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OFDM Systems and PAPR Reduction Along With Channel Estimation

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Abstract: *Communication has got a vast changes regarding to its transmission techniques as well as its high speed data rates. Multimedia data services has grown up rapidly from generation to generation i.e.,2G ,3G and at present 4G wireless communication networks. Orthogonal Frequency Division Multiplexing (OFDM) forms the basis due to its large capacity to allow the number of subcarriers. Although OFDM has its own advantages, it also has its own limitations that suffers it and degrades its overall performance. Peak-to-average-power (PAPR) is the major drawback that makes high power amplifiers involved in transmitters to be operated in non linear region which exhibits amplitude and phase distortion and causes loss of orthogonality among subcarriers, and tends to introduction of inter-carries interference(ICI) in the transmitted signal.In this paper we have focused on learning the basics of an OFDM System and have undertaken different techniques to reduce the PAPR in the system so that this system can be used more commonly and effectively. Like Partial Transmit Sequence(PTS), Amplitude Clipping and Selective Level Mapping(SLM) in order to reduce PAPR along with channel estimation using Least Square and Minimum Mean Square Error techniques.*

Keywords: *OFDM, IDFT, ISI, ICI, PAPR, Cyclic Prefix, Amplitude Clipping & Filtering, SLM, PTS*

I. Introduction

Nowadays the wireless applications are focused towards high data rates.The concept of multi carrier transmission provides high data rates in communication channel.OFDM operates with the principle of frequency division into equal bands of channels.Here the bit streams are divided into many sub streams and send the information over different sub channels. A sub-carrier carrying the user information is transmitted in each band.

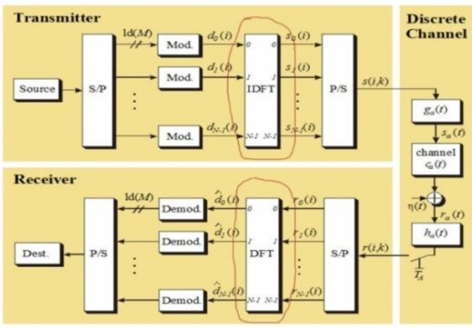


Fig. Block diagram of OFDM system

The sub carriers are closely spaced and overlapped to achieve high bandwidth efficiency. Each sub carrier is orthogonal with other sub carrier and it is carried out by a modulation scheme. Data's are transmitted simultaneously in super imposed and parallel form.

The main dis-advantage of OFDM systems is high peak to average power ratio. The peak values of some of the transmitted signals are larger than the typical values. High PAPR of the OFDM transmitted signals results in bit error rate performance degradation, inter modulation effects on the sub carriers, energy spilling into adjacent channels and also causes non linear distortion in the power amplifiers. The main work of this paper is to reduce the high peak powers in OFDM systems. Several PAPR techniques like clipping, coding, partial transmit sequence, tone reservation and tone injection are there to reduce high peak signals . The simplest solution to overcome this problem is to operate the non-linear amplifier at the linear region by taking out enough power from the input, i.e., input back-off..Thus implementation of OFDM technique in a power efficient manner has drawn significant research attention in the recent past and many methods have been proposed with the objective of PAPR reduction. A survey done on PAPR reduction techniques reveals that perhaps the most widely known methods are signal clipping , block coding , selected mapping SLM and partial transmit sequence (PTS) . Of them, clipping is a very simple method to reduce PAPR. This lowers the PAPR easily by clipping away the signal above the assigned clip level. But it results in out-of-band radiation and in-band distortion causing poor signal quality. Finally, SLM and PTS are the phase control method to reduce PAPR. SLM multiplies an OFDM data by several phase sequences in parallel and selects the data sequence of the lowest PAPR among them. PTS divides the input OFDM data into several clusters and phase rotation factors (or combining sequences) are multiplied to get the low PAPR signal. Although these two methods can reduce PAPR effectively without any signal distortion, the side information about the phase rotation must be transmitted to the receiver.

II. Orthogonal Frequency Division Multiplexing

OFDM system in which the Discrete Fourier Transform (DFT) was applied to generate the orthogonal sub-carriers waveforms. In their proposed model, baseband signals were modulated by the DFT in the transmitter and then demodulated by inverse DFT (IDFT) in the receiver. So, the implementation complexity is reduced by the use of DFT algorithms (i.e. IFFT/FFT). Therefore, all the sub-carriers overlapped with each other in the frequency domain maintain their orthogonality as shown in figure below. The OFDM systems have some major problems (like high PAPR, timing and frequency synchronization, Inter-Carrier Interference (ICI) etc.) and lot of work has been reported to solve these problems.

Principle of Orthogonality

In multi-carrier system, occupied bandwidth on the channel is minimized as possible. This minimization is possible by reducing the frequency space between carriers. The narrow space among the carriers is obtained when they are orthogonal to each other. To be orthogonal, the time averaged integral product of two signals should be zero. OFDM communication systems are able to effectively utilize the frequency spectrum through overlapping subcarriers. Simulation of Figure for five sub-carriers shows that sub-carriers are able to partially overlap without interfering with adjacent sub-carriers because the maximum power of each subcarrier corresponds directly with the minimum power of each adjacent channel. In additional, different sub-carriers are orthogonal to each other and they are totally different from one another.

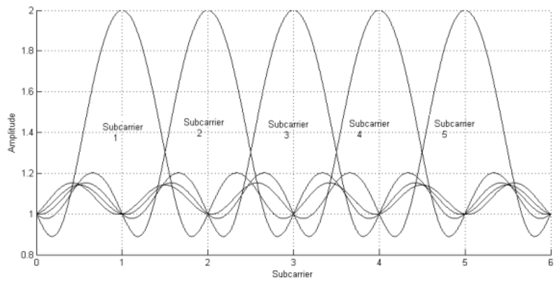


Figure2.1-Frequency response of 5 sub-carriers of OFDM signal.

III. Problem Papr In Ofdm

The transmit signal in an orthogonal frequency division multiplexing (OFDM) system can have high peak values in the time domain since many carriers components are added in inverse fast fourier transformation. As a result OFDM are known to have high peak to average power ratio when compared to single carrier systems .In fact the high papr is the one of the most problem in ofdm system as it decreases the signal to quantization noise ratio of analog to digital convertor and digital to analog convertor while degrading the efficiency of the power amplifier in the transmitter. As a result PAPR in OFDM is more ,since the efficiency of the power amplifier in transmitter is critical due to limited batter power in mobile terminal.
The PAPR of the transmit signal is defined as

$$x(t) = \sum_0^{k-1} a_k \, e^{\frac{j2\pi kt}{T}}$$

Due to the large number of sub-carriers in typical OFDM systems, the amplitude of the transmitted signal has a large dynamic range, leading to in-band distortion and out-of-band radiation when the signal is passed through the nonlinear region of power amplifier.

Peak Power

$$\text{Max}[\,x(t)\,x^*(t)] = \text{Max}[\sum_0^{k-1} a_k e^{\frac{j2\pi ki}{T}} \sum_0^{k-1} a_k^* \, e^{\frac{-j2\pi ki}{T}}\,]$$

Average power

$$E\,[\,x(t)\,x^*(t)] = \quad E\,[\sum_0^{k-1} a_k e^{\frac{j2\pi ki}{T}} \sum_0^{k-1} a_k^* \, e^{\frac{-j2\pi ki}{T}}]$$

$$= K$$

So, mathematically PAPR is given by,

$$\text{PAPR} = K^2 / K = K$$

If we taken the As Per the IEEE 802.16 for the WI-max specification, we used 256 sub-carriers. So, expected maximum PAPR is around 256(Around 24.08db)

$$\mathrm{PAPR} = \frac{P_{peak}}{p_{avg}} = \max[\![x_n{}^2]\!]/E[\![x_n{}^2]\!]$$

PAPR=10log(max[x(t)x*(t)] E[x(t)x*(t)])

IV. Paper Reduction Techniques

1. Clipping/filtering
2. Coding
- FEC
- Phase Optimization
- Partial Transmit Sequence
- Selected Mapping (SLM)
3. Probabilistic
- Tone Reservation (TR)
- Tone Injection (TI)
- Active Constellation Extension (ACE)
- Error Insertion (EI)

PAPR reduction at the expense of: complexity↑, average power↑, BER↑, and data rate↓

♦ **Amplitude Clipping and Filtering**

A threshold value of the amplitude is set in this process and any sub-carrier having amplitude more than that value is clipped or that sub-carrier is filtered to bring out a lower PAPR value.

♦ **Selected Mapping**

In this a set of sufficiently different data blocks representing the information same as the original data blocks are selected. Selection of data blocks with low PAPR value makes it suitable for transmission.

V. Partial Transmit Sequence

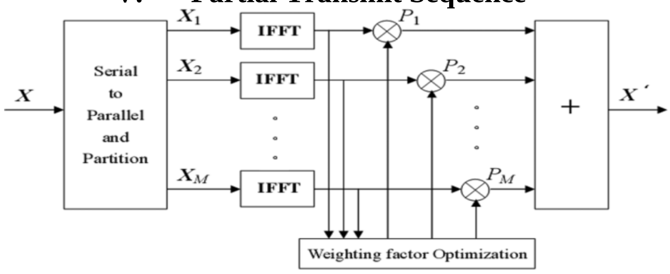


Figure 5.1 PTS Block Diagram

In the PTS approach, the input data block is partitioned into disjoint sub-blocks,
There are three partition methods for PTS scheme

- Interleaved
- adjacent
- Pseudo-random.

Among them, pseudo-random partitioned PTS scheme can obtain the best PAPR performance. The sub-carriers in each sub-block are weighted by phase factor rotations. This rotation factor generates time domain data using which it selects signal having lowest PAPR.

At the receiver, the original data are recovered by applying inverse phase factor rotations

Table 1: Comparison of the reduction techniques

Differ-ent Tech-niques	Imple-entation Complexity	Band-width Expansion	BER Degr-adation	Distortion
CLIPPING	Low	No	Yes	Yes
CODING	Low	Yes	No	Yes
PTS	High	No	No	No

Why The Complexity Is High In The Pts??

Main complexity issues are

- Number N IFFT operations
- of complex multiplication and summation factors

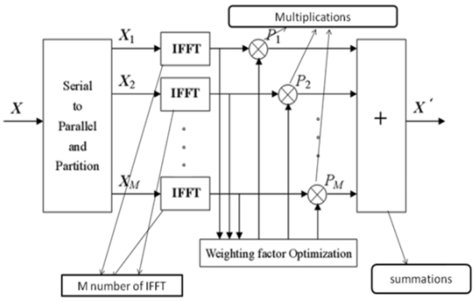


Fig:For the measurement of the computational complexity of our PTS, computational complexity reduction ratio (CCRR).

VI. Channel Esimation

As discussed above, there are two types of channel estimation i. e. block type and comb type. Block diagram for block type channel estimation is as shown below.

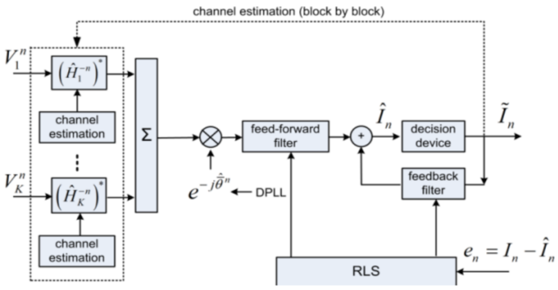


Figure: Channel Estimation using LS/MMSE Estimators

In block-type pilot based channel estimation,each subcarrier in an OFDM symbol is used in such a way that all sub-carriers are used as pilots. The estimation of the channel is then done using Least Square Estimator and Minimum Mean Square Error Estimator.

The system shown in Fig.3 is modeled using the following equation:

$y = DFT_N\,(IDFT_N(X)\odot\frac{h}{\sqrt{N}} + \widetilde{w}\,)$

where,

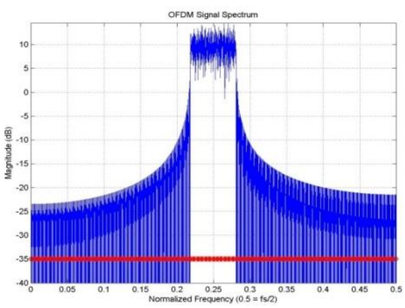
$x = [\,x_0\;\; x_1\;\; \ldots\ldots\;\; x_{N-1}]^T$

$y = [y_0\;\; y_1\;\; \ldots\ldots\;\; y_{N-1}]^T$

$\widetilde{w}=[\widetilde{w}_0\widetilde{w}_1\;\; \ldots\ldots\;\; \widetilde{w}_{N-1}\,]^T$

$h = [h_0\;\; h_1\;\; \ldots\ldots\; h_{N-1}]T$

VII. Simulations



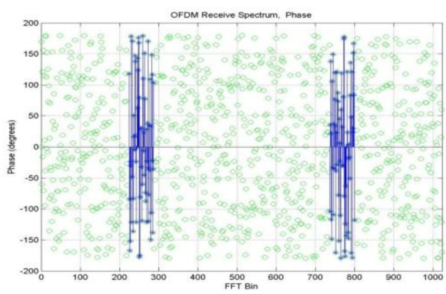


Fig1 OFDM received phase spectrum   Fig2 OFDM Signal spectrum

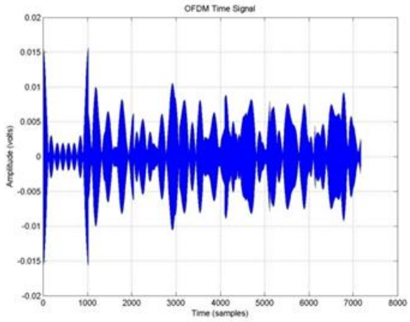


Fig3 **OFDM Time domain signal**

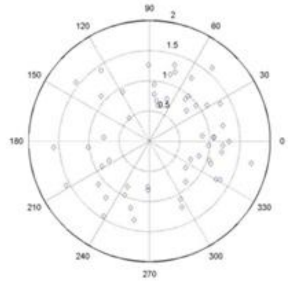


Fig4 **Plotting each received symbol**

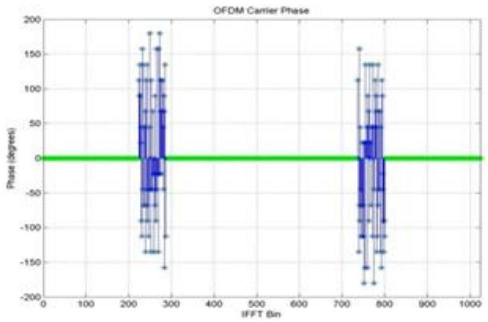


Fig5 **OFDM Carrier phase simulated plot**

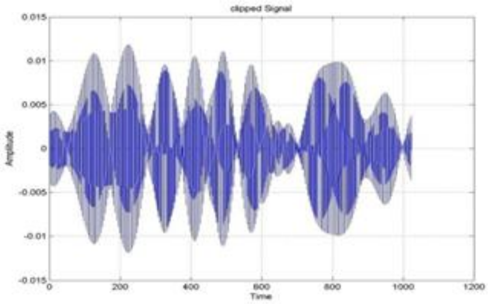


Fig6 **OFDM Clipped signal spectrum**

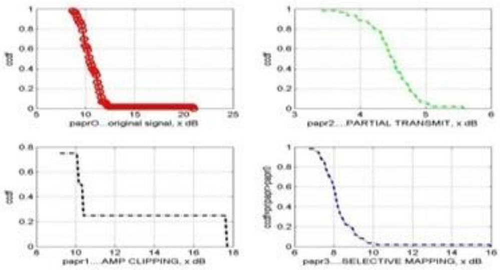


Fig.7 Individual simulation results of PAPR reduction signal

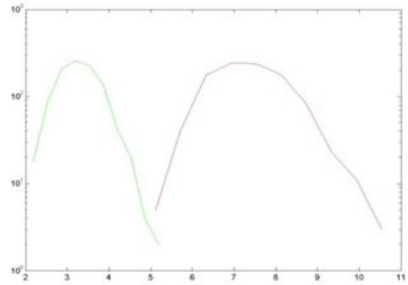


Fig8 CCDF comparision for PTS and original

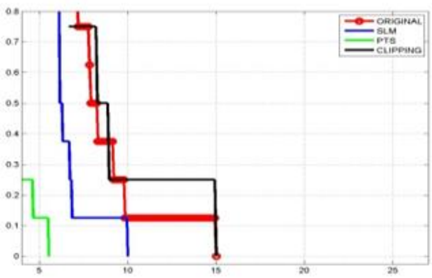


Fig.Comparison of reduced PAPR after applying techniques

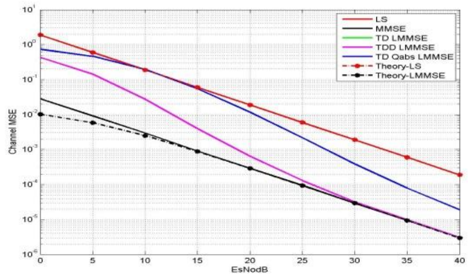


Fig.Channel Estimation in OFDM

VIII. Conclusion

We have been researching for some of the techniques which are in common use to reduce the high PAPR of the system. Among the three techniques that we found out that Amplitude Clipping and Filtering results in Data Loss, whereas, Selected Mapping (SLM) and Partial Transmit Sequence (PTS) do not affect the data but increase in bit error rates.

Whereas it can be concluded that PTS is the technique that has shown a better results in PAPR reduction in OFDM systems and is more efficient but little complex to implement, but low complexity PTS systems are been introduced to prevent that problems. It is not sure that these are the only techniques that are used

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