PAPR Reduction of Space-Time Coded OFDM Systems Using DFT Spreading Technique

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ABSTRACT- DFT spreading is one of the techniques introduced for peak to average power ratio (PAPR) reduction of OFDM systems. In this technique, the input signal with DFT is spreaded such that the PAPR is minimized but this can reduce the PAPR of OFDM signal to the level of single carrier transmission. In this paper, a DFT spreading method is proposed for the PAPR reduction of OFDM systems with spatial diversity of space time coding. The proposed method is such that PAPR is reduced simultaneously at all antennas, while the spatial encoding relationship still holds. Simulation results show that its performance is very close to the performance of single carrier-FDMA (SC-FDMA).

Keywords: Peak to Average Power Ratio (PAPR), Orthogonal Frequency Division Multiplexing (OFDM), Interleaved FDMA (IFDMA), Local FDMA (LFDMA).

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is a well known technique for high data rate transmission [1, 11]. One of the drawbacks of OFDM systems is high PAPR, which leads to saturation of high power amplifiers. Thus, a high dynamic range amplifier is required, which increases the cost of the system. Moreover the non-linear characteristic of HPA, excited by large input out-of-band radiation that affects signals in adjacent bands and in-band distortions that result in rotation. Attenuation and offset in received signal. A number of approaches have been proposed to deal with the PAPR problem [12]. These techniques achieve PAPR reduction at the expense of transmit signal power increase, bit error rate (BER) increase, data rate loss, computational complexity increase, and so on. In the proposed method, at each number of trials the antenna with maximum PAPR is selected and the clipping, filtering is applied and to spread the input signal with DFT which is subsequently taken into IFFT where the signals of other antennas are produced by using STBC relationships.

The remainder of this paper is organized as follows: In section 2, the single carrier OFDM systems, i.e. equivalent to single carrier FDMA systems are modeled and discussed the DFT spreading technique for PAPR reduction in these systems. In section 3, STBC-OFDM systems are discussed briefly. In section 4, Simulation results for proposed technique are analyzed.

II. Single-Carrier OFDM Systems

In single carrier OFDM systems, the input bit stream is interleaved and encoded by a channel encoder. Then, the coded bits are mapped onto digital modulation techniques. Let \( X = [X_0, \ldots, X_N] \) be a sequence of complex symbols and \( x = [x_0, \ldots, x_{N-1}] \) be its discrete Fourier transform[4, 12]. The OFDM baseband signal is expressed as,

\[
x(n) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k e^{j2\pi kn/N}, \quad n=0,1,\ldots,N-1 \quad \text{...(1)}
\]

Where \( N \) denotes the number of subcarriers.

In this scheme, the \( L \)-times oversampled discrete-time signal \( x[m] \) is generated from the IFFT of following equation \( X_k \) with \( N.(L-1) \) zero padding in the frequency domain i.e.,

\[
x'[m]= \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k e^{j2\pi km/N.L} \quad \text{..........................(2)}
\]

Then the corresponding PAPR of OFDM signal is expressed as

\[
PAPR \{x[n]\} = \max|x'[m]|^2 / E\{|x[m]|^2\} \quad \text{..........................(3)}
\]

Where \( E\{ \} \) denotes expectation operator.
\[
X_k' = \begin{cases} 
X_k, & \text{for } 0 \leq k \leq N/2 \text{ and } NL-N/2 < k < NL \\
0, & \text{elsewhere}
\end{cases}
\]  
(4)

And then modulated with a carrier frequency \(f_c\) to yield a pass band signal \(x^p[m]\). Let \(x'^p[m]\) denote the clipped version of \(x^p[m]\), which is expressed as

\[
x'^p[m] = \begin{cases} 
-V, & x^p[m] \leq -V \\
x^p[m], & |x^p[m]| < V \\
V, & x^p[m] \geq V
\end{cases}
\]  
(5)

Where, \(V\) is the pre-specified clipping level. Here, we define the clipping ratio (CR) as the clipping level normalized by the RMS value \(\mu\) of OFDM signal such that

\[
CR = \frac{V}{\mu}
\]

Where \(\mu = \sqrt{N}\) and \(\mu = \sqrt{N/2}\) in the baseband and passband OFDM signals with \(N\) subcarriers respectively.

In OFDMA systems, subcarriers are interleaved and assigned to multiple mobile users. Each terminal in uplink uses a subset of subcarriers to transmit its own data. The rest of the subcarriers, not used for its own data transmission, will be filled with zeros. Here, the number of subcarriers allocated to each user is assumed to be \(M\). In this proposed technique, \(M\)-point DFT is used for spreading, and the output of DFT is assigned to the subcarriers of IFFT. Here, the effect of PAPR reduction depends on the way of assigning the subcarriers to each terminal. In order to assign subcarriers among users, we have two different approaches i.e. LFDMA and IFDMA. In particular, LFDMA allocates DFT outputs to \(M\) consecutive subcarriers in \(N\) subcarriers and in IFDMA allocates DFT outputs with equi-distance \(N/M = W\), where \(W\) denotes bandwidth spreading factor.

\[
\text{Figure1: (DFT Spreading technique of IFDMA at uplink transmitter)}
\]

The input data \(x[m]\) for IFDMA is DFT spread to generate \(X[i]\) and then allocated as

\[
X'(k) = \begin{cases} 
X[k/W], & k=W.m_1, \quad m_1 = 0,1,2 \ldots \ldots M-1 \\
0, & \text{otherwise}
\end{cases}
\]  
(6)

The IFFT output sequence can be expressed as

\[
x'(n) = \frac{1}{N} \sum_{k=0}^{N-1} x'(k) e^{j2\pi nk/N}
\]
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\[ \sum_{m=1}^{M-1} X[m] e^{j2\pi m/n} \]

\[ \sum_{m=1}^{M-1} X[m] e^{j2\pi (Mw+m)m/n} \]  
\[ \sum_{m=1}^{M-1} X[m] e^{j2\pi m1/m} \]

\[ \frac{1}{W} x[m] \]

Where \( w = 0, 1, 2, \ldots, W-1 \)

Similarly, the IFFT signal for DFT spreading in LFDMA at the transmitter can be allocated as

\[ X'[k] = \begin{cases} X[k], & k = 0, 1, 2, \ldots, M-1 \\ 0, & k = M, M+1, \ldots, N-1 \end{cases} \]  

The IFFT output signal can be expressed as

\[ x'^{(m)} = X'[w, m+w] = \frac{1}{N} \sum_{k=0}^{N-1} X'[k] e^{j2\pi nk/N} = \frac{1}{W} \sum_{m=1}^{M-1} X[k] e^{j2\pi (Wm+w)k/W} \]

Where \( n = W, m + w \)

III. STBC-OFDM systems

In STBC-OFDM systems with \( M \) transmitter antennas, the symbol transmitted from \( l \)th antenna and denoted by \( X^l_m \) where \( n = 0, 1, \ldots, N-1 \). Here, we denote the time-domain samples from \( l \)th antenna as \( x^l_m = [x^l_m(0), x^l_m(1), \ldots, x^l_m(N-1)]^T \).

The information bits are first modulated using an M-ary modulation schemes. The encoder then takes a block of two modulated symbols \( x^1 \) and \( x^2 \) in each encoding operation and gives it to the transmit antennas according to the code matrix

\[ X = \begin{bmatrix} x^1 - x^2^* \\ x^2 \end{bmatrix} \]

In (10) the first column represents the first transmission period and the second column the second transmission period. The first row corresponds to the symbols transmitted from the first antenna and the second row corresponds to the symbols transmitted from the second antenna. During the first symbol period, the first antenna transmits \( x^1 \) and the second antenna transmits \( x^2 \). During the second symbol period, the first antenna transmits \( -x^2^* \) and second antenna transmits \( x^1^* \) being the complex conjugate of \( x^1 \).

![Figure 2: (A block diagram of the STBC-OFDM with two transmitter antennas)](image)

IV. Simulation results

In simulation, the OFDM frames with \( N=256 \) subcarriers have been assumed with QAM modulation. To find the peak values and to estimate PAPR, the oversampling ratio \( (N_0) \) of 8 for pulse shaping has been used. To calculate
PAPR, the ratio of the maximum power to average power has been considered. Here, the performance of proposed method is evaluated by Complementary Cumulative Density Function (CCDF).

**Input:**

- **User Requirements**
  - \( N = 256 \), \( N_d = 64 \) (FFT size)
  - No. of OFDM blocks for iteration = 4000

- **Derived parameters**
  - \( N_{blk} \) = no. of OFDM block for iteration
  - \( b \) = no. of bits per symbol
  - Spreading factor, \( W = N/N_d \)
  - Set Roll-off factor = 0.3

**Algorithm:**

```
for \( \text{iter} \), no. of bit per symbol = \text{iter} \times \text{no. of bit per QAM symbol} \) do
  \( M \leftarrow 2^b \)
  CCDF-IF ← CCDF-PAPR-DFT spreading
  CCDF-LF ← CCDF-PAPR-DFT spreading
end
```

**Figure 3:** (DFT spreading algorithm for the STBC-OFDM system)

**Table 1:** Parameters used in DFT-spreading of PAPR reduction

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of subcarrier (N)</td>
<td>256</td>
</tr>
<tr>
<td>FFT size</td>
<td>64</td>
</tr>
<tr>
<td>Modulation used</td>
<td>QAM</td>
</tr>
<tr>
<td>Size of OFDM block</td>
<td>4000</td>
</tr>
<tr>
<td>Over-sampling factor</td>
<td>8</td>
</tr>
</tbody>
</table>

We have shown the PAPR performance of DFT spreading in Figure 4, 5. When we are taking the case of 16-QAM, the values of PAPR with IFDMA, LFDMA 3.8 dB and 8.2 dB. Figure 3 shows the performance of DFT spreading technique in STBC-OFDM systems with two IFDMA & LFDMA and 256 subcarriers with QAM modulation. Figure 4 shows the PAPR performance of DFT spreading technique IFDMA & LFDMA varying with roll-off factor ‘a’ of raised cosine (RC) filter. We have obtained the results with simulation parameter of \( N = 256 \), \( M = 64 \), \( W = 4 \) and \( N_{os} = 8 \) for QAM.
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Figure 4: (PAPR of DFT spreading technique with roll-off factor)

Figure 5: (PAPR for LFDMA, IFDMA using DFT spreading)
V. Conclusions

In this paper, the DFT-spreading technique has been proposed for PAPR reduction of the STBC-OFDM systems with M antennas. In this technique, in each number of trials, clipping & filtering, DFT spreading are applied to both LFDMA & IFDMA. Simulation results for STBC-OFDM systems with two transmitter antennas show that the proposed technique of PAPR reduction is lower than that of OFDMA with no DFT spreading.

References