Efficient Data Recovery scheme in PTS-Based OFDM systems with MATRIX Formulation

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ABSTRACT

Partial transmit sequence (PTS) scheme is one of the peak-to-average power ratio (PAPR) reduction technique in OFDM systems. In the PTS scheme, in order to generate signals with low PAPR, one OFDM symbol is partitioned into disjointed sub-blocks, and each sub-block is multiplied by a phase factor. For data recovery, receivers must have side information (SI), e.g., phase factors, from transmitters. In the proposed method, the data recovery process in PTS-based OFDM systems is performed without SI. An additional pilot symbol is intentionally inserted at the end of each sub-block, so that efficient data decoding based on channel estimation can be executed with known pilot symbols. Also in existing method the OFDM symbols are processed in sequence order, it is modified into matrix order in order to achieve a fast data transaction. The simulation results shows that the Bit Error Rate (BER) performance without SI is approximately the same as compared to the BER performance of the PTS scheme with perfect SI and a maximum likelihood decoding scheme.

General Terms

PAPR reduction technique, Partial Transmits Sequence.

Keywords

Orthogonal frequency division multiplexing (OFDM), partial transmits sequence (PTS), peak-to-average power ratio (PAPR), side information (SI).

1. INTRODUCTION

With the ever growing demand of this generation, need for high speed communication has become an utmost priority. Many multicarrier modulation techniques have evolved in order to meet these demands, few notable among them being Orthogonal Frequency Division Multiplexing (OFDM) and Code Division Multiple Access (CDMA).

OFDM is one of the many multicarrier modulation techniques, which provides high spectral efficiency, low implementation complexity, less effects to echoes and non – linear distortion. Due to these advantages of the OFDM system, it is vastly used in various communication systems.

But the major problem one faces while implementing this system is the high Peak to Average Power Ratio (PAPR) of this system.

A large PAPR, Increases the complexity of the Analog to Digital Converter (ADC) and Digital to Analog Converter (DAC) and Reduces the efficiency of the Radio–Frequency (RF) power amplifier. PAPR reduction techniques vary according to the needs of the system and are dependent on various factors. PAPR reduction capacity, increase in power in transmit signal, loss in data rate, complexity of computation and increase in the bit-error rate at the receiver end are various factors which are taken into account before adopting a PAPR reduction technique of the system.

To satisfy this problem, many PAPR reduction techniques have been proposed in the literature. One of the classical and most popular techniques is known as Partial Transmit Sequence (PTS).

2. PARTIAL TRANSMIT SEQUENCE

PTS is known to achieve a high performance and redundancy utilization, but implementation problems arise, A relatively high computational complexity for searching the optimum sequence The need to transmit SI about the selected sequence to the receiver to undo the rotation of OFDM subcarriers.

In PTS technique data symbols in X are partitioned into V disjoint sub blocks $X^{(v)}$,

$$X^{(v)} \triangleq \left[X_0^{(v)} \ \dots \ X_{N-1}^{(v)}\right] \quad (1)$$

With

$$X_k^{(v)} = X_k \text{ or } 0, \quad 0 \le v \le V-1 \quad (2)$$

Such that

$$x = \sum_{v=0}^{V-1} X^{(V)} \quad (3)$$

A variety of different methods for PTS-based OFDM systems have appeared in the literature to recover transmitted data without SI [3]–[8]. According to marking algorithm proposed in [3], phase factors are binary numbers. The phases of sub-blocks are rotated as much as predefined amount when the phase factor of the sub-blocks is one of such binary numbers and are unchanged when the phase factor is the other binary number. So, the receivers need the detection process checking whether the predefined phase rotation is placed. In [7], [14], the symbol positions in symbol constellation are determined by constellation mapping based on phase factors. The hexagonal constellation mapping [7] and square mapping [14] are respectively used for these schemes. Another PTS-based OFDM system without SI is discussed in [5]. According to the scheme in [5], pilot sub-channel is transformed into time domain and zero-padding is performed to get channel estimation for each sub-block. The scheme in [9] recovers data without SI by a maximum likelihood decoding. The scheme in [8] uses combined block-type.

The number of non-zero components of $X^{(v)}$ is denoted by n_v, which in general is different for different v. Three partitioning strategies have been proposed. Also apply the random partitioning strategy, which typically yields the best PAR reduction performance, for the numerical results. The sub blocks $X^{(v)}$ are transformed into V time-domain partial transmit sequences x(v) ,

$$\mathrm{x}^{(v)} \triangleq \left[x_0^{(v)} \ldots x_{\mathrm{LN}-1}^{(v)}\right] = \mathrm{IDFT}_{\mathrm{LN}*\mathrm{N}}\left(X^{(v)}\right) \quad (4)$$

These sequences are independently rotated by some phase factors and then combined to produce the time-domain OFDM signal

$$x = \sum_{v=0}^{V-1} \mathrm{b}_v x^{(v)} \quad (5)$$

Sequence Search as a CO Problem

Using the following notation, we can state the optimization problem of PTS, to find the vector b that yields the transmit signal with the minimum PAR, as the following binary CO problem,

$$\begin{aligned} &\underset{\mathrm{b}}{\text{Minimize}} \quad f(\mathrm{b}) \\ &\text{Subject to:} \quad \mathrm{b} \in \{\pm 1\}^{V-1}, \end{aligned} \quad (6)$$

Thereby, we have exploited the fact that the phase rotations do not change the average signal power. Finding the exact solution of requires full enumeration of all 2^{V-1} possible phase vectors. Each evaluation of the objective function involves Combining partial transmit sequences x^v and Computing the peak power of the corresponding sequence x.

Assuming that complex numbers are stored as pairs of real and imaginary parts and since $b^v \in \pm 1$, calculating the transmit sequence involves 2NL (V - 1) additions and computing the peak power requires 2NL real multiplications per trial vector. Especially the large number of multiplications renders full enumeration computationally prohibitive even for moderate values of V. A PTS algorithm performing a reduced number of searches for the best phase vector becomes attractive.

3. EXISTING SYSTEM

In the existing system, input data symbols are divided into disjointed sub-blocks and then each sub-block are separately phase rotated by individually selected phase factors during PAPR optimization process. The phase factors are also transmitted as side information (SI) when data symbols are sent. For successful data recovery, receivers must have the SI. (see figure 1). Since SI is very critical for successful operation of the PTS scheme, it is protected by channel coding to combat frequency-selective fading. To do so requires increased system complexity, further loss in data transmission rate, and additional PAPR growth due to SI production following the PAPR optimization process. A variety of different methods for PTS-based OFDM systems have appeared in the literature to recover transmitted data without SI.

4. PROPOSED SYSTEM

In the proposed scheme, an efficient data recovery without SI is presented for adjacent partitioning PTS scheme. The adjacent partitioning PTS scheme can be more simply implemented and demonstrates similar PAPR performance in comparison with the interleaved or the randomized partitioning PTS scheme.

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The pilot symbol pattern for pilot interval L=3 of the proposed scheme, where data and pilot symbols are respectively represented by small empty circles and big black- filled circles (see figure 2). An extra pilot symbol is added at the end of the v^{th} sub-block. Without the extra pilot symbol, the data symbols between the last pilot symbol in $(V+1)^{th}$ sub-block and the first pilot symbol in v^{th} sub-block are hard to be recovered from channel estimation, due to different phase factors b_v and b_{v+1}. In the presence of the extra pilot symbol, complete channel estimation for each and whole sub-block including those data symbols is enabled.

The proposed scheme does not need any other processes to protect and to extract SI. With an extra pilot symbol at the end of each sub-block, complete channel estimation including data symbols between the last two pilot symbols $X_{vp}[N_{vp}-2]$ and $X_{vp}[N_{vp}-1]$ is readily made. As a result, because of different phase factors for different sub-blocks in PTS-based OFDM systems, the presence of the extra pilot symbol at the end of a sub-block enables consistent channel estimation throughout the sub-block.

At receivers, according to the process of the general pilot aided channel estimation in [6], pilot sub-channels are estimated, and then data sub-channels are interpolated based on neighbored pilot sub-channels. The channel estimation of the proposed scheme is performed for each sub-block based on the pilot pattern. For the PTS scheme, since channel estimation is made when phase factors are removed beforehand, the BER performance does not depend on the number of sub-blocks. The estimation of composite data sub-channels is made by a linear interpolation and a cubic spline interpolation (see Figs. 3 and 4)

BER performances of the proposed scheme, the scheme in [9] (θ=30°), and the PTS scheme for a typical urban (TU-6) channel, according to the number of partitioned sub-blocks. V=4, 6, and 8 with four allowed phase factors, when linear interpolation is used for data sub-channel (see figure 3).

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The channel estimation for each sub-block based on the pilot pattern is compared with the condition when no channel is estimated (see figure 5). From the estimated channel the data symbols are retrieved and from those symbols the data is recovered.

5. FIGURES/CAPTIONS

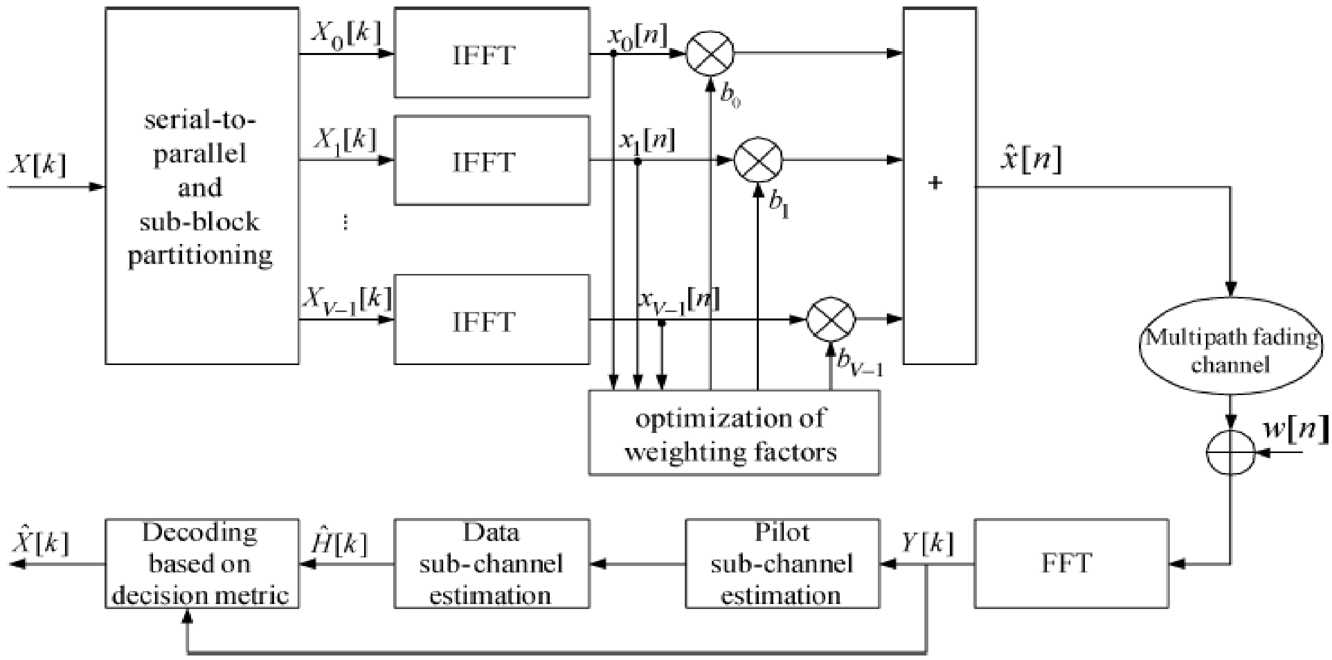

Fig. 1: Block diagram of OFDM systems based on the PTS scheme with perfect SI.

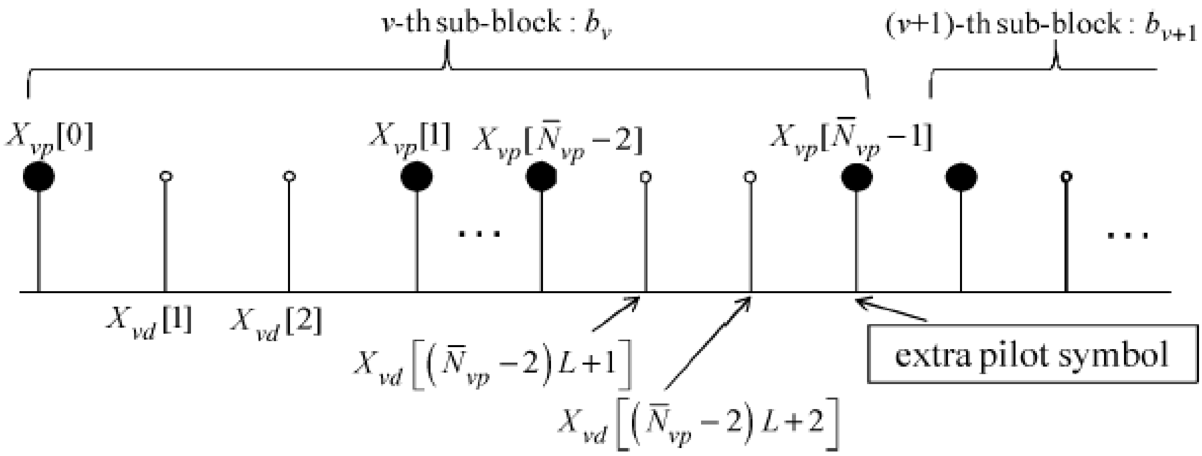

Fig.2.Pilot symbol pattern

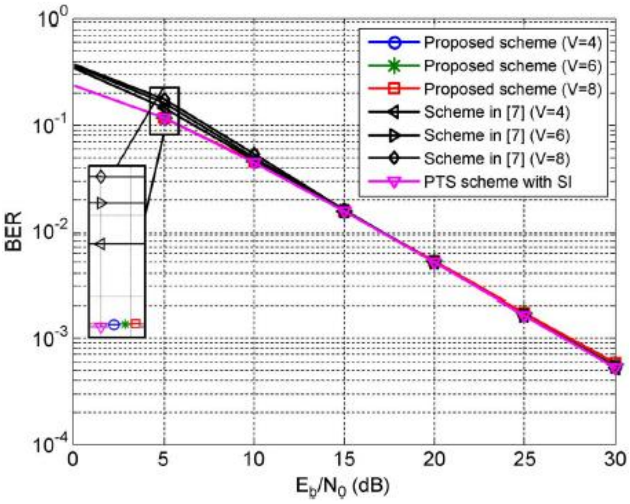

Fig.3.Spline interpolation

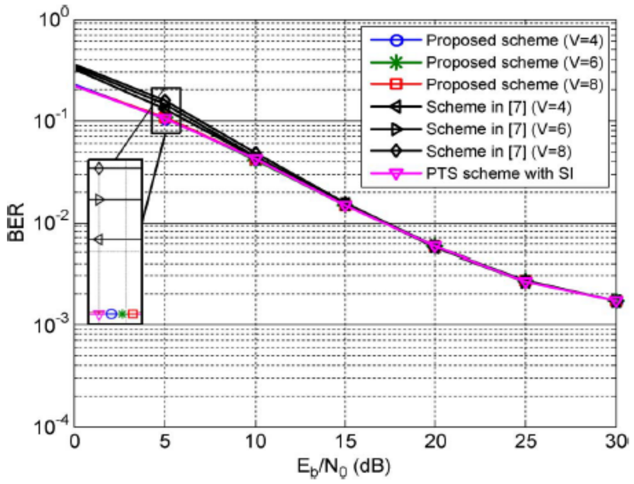

Fig.4.Linear interpolation

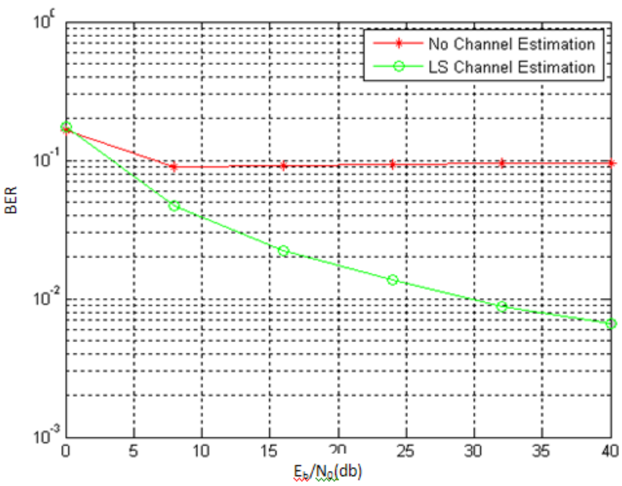

Fig.5.Channel estimation using pilot symbol

6. CONCLUSION AND FUTURE WORK

OFDM techniques are quickly becoming a popular method for advanced communication networks. It is very effective if there is an efficient data recovery without SI transmission in PTS-based OFDM systems is used. At the cost of an additional pilot symbol placed at the end of each sub-block, complete channel estimation even for data symbols around the end of each sub-block is performed without SI. Simulation results show that the proposed scheme without any SI transmission achieves approximately the same BER performance compared with the PTS scheme with perfect SI. Moreover, the proposed scheme has significantly lower computational complexity. Also the proposed method is more efficient in recovering the data from the transmitted sequence. Here the channel estimation is carried out using the known pilot symbols through which the data sub channels are estimated and the data is recovered efficiently.

The sequence order search carried out to recover the data is modified into matrix formulation by which the fast recovery of data is achieved by random order search.

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