LFDMA for CCDF of 1% are 3.5dB, 8.3dB, and 10.8dB, respectively. It implies that the PAPRs of IFDMA and LFDMA are lower by 7.3dB and 3.2dB, respectively, than that of OFDMA with no DFT spreading [34].

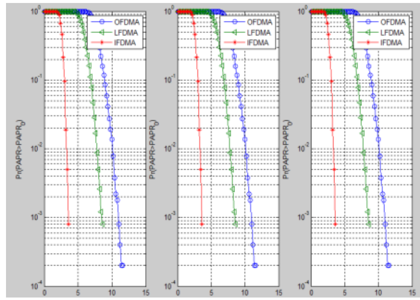

Fig.5.3 PAPR performances of DFT-spreading technique for IFDMA, LFDMA, and OFDM[27].

Modified DFT spreading technique with pulse shaping MATLAB results

Here we have considered the effect of pulse shaping on the PAPR performance of DFT spreading technique. Figure 5.4 shows that PAPR performance of IFDMA and LFDMA varies with the roll off factor of raised cosine filter for pulse shaping after IFFT. The performance of IFDMA is improved significantly after raising the roll off factor from 0 to 1. This is in contrast with LFDMA which is not affected by pulse shaping.

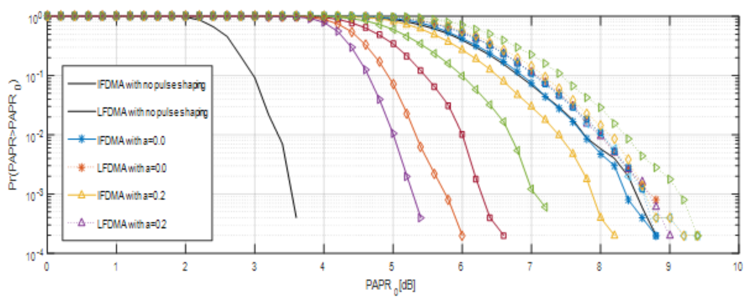

Figure 5.4 PAPR performances of IFDMA &LFDMA techniques with pulse shaping

The result here have been obtained with simulation parameters of N=256, M=64, S=4 (Spreading factor) for 32 QAM

Conclusion

In This paper we analyzed the performance of DFT spread method with the pulse shaping effect for reducing the PAPR in OFDM. The simulation results shows IFDMA method is best among the OFDMA, LFDMA and IFDMA. But the disadvantage of IFDMA scheme is that we are losing user diversity and investigates one of the bottleneck problems that exist in OFDM wireless communication system.

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