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Conceptual Study of OFDM-Coding, PAPR Reduction, Channel Estimation

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Abstract

At present for high data rate transmission, Orthogonal Frequency Division Multiplexing (OFDM) which is one of multi-carrier modulation (MCM) techniques offers a considerable spectral efficiency; multipath delay spread tolerance, immunity to the frequency selective fading channels and power efficiency. As a result, OFDM has widely been deployed in many wireless communication standards such as Digital Video Broadcasting (DVB).In using turbo codes for OFDM performance can be sufficiently improved as seen in LTE standard systems. One of the challenging issues for Orthogonal Frequency Division Multiplexing (OFDM) system is its high Peak-to-Average Power Ratio (PAPR). In this paper we present turbo coded OFDM systems, its channel estimation scheme and methods for reducing PAPR in the system.

Keywords

OFDM, PAPR, CCDF, turbo codes, channel estimation.

1. Introduction

All OFDM presents one of the most reliable multiplexing schemes for fading channels. In OFDM, the data is divided in to large number of closely of closely spaced carriers. Hence called frequency division multiplexing. However, channel responses with time-varying magnitude and phase is one of the characteristic of mobile communication system. For this purpose different channel estimation technique has been developed. Of which Pilot-aided channel estimation technique are the most commonly used due to the increase in estimation accuracy, this is basically an iterative scheme which improves decoder performance. But when this schemes is combined with a turbo decoding iterations the system become more complex.

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OFDM system performance is highly influenced on PAPR, it get sufficiently degraded by an increase in PAPR. This problem is because of the modulation scheme itself. As in the OFDM system multiple sub-carriers are added together to form the signal to be transmitted the effect of PAPR is more predominant. In OFDM systems, the PAPR is a random variable. It is often characterized by its distribution which is expressed in terms of Complementary Cumulative Distribution Function (CCDF) [1].There are Numbers of techniques proposed in the literature for reducing the PAPR in OFDM systems. In this paper we propose a method for reducing PAPR using combined weighting and Partial Transmit Sequences techniques (CWP). Therefore a new channel estimation technique which could be applied to the turbo coded (LTE standard) is to be focused in case of OFDM systems with performance comparable to that of the existing iterative estimation system but will significantly reduce the complexity. In this paper, the channel estimation scheme works in synchronism with iterative decoding. The iterative turbo decoder feedback loop is broken and the estimator is inserted. The soft channel input is updated before each stage of decoding, new estimate is formed by the updated decoder decision variable. Moreover various PAPR reduction techniques are also addressed.

2. System Model

The transmitter and receiver of the LTE (Long Term Evolution Standard) system, which employs turbo coded OFDM is as shown in Figure. The information bits are encoded, interleaved, and mapped into M-ary complex symbols forming the data sequence Xd. Then pilot sequence is inserted and IFFT is performed to optimize this for OFDM transmission. The information sequence is now in time domain. The data in parallel form is then converted serial form and transmitted over the wireless communication channel. At the receiver side the received data is first converted back to parallel form. The cyclic prefix is removed and pilot sequence is extracted from the data. This pilot sequence is used to determine the channel characteristics initially using the pilot sequence an initial estimate of the channel transfer function is obtained. This initial estimate is then corrected through iteration of the turbo decoder with the help of interpolation using an algorithm. Here we use a rate 1/3 turbo code for encoding the information sequence. The output of this turbo encoder is interleaved. The code is recursive meaning that one of the outputs is the input sequence itself. The parity bits can be punctured to get higher rates.

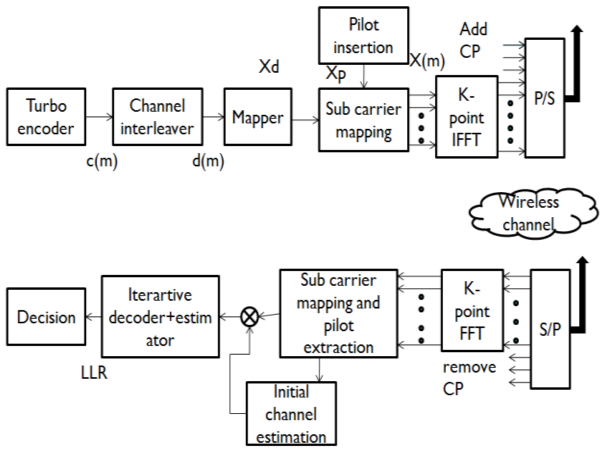

Fig.1: General LTE system model-OFDM

Channel estimation in fading channels with very high mobility usually consists of two steps. Channel estimation at pilot symbols is the first step. The next step, we need to perform interpolation between the pilot symbols to obtain the channel estimate of data symbols (symbols only with unknown data subcarriers), which are transmitted between these pilot symbols. The approach used here closely resembles that of factor graph approach for loopy belief propagation decoding. An input vector q € Q^n has components q_j € Q for some set Q of message sequences and generates an unknown coded sequence x € R^n through turbo coding described by a conditional distribution $PX/Q(x_j /q_j)$. When x is passed through channel a linear transform occurs.

$$z = Ax \tag{1}$$

Where A or *H* is the transform matrix Finally, each component of z_i of z randomly generates an output component y_i of a vector y € Y m through decoding with conditional distribution $PY/Z(y_i /z_i)$. Where Y is some output set. The problem is to estimate the transform input x and output z.

3. Literature Review

Of the coding schemes used, Turbo excels others in terms of capacity and performance as seen in [2]. In 2008, M.A Saeed [3] proposed adaptive channel estimation and tracking scheme based on recursive least squares. Preamble aided channel estimation is performed in time-domain (TD). The estimator is then extended to perform decision-directed (DD) channel tracking during data transmission. In 2011, Hoda Hafez [4], incorporated pilot symbols into the transmission. Like pilot tones, pilot symbols are used at the receiver to obtain an estimate of the channel response so that coherent detection can be performed. Also estimation using adaptive filters is common. In 2012, Dae-Jung Yoon came up with a three-stage estimation scheme [5], based on Kalman filter, proposed to reduce the complexity and adapt the channel estimates with respect to the feedback information. But this is significantly complex system. In 2000, Zhongpeng Wang [6] proposed two effective PAPR reduction schemes. These techniques combine the DCT and SLM techniques. In the trans-mit end, the data stream is firstly transformed by DCT matrix, then the transformed data is processed by the SLM unit. If data block passed by DCT matrix before IFFT, the autocorrelation coefficients of IFFT input is reduced, then the PAPR of OFDM signal could be reduced. In 2011, Zhongpeng Wang [7] proposed another efficient method to reduce the PAPR of OFDM signal. A joint reduction in PAPR of the OFDM signals based on combining the discrete cosine transform (DCT) with companding is proposed. In the first step of the proposed scheme, the data are transformed by a DCT into new modified data. In the second step, the proposed scheme utilizes the companding technique to further reduce the PAPR of the OFDM signal.

4. Algorithm for receiver section

In this Modified Approximate Message Passing (MAMP) algorithm, the scalar operations are defined by two functions, gout (.) and gin (.), called the scalar estimation functions. The algorithm produces a sequence of estimates for the unknowns x and z [11].

Steps

Given a matrix A or *H* obtained from pilot sequence system inputs and outputs q and y and scalar estimation functions gin (.), and gout (.), generate a sequence of estimates through the following recursions [12]:

1. Initialization: Set t=0, i=j=1 corresponding to first row and column and $\hat{s}(-1) = 0$ for the first iteration.

2. Computation: **For each i, compute:**

$$\zeta_p^i(t) = \sum_j |aij|^2 \zeta_x^j(t)$$
$$\hat{p}^i(t) = \sum_j aij\,\hat{x}_j(t) - \zeta_p^i(t)\,\hat{s}^i(t-1)$$
$$\hat{z}_i(t) = aij\,\hat{x}_j(t) \qquad (2)$$

3. *Updating values:* For each i,

$$\hat{s}_i(t) = gout\,(t, \hat{p}^i(t), yi, \zeta_p^i(t)) \qquad (3)$$
$$\zeta_s^i(t) = -\frac{\partial}{\partial p} gout\,(t, \hat{p}^i(t), yi, \zeta_p^i(t)) \qquad (4)$$

4. *Input side:* For each j,

$$\zeta_r^j(t) = [\sum_i |aij|^2 \zeta_s^i(t)]^{-1} \qquad (5)$$
$$\hat{r}_j(t) = \hat{x}_j(t) + \zeta_r^j(t) \sum_j aij\,\hat{s}_i(t) \qquad (6)$$

Where,

$$\hat{x}_j(t+1) = gin(t, \hat{r}^j(t), q_j, \zeta_r^j(t)) \qquad (7)$$
$$\zeta_r^j(t+1) = \zeta_r^j(t)\frac{\partial}{\partial r} gin(t, \hat{r}^j(t), q_j, \zeta_r^j(t)) \qquad (8)$$

Then increment t= t+1 and return to step 2 until enough iterations are performed

5. PAPR Reduction

The definitions of N frequency domain signals in OFDM are $\{X_n, n=0, 1, 2...N-1\}$. These N signals construct one OFDM block. A set of N sub-carriers, i.e. $\{f_n, n=0, 1, 2...N-1\}$, is used for these signals in the OFDM. The N sub-carriers are said to be orthogonal, if,

$$f_n = n\Delta f \qquad (9)$$

in frequency domain

$$\Delta f = 1/NT \qquad (10)$$

and T is the OFDM time domain signal duration. The OFDM signal is expressed as [6]:

$$X(t) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_n e^{j2\Pi f_n t}; 0 \le t \le T \qquad (11)$$

In some blocks of OFDM signals, high PAPR occurs since the structure of the given symbols may cause this peak.

High PAPR is a serious issue in RF analog circuits, particularly in a high power amplifier. Nonlinearity of high power amplifier leads to inter-carrier interferences (ICI) and thus out-of-band radiation.

Weighted ofdm signal scheme

A PAPR reduction scheme based on a weighted OFDM signal is proposed in [7] to reduce the PAPR without distortion in removing the weight at the receiver side. This weighting technique is motivated by a circular convolution process, i.e., the modulated OFDM signal is convoluted with a certain kind of band limited signal for smoothing the peak of the OFDM signal before the HPA. In this weighted OFDM method, the time duration needed to transmit the weighted OFDM signal is the same as the time duration for the simple OFDM signal. Also, the original discrete data can be recovered completely at the receiver side with additional 2N complex multiplications without extra cost in transmission.

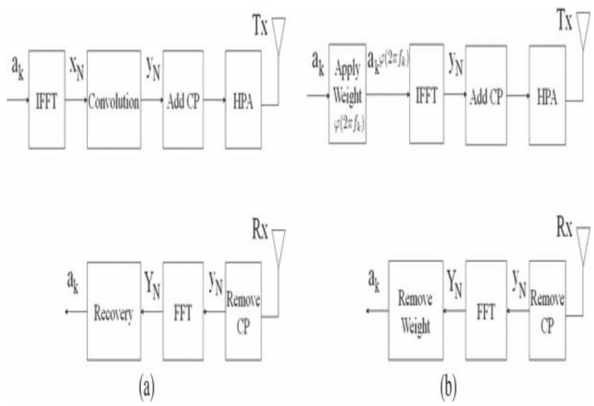

Fig. 2: Simplified block diagrams for an OFDM system with (a) convolution scheme and (b) weighting scheme

The modified weight with a positive constant α is [7]:

$$\varphi_\alpha(x) = \frac{1-\sin c(x)}{\Pi^2 x^2} + \frac{\alpha}{\log N} \qquad (12)$$

Where α is a shift parameter, and log N is obtained by experiment.

PAPR reduction using PTS

In the PTS scheme [8] as shown in figure 3, the input symbol sequence is partitioned into a number of disjoint symbol subsequences. IFFT is applied to each symbol subsequence. Then the resulting signal subsequences are summed after being multiplied by a set of distinct rotating vectors. The PAPR is computed for each resulting sequence and finally the signal sequence with the minimum PAPR is transmitted. As the number of subcarriers and the order of modulation are increased, reducing the computational complexity becomes more important. A new phase sequence is proposed in [9], in order to decrease computational complexity of the conventional PTS technique. If we consider the number of allowed phase factor *W=2*, then the new phase sequence is based on the generation of *N* random values from the possible phase factors *{1 -1}*.. Therefore the new phase sequence can be constructed as follows

$$\hat{b} = \begin{bmatrix} b_{1,1}, b_{1,2} \ldots b_{1,N} \\ \ldots\ldots\ldots\ldots \\ \ldots\ldots\ldots\ldots \\ \ldots\ldots\ldots\ldots \\ b_{v,1}, b_{v,2} \ldots b_{v,N} \end{bmatrix} \quad (13)$$

Where *N* is number of subcarriers and *V* is number of sub blocks partitioning.

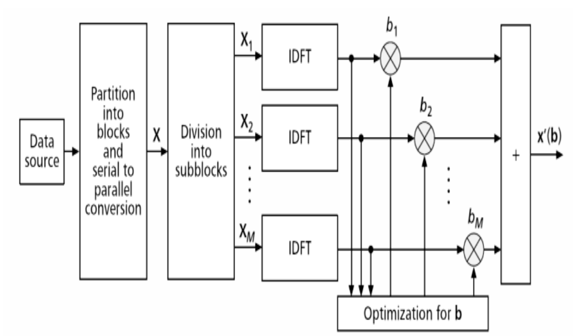

Fig. 3: Block diagram of PTS technique with new phase sequence

N random phase sequence is generated periodically *V* times. The new phase sequence matrix generated has N different random values. The way to find the optimum phase factor will be different for the new phase sequence format. In this case, first *N* different random phase sequence is generated and this is continued *V* times according to [9], hence the optimum phase factor is each row of this matrix. But for finding the optimum phase factor, matrix in equation (13) should be randomly generated several times. We constrain the number of times that the matrix would be generated to be the same as in the conventional PTS for proper comparison. Hence for the case of *W=2* and *V=4*, C-PTS has 8 iterations and therefore (13) should be generated 8 times. In this case we have 8 possibilities, since the initial bit is fixed, {1,1,1}, {1,1,-1}, {1,-1,1}, {1,-1,-1},{-1,1,1},{-1,-1,1},{-1,1,-1},{-1,-1,-1}. Optimum phase factor will be chosen from these possible 8 phase sequences. In our proposed method, because there are N different random phase factors, to search for the optimum phase sequence it requires 8 iterations which is not practical. But here, we only apply the same iteration as was applied in conventional PTS and later it will be shown through simulations, that good PAPR performance is achieved, and it is also possible to have less iteration while keeping the PAPR performance same as that of conventional PTS but with reduced complexity[10].

SLM method

In this method from a set of sufficiently different signals representing same information transmit signal having lowest PAPR is selected. As there is no restriction on the modulation applied on the sub carriers or on their number this method is very flexible. Block diagram or SLM technique is shown below

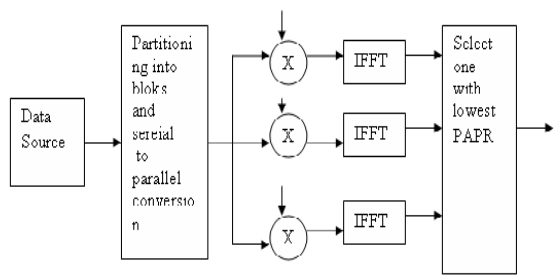

Fig. 4: Block Diagram of OFDM transmitter with the SLM Technique

Let's $X=[X_0, X_1\text{--------},X_{N-1}]^T$ be data stream after serial to parallel conversion . From those data of the lowest PAPR is selected to transmit. When the number of copy block U is increased PAPR reduction effect will be better but result in system complexity. This method reduces PAPR without any signal distortion. But have a disadvantage that it has higher system complexity as the reduction depend on number of cop block. This complexity can be reduced by reducing the number of IFFT block.

6. Proposed PAPR Reduction Scheme

We propose a new PAPR reduction scheme for the system model considered in section **(3)**. The matrix in equation (13) is extended as follows

$$\hat{b} = \begin{bmatrix} b_{1,1}\ldots\ldots\ldots\ldots b_{1,N}\,. \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ b_{v,1}\ldots\ldots\ldots\ldots b_{v,N} \\ b_{v+1,1}\ldots\ldots\ldots b_{v+1,N} \\ \ldots\ldots\ldots\ldots\ldots\ldots \\ b_{p,1}\ldots\ldots\ldots\ldots b_{p,N} \end{bmatrix} \qquad (14)$$

Where, *P* is the number of iterations that should be set in accordance with the number of iterations of the C-PTS. The value of *P* can be calculated as follows [9]:

$$P = DW^{V-1} \qquad (6)$$

Where *D* is coefficient that can be specified based on the PAPR reduction and complexity and *DN* is amount that is specified by user. Value of *P* explicitly depends on the number of sub blocks *V* if assuming the number of allowed phase factor is constant. The optimum phase sequence of equation (5) can be derived by successive search of phase sequence based on the value derived from equation (6) and then multiplied with input signal. Finally the PAPR is computed for each resulting sequence and the signal sequence with the minimum PAPR is transmitted.

7. Simulation Results

The analysis has been carried out using MATLAB 7.11. The modulation used is QPSK. The performance evaluation is done in terms of complementary cumulative distribution function. A comparison of the detection schemes for turbo coded OFDM systems (LTE) with our proposed new channel estimation algorithm is performed, as indicated by figure 5,i.e the hard decision ,soft decision and LLR decision. It is found that LLR decoding has better performance than the other two for a given SNR.

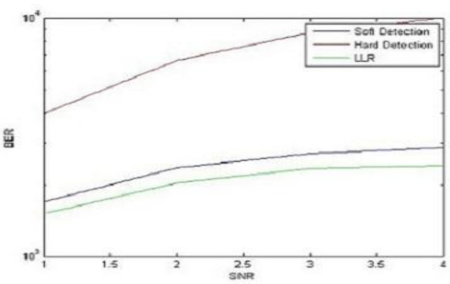

Fig. 5: Comparison of different detection schemes for MAMP LTE system

Figure 6 shows CCDF of weighted OFDM system alone for α=0.03 and N=128. Fig 7 shows CCDF of weighted OFDM system for different values of α such as 0.05, 0.15 and 0.8. It can be concluded that for lower values of α PAPR reduction is better. Hence lower values of α is chosen for simulation.

Fig 8 compares the proposed combined weighting and PTS technique (CWP) with weighted OFDM signal scheme, PTS technique and clipping for CCDFs over AWGN channel. As shown in the figure, the CCDF of proposed CWP scheme is superior

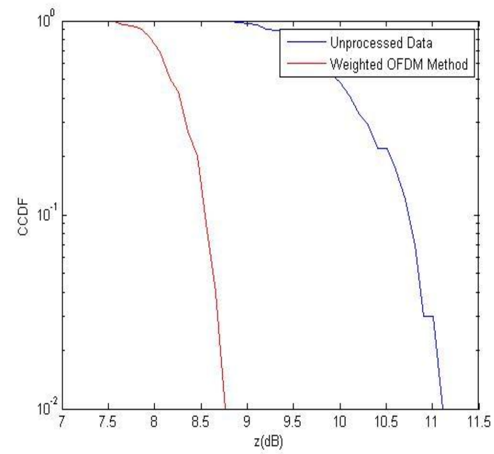

Fig. 6: CCDF of weighted OFDM system

Fig 9 shows the BER performance. It can be concluded from the figure that the proposed CWP system in LTE standard has better performance, than existing systems.

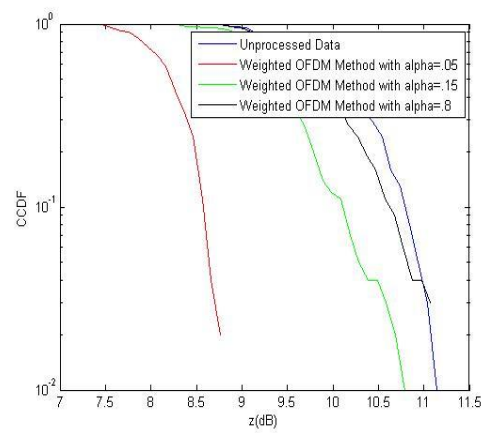

Fig. 7: CCDF of weighted OFDM system for different values of α

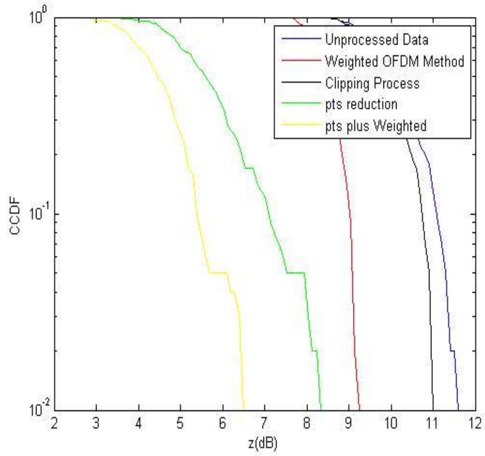

Fig. 8: CCDF of proposed system

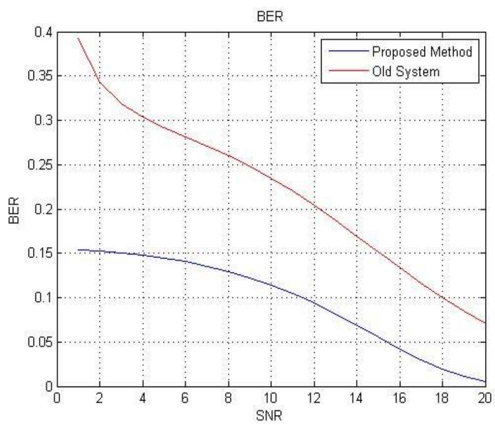

Fig. 9: BER of the proposed system

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8. Conclusion and Future Work

This paper concentrates on improving the performance of coded OFDM systems. For this turbo-coded (LTE Standard) system is considered. Simulation results show that the proposed joint estimation scheme for turbo codes is highly effective and have much performance improvement over the existing systems for channel estimation. Moreover this system does not add to complexity. The estimation accuracy is improved in each stage by iteratively feeding back the channel information to the decoder. We also discuss a new PAPR reduction method by combining weighting and PTS technique. Simulation results shows that the proposed system has better PAPR reduction when compared with other PAPR reduction techniques such as weighting, PTS and clipping. It has been shown that the proposed method is an effective way to reduce the PAPR of an OFDM signal. Also the BER performance is improved compared with existing method. This system finds application in widely used present.

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