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A Newsubblock Partition Technique for PTS in OFDM Systems

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Abstract
In recent years, OFDM has gained a lot of interest in diverse-digital communication applications. This has been due to its favorable properties like high spectral efficiency and robustness to channel fading. Some of the major drawbacks in OFDM are its high peak-to-average-power ratio(PAPR) of the transmitted signals and the synchronization of signals. In this paper, a new subblock partition technique has been proposed in which signal subbands are partitioned in no. of subblocks using pseudo-random partitioned technique and then interleaved partition technique is applied. It is observed that PAPR is reduced as compared to conventional PTS.
Keywords—Orthogonal frequency division multiplexing (OFDM), peak-to-average power ratio (PAPR), partial transmit sequence (PTS), complementary cumulative distribution function (CCDF), inter-carrier-interference (ICI),Power amplifier (PA)

I. Introduction

OFDM is a special case of multicarrier transmission,where a single datastream is transmitted over a number oflower rate subcarriers. The main advantages of OFDM areits increased robustness against frequency selective fadingor narrowband interference as well as the efficient useof available bandwidth. Two major drawbacks of OFDMsystems are the great sensitivity to time and frequencysynchronization errors, and the high PAPR. Due to highPAPR, the amplified signal suffers from distortion and out-of-band noise when passed through nonlinear devices, suchas a Power Amplifier (PA). A solution to this problemis the use of highly linear Power Amplifiers (PA) withsufficient back-off. However this solution comes at thepenalty of high power consumption. Therefore, the use ofa PAPR reduction method, such as deliberately clipping [1],appropriate block coding [2], or nonlinear predistortion ofthe transmit signal [3] is essential. Two promising anddistortionless techniques for improving the statistics of thePAPR are the Selective Mapping approach [4] and the PartialTransmit Sequence approach [5][6]. SLM and PTS-basedPAPR reduction can be exploited to achieve system-levellow-power operation in cases of practical interest [7][8].

OFDM provides strength in favor of intersymbol interference and multipath fading because for the lower rate subcarriers, the symbol period increases. And it also robust against narrowband interference. With the utilization of adaptive modulation technique, OFDM allows resourceful use of in band radio frequency (RF). It enables the bandwidth-on-demand technology and privileged spectral efficiency. So OFDM does not necessitate adjacent bandwidth for operation. OFDM makes on its own frequency networks possible, which is for the most part attractive for broadcasting applications.

Multicarrier systems are naturally more vulnerable to phase noise and frequency offset. Doppler shift and Frequency jitter between the transmitter and receiver causes inter-carrier-interference (ICI) which humiliates performance of the system unless suitable compensation techniques are employed.

OFDM remains a chosen modulation scheme for upcoming broadband radio area systems because of its inherent flexibility in power loading across the subcarriers and concerning adaptive modulation.

This paper is organized as follows. In section II, we discussed the principle of OFDM and PAPR respectively; in section III, CCDF is discussed; in section IV, conventional PTS for PAPR reduction is reviewed; in section V, the principle and implementation of our approach is introduced in detail; in section VI, performance analysis of the proposed technique is given, finally section VII concludes this paper.

II. OFDM and PAPR

A. *OFDM*

OFDM is a block modulation scheme where a block of information symbols is transmitted in parallel on sub-carriers. The time duration of an OFDM symbol is many times larger than that of a single-carrier system. An OFDM modulator can be implemented as an inverse discrete Fourier transform (IDFT) on a block of information symbols followed by an analog-to digital converter (ADC).

B. *PAPR*

Consider an OFDM system with N sub-carriers. EachOFDM block(OFDM symbol), s(t), 0 ≤ t ≤ T, consists of Ncomplex baseband data $X0$, $X1,\ldots, Xn$-1 carried on the Nsubcarriers respectively for a symbol period of T. The OFDMsymbol s(t) is

$$S(t) = \begin{cases} \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_n e^{j2\pi f_n t}, & 0 \le t \le T \\ 0, & otherwise \end{cases} \quad (1)$$

Where $\Delta f = 1\ T$ is the sub-carrier spacing and $X_k$is thecomplex baseband data modulating the k-th subcarrier for s(t).For the OFDM symbol s(t), the peak instantaneous power is

$$P_{max} = \max_{t\epsilon[0,T)} |s(t)|^2$$

An OFDM symbol sequence can be represented by…, $s(t)$, $s(t + \mathrm{T})$,..., $s(t + mT)$,…. We define the average power of the OFDM symbol sequence following the approach as follows

(2)

$$P_{av}\left(X_0, X_{1,\ldots} X_{n-1}\right) = \frac{1}{N} \sum_{k=0}^{N-1} E[|X_k|^2] \quad (3)$$

Where$E[|X_k|^2]$ is the expected value of $|X_k|^2$.The peak average power ratio (PAPR) of the OFDM symbol s(t) is

$$PAPR = \frac{P_{max}}{P_{av}(X_0, X_1, \ldots X_{n-1})} = \frac{\max_{t\epsilon[0,T)} |s(t)|^2}{\frac{1}{N}\sum_{k=0}^{N-1} E[|X_k|^2]} \quad (4)$$

If the power of input signal is standard, the $E[|X_k|^2]$equalsto 1. Then

$$PAPR = \max_{t\epsilon[0,T)} |s(t)|^2 = \max_{t\epsilon[0,T)} \left|\frac{1}{\sqrt{N}}\sum_{n=0}^{N-1} X_n e^{j2\pi\Delta f t}\right|^2 \le N (5)$$

As a result, the PAPR value is not larger than the number N of subcarriers, e.g. the peak power value of OFDM signals is N times larger than its average power. So, the maximum of PAPR equals to N. With the increase in the number N of sub channels, the maximum of PAPR increases linearly. This makes high demands on the linear range of the front-end amplifier in sending side.

Although the probability of largest PAPR is low, in order to transfer these high PAPR of OFDM signal with non-distortion, all the linearity of the HPA in sending side, the front-end amplifier and A/D converter should meet the high requirement. But these equipments meeting the high requirement are expensive. Therefore, it is necessary and important to reduce PAPR in OFDM system.

III. CCDF

Cumulative distributive function is to describe the probability of the random variable with the given probabilitydistribution function. Complementary cumulative distributive function is also called as tail distribution which is used to illustrate the PAPR of OFDM signal. The output curve is used to conclude the design parameters of themodulation system. The CCDF of an OFDM system to measure the PAPR can be given as

$$CCDF = P_r(PAPR > PAPR_0) \quad (6)$$

Where P_r is the probability distribution function and $PAPR_0$ is the threshold value.CCDF of PAPR can be used to estimatethe bounds for the minimum number of redundancy bits requiredto identify the PAPR sequences and evaluate the performanceof any PAPR reduction schemes.

IV. PARTIAL TRANSMIT SEQUENCE

Partial Transmit Sequence (PTS) algorithm is a technique for improving the statistics of a multi-carrier signal. The basic idea of partial transmit sequences algorithm is to divide the original OFDM sequence into several sub-sequences, and for each sub-sequence, multiplied by different weights until an optimum value is chosen.

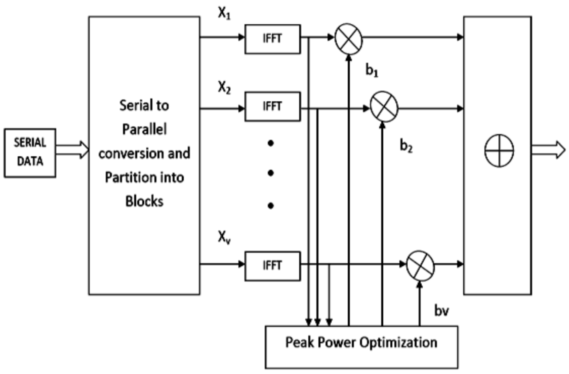


Fig. 1 Block diagram of PTS algorithm

Fig. 1 is the block diagram of PTS algorithm. From the left side of diagram, we see that the data information in frequency domain X is separated into V non-overlapping sub-blocks and each sub-block vectors has the same size N. Hence, we know that for every sub-block, it contains N/V nonzero elements and set the rest part to zero. Assume that these sub-blocks have the same size and no gap between each other, the sub-block vector is given by

$$X = \sum_{V-1}^{V} b_v X_v \ (7)$$

Where $b_v = e^{j\varphi_v} (\varphi_v \in [0, 2\pi])\{v = 1, 2, \ldots, X_v\}$ is a weighting factor been used for phase rotation .The signal in time domain is obtained by applying IFFT operation on , that is

$$\hat{x} = IFFT(X) = \sum_{v-1}^{V} b_v\, IFFT(X_v) = \sum_{V-1}^{V} b_v X_v$$

(8)

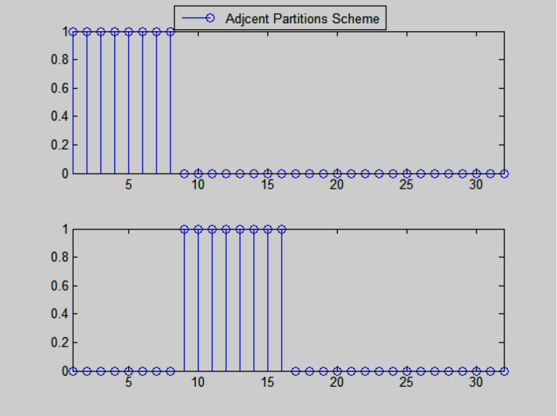
Select one suitable factor combination b = [b1,b2,..,bv] which makes the result achieve optimum. The combination can be given by

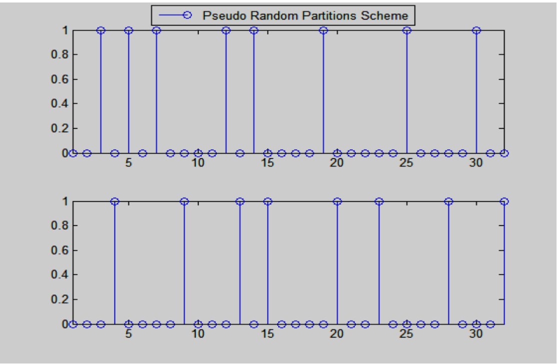
$$b=[b_1,b_2,....b_V]= \arg\min_{(b1,\, b2,\, ...,\, bV)}\left(\max_{1\le n\le N}\left|\sum_{v=1}^{V} b_v x_v\right|^2\right) \quad (9)$$

Whereargmin [(·)] is the judgment condition that output the minimum value of function. In this way we can find the best **b** so as to optimize the PAPR performance. The additional cost we have to pay is the extra *V*-1 times IFFTs operation.

V. NEW SUBBLOCK PARTITION SCHEME

PAPR reduction performance and computational complexity of PTS algorithm is closely related to the sub-block partitions schemes. In PTS-OFDM system, there exist three sub-block partition schemes: adjacent partition, pseudo-random partition and interleaved partition. In Fig. 2, graphs are shown for the illustration of these three partition schemes. From the figure we can see that adjacent partition is divide sequence into V sub-blocks, for each one, it contains N/V consecutive sub-carriers. Conventional PTS uses adjacent partitions scheme. In pseudo-random partition, each sub-carrier can be randomly assigned to any position of sub-block with the length V. The common point of these three different partition schemes is that each sub-carrier is only been assigned once, and the length of each sub-sequence is same





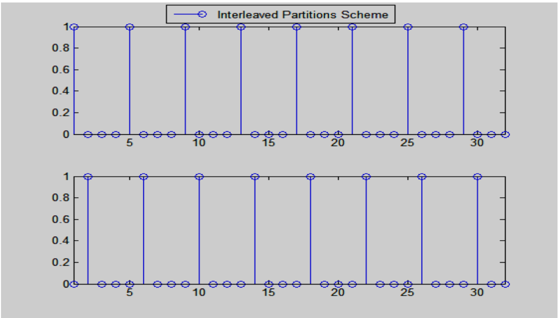


Fig.2 Different sub-block Partitions schemes

In the proposed scheme, first signal subbands are partitioned into n subblocks using pseudo-random partition scheme and then interleaved partition scheme is applied on the subblocks.

VI. PERFORMANCE ANALYSIS

To evaluate and compare the performance of the new subblock partition scheme with the conventional PTS [13]-[14], computer simulation has been performed where the number of subbands in an OFDM symbol and sub- blocks are set to 1000 and 16, respectively. Constellation of quadriphase shift keying (QPSK) is used as a signal mapper Fig. 3. According to simulation result, PAPR of new subblock partition scheme is reduced by 0.20 units from conventional PTS.

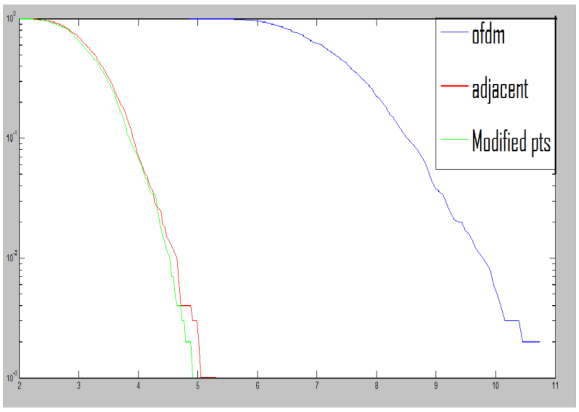


Fig 3: Simulation result of new subblock partition scheme

VII. CONCLUSION

Large PAPR of transmitted signals may be a main cause of performance degradation of OFDM system. In conventional PTS OFDM to solve the problem, computational complexity has been increased extensively with increase of number of subbands.

In this paper, new subblock partition scheme has been proposed and its performance is analysed. As a result of simulation, when number of OFDM symbols is 1000 and number of subblock is 16,Modified PTS shows 0.20 units reduction from conventional PTS.

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