Performance Analysis of PTS Technique for PAPR Reduction of OFDM Signal Generated by Different Modulation Schemes

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Abstract—Orthogonal frequency division multiplexing has been selected for high data rate transmission & has been widely used in various wireless communication standards like Digital Video Broadcasting(DVB), Digital Audio Broadcasting (DAB), WiMAX etc. High Peak to Average Power ratio of OFDM signal is one of the demanding issues. Among number of methods PTS is most successful method of PAPR reduction of OFDM.In this paper we show the comparison of performance of partial transmit sequence technique applied on OFDM signal, generated by different modulation scheme like QPSK, 16-QAM & 64-QAM.

Keywords—Orthogonal Frequency Division Multiplexing (OFDM) , Partial Transmit Sequence (PTS), Peak to Average Power Ratio (PAPR).

I. INTRODUCTION

High speed data communication for wireless system uses OFDM as a promising technique, due to its unique robust performance on frequency selective fading channels & for digital multicarrier modulation. The multipath fading effects is mitigated by separating the data into large number of relatively narrowband channels [1] .However an OFDM signal can exhibit a high peak to average power ratio. This causes clipping of OFDM signal by high power amplifier, producing nonlinearities in the HPA output. Hence the OFDM spectrum may have severe in band & out of band distortion which degraded the BER performance. As a result, an expensive HPA with a large linear range is required [2].

Numerous methods have appeared in the literature to improve the PAPR performance of OFDM signal like clipping, tone reservation, tone injection, selective mapping & partial transmit sequence, which is the most attractive ones due to good system performance & low complexity [3] .Among these methods, PTS scheme is most efficient approach & distortion less scheme for PAPR reduction by optimally combining signal sub-blocks [4].

In PTS technique the input data are divided into smaller disjoint sub blocks. These sub-blocks are then given to inverse fast Fourier transform (IFFT).The output of each sub-block is then multiplied by rotating phase factor preferred between [0- 2π].Subsequently, the sub-blocks are added to form OFDM symbol for transmission [5] .In PTS we need an exhaustive search over all combination of allowable phase factors, the search complexity increases exponentially with number of sub-blocks [6].

In section II we present briefly the OFDM signal generation & PAPR of OFDM signal. Section III presents the CCDF for performance evaluation. In the section IV we give an overview on different PAPR reduction methods used with OFDM.Section V includes the PTS technique for PAPR reduction of OFDM signal generated by different modulation schemes & also discuss the complexity and system performance .Section VI includes the simulation results and conclusion.

OFDM Signal Generation & PAPR of OFDM

The block diagram of OFDM signal generation is shown in Fig.1.In that the input bit stream is first mapped according to the modulation scheme. Let an OFDM symbol is formed with N orthogonal sub carriers, and each subcarrier is modulated with a conventional modulation scheme such as Quadrature Amplitude Modulation (QAM) or Phase Shift Keying (PSK) at a low symbol rate. When the frequency domain signal is Xn, $0 \le k \le$ N-1. Then after inverse discrete Fourier transform, the signal in time domain is given by [7]

$$x(n) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_n e^{j2\pi \frac{k}{LN} n}, \quad n = 0, 1, 2, 3, \ldots, LN \qquad (1)$$

Where N is number of sub carrier & L is oversampling factor. OFDM has several advantages such as can easily adjust to severe channel conditions, is robust against ISI and fading caused by multipath and provide high spectral efficiency. The spectrum of original OFDM signal generated by 16-QAM scheme is shown in Fig.2. But OFDM also has disadvantages as it is sensitive to Doppler shift, defined as the change in frequency of a wave for an observer moving relative to the source of the waves. It is also sensitive to frequency synchronization problems and having high peak-to-average-power ratio (PAPR).Within an OFDM signal, in some cases all signal components can add up in phase and produce a large output, and in some cases, they may cancel each other, producing zero output. Thus, the peak to average power ratio of an OFDM signal is very large. The PAPR for OFDM signal is given by Muller & Hubber & equation is

$$\text{PAPR} = \frac{\max_{0 \le n \le N-1} |x_n|^2}{E[|x_n|]^2} \qquad (2)$$

Where PAPR–Peak-to-Average Power Ratio

x_n – Oversampled OFDM signal

$\max_{0 \le n \le N-1}$ - Peak Power

$[\,|x_n|\,]^2$ – Average Power

E{.} denotes the expected value

When the oversampling factor is 4 then the PAPR for discrete time & continues time is same [8].

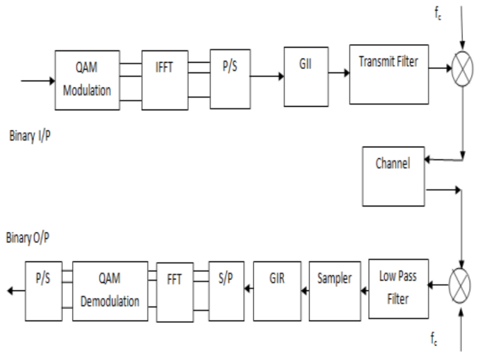


Figure.1 Block Diagram of OFDM System

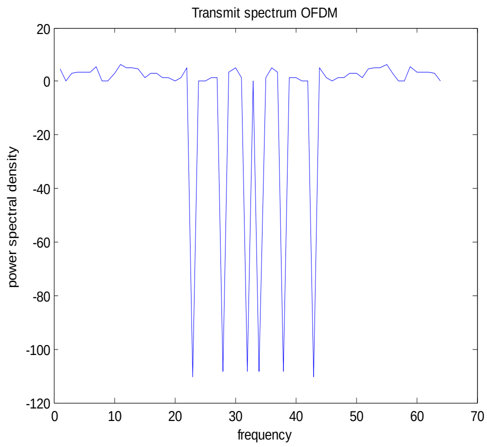


Figure.2 Spectrum of Original OFDM Signal

The nonlinear characteristic of high power amplifier is very susceptible to the variation in signal amplitudes. However, the variation of OFDM signal amplitudes is very large with high PAPR.Therefore HPA will introduce inter-modulation between the different sub- carriers and introduce additional interference into system due to high PAPR of OFDM. This additional interference leads to an increase in BER. To keep low BER, it requires a linear work in its linear amplifier region with a large dynamic range.However, this linear amplifier has poor efficiency and so expensive. Large PAPR also demands the DAC with adequate dynamic range to accommodate the large peaks of OFDM signal [3].

COMPLEMENTARY CUMULATIVE DISTRIBUTION FUNCTION

The CCDF of PAPR can be used to estimate the limits for the minimum number of redundancy bits required to identify the PAPR sequences and evaluate the performance of any PAPR reduction technique [9]. It gives the probabilities that PAPR of input data blocks cross the specified threshold level . The equation for CCDF is

$$P_r(\text{PAPR} > \text{PAPR}_o) = 1 - (1 - e^{-\text{PAPRo}})^N \qquad (3)$$

The CCDF of original OFDM signal is shown in Fig.3.The PAPR of original OFDM signal is 11.8 db with CCDF of 10^{-2}.

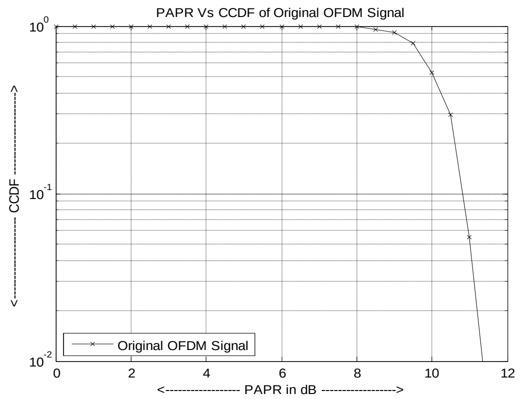


Figure.3 PAPR Vs CCDF of Original OFDM Signal

PAPR REDUCTION METHODS

The high Peak-to-Average Power Ratio (PAPR) of the Orthogonal Frequency Division Multiplexing (OFDM) systems can be reduced by using various PAPR reduction techniques as follows [3,7]:

- Tone Reservation (TR).
- Clipping.
- Companding Transforms.
- Tone Injection (TI).
- Partial Transmit Sequence (PTS).
- Selective Mapping (SLM).
- Active Constellation Extension Methods.

PARTIAL TRANSMIT SEQUENCE TECHNIQUE

Partial Transmit Sequence technique is a probabilistic (Scrambling) technique which scrambles an input data block of the OFDM symbol & select one of them with the minimum PAPR for transmission as shown in Fig.4[8].

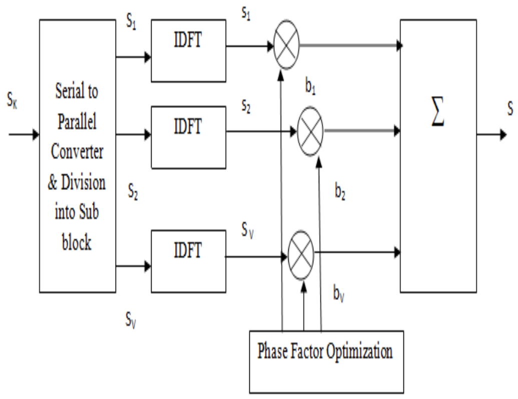


Figure.4 Block Diagram of PTS Technique of PAPR Reduction

In this method the input data S of N symbol is partitioned into disjoint V sub blocks.

$$S=[S^0\ S^1 \ldots\ldots S^{V-1}]^T \quad (4)$$

Each sub block are of equal size. After that each sub block are phase shifted separately. Let complex phase factor is

$$b^v= e^{j\phi v} \quad (5)$$

Where v= 1 2 3….V

Subsequently taking its IFFT it gives

$$x=\text{IFFT}\{\textstyle\sum_{v=1}^{V} S^v b^v\ \}= \ \textstyle\sum_{v=1}^{V} s^v\, b^v \quad (6)$$

Where s ^{v} is referred to as a partial transmit sequence (PTS). The phase factor is selected so that the PAPR can be minimized. So the received signal with lowest PAPR can be given as

$$\tilde{s}=\textstyle\sum_{v=1}^{V} s^v\, \tilde{b}^{\,v} \quad (7)$$

The PTS performance evaluation shows that the PAPR is reduced when we increased the number of sub blocks but at the same time searching complexity is increased exponentially with sub blocks as shown in Fig.5. Alternatively the optimization methods are used in which best transmit signal is stored until superior one is found .To choose the optimum phase weighting factor for each input sequence we have to verify W^{V-1} possible combination. At the receiver for decoding the data, side information is required in the form of phase factor i.e. log $_2W^{V-1}$.

There are three sub block partition schemes that are pseudo-random, adjacent & interleaved shown in Fig.6 .Pseudo random sub block partition scheme gives the best result compared to other two methods. But the hardware complexity is very large in the pseudo random scheme compared to others [12, 13].

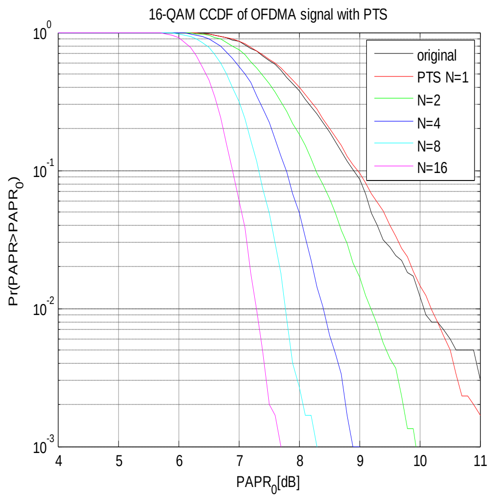
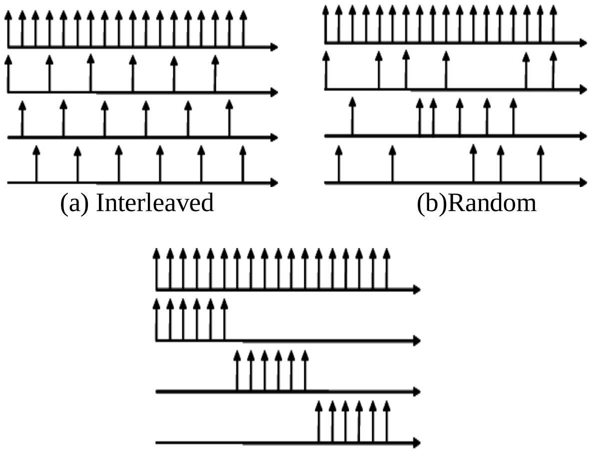


Figure.5 PAPR Performance of a 16 QAM/OFDM System with PTS Technique When the Number of Sub block Varies



(a) Interleaved (b)Random

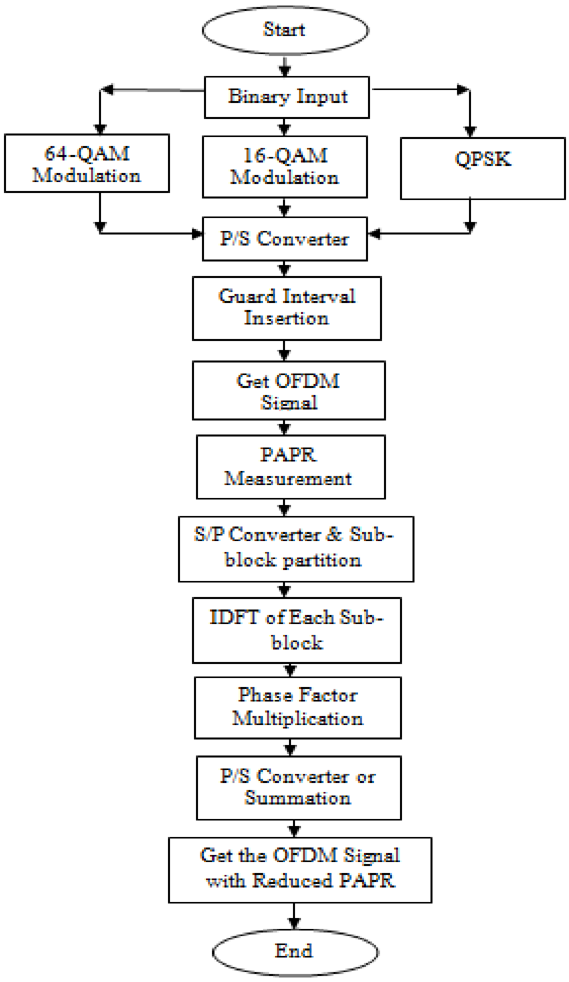
(c) Adjacent

Figure. 6 (a) (b) & (c) Sub block Partition Mechanisms

We have the different kind of optimization used to optimize the phase factor in PTS scheme like Particle Swarm optimization [4, 18], Cross Entropy [15,16] Artificial Bee Colony[17,18], Harmony Search optimization[21-24] etc. These sub optimal schemes offer the best combination of phase factor with very less computational complexity& at the same time it gives superior PAPR performance.

SIMULATION RESULTS & CONCLUSION

In this paper we mainly focus on Partial transmit Sequence technique, of PAPR reduction of OFDM signal.Fig.7 illustrates some performance of PTS scheme in PAPR reduction for OFDM signal generated by modulation schemes like QPSK, 16-QAM & 64-QAM. The QPSK modulation is employed with N= 512 subcarriers. The phase weighting factor W=[1,-1] have been used. The sampling rates for an accurate PAPR need to be increased by 4 times. The number of OFDM blocks for iteration is 10000.



Simulation result shows the PAPR of original OFDM signal is 12.2 db with CCDF of 10^{-4}. For number of sub-blocks M=4,after PTS technique the PAPR of OFDM signal is around 10.2 db with CCDF of 10^{-4}.The 16QAM-OFDM signal is generated by 256 total sub carrier & for generating CCDF of PAPR total ,10000 OFDM blocks are generated randomly. For 16QAM-OFDM signal the PAPR is 11.4db with CCDF of 10^{-3}. For M=4 the PTS assisted 16QAM-OFDM signal, has the PAPR of around 9.2 db for 10^{-3} CCDF.With same parameters consideration, the 64QAM –OFDM signal has PAPR of around 11.7db & after PTS the PAPR is 9.4 db approximately.

TABLE I. SIMULATION PARAMETERS

S. No.	Parameters	For 16-QAM & 64-QAM OFDM	For QPSK OFDM
1	No. of Sub-carriers	256	512
2	FFT Size	256	512
3	No. of Sub-blocks	4	4
4	No. of Phase Factors	2 (1, -1)	2 (1, -1)
5	No. of OFDM Blocks for Iteration	10,000	10,000
6	Oversampling Factor	4	4

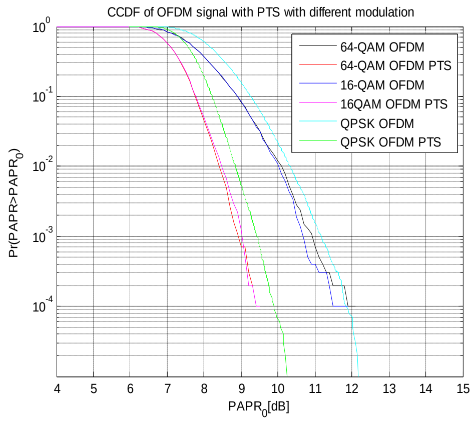


Figure.7 The Comparison of PTS –Technique Applied on OFDM Signal Generated by Different Modulation Schemes.

TABLE II. COMPARISON OF PERFORMANCE OF PTS TECHNIQUE FOR PAPR REDUCTION OF OFDM SIGNAL GENERATED BY DIFFERENT MODULATION SCHEMES

S. No.	Modulation Technique	PAPR of original OFDM	PAPR of OFDM after PTS
1	16-QAM	11.4db	9.2db
2	64-QAM	11.7db	9.4db
3	QPSK	12.2db	10.2db

From the simulation results we can say that the QPSK -OFDM signal has PAPR which is greater than the PAPR of QAM-OFDM signal .And after PTS technique of PAPR reduction the improvement in PAPR performance is achieved. When this simulation is performed for different sub blocks the computational complexity is increased linearly. To overcome this problem the optimization methods are used with PTS, Which gives the good tradeoff between PAPR performances & computational complexity.

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