Enhancement in Reduction of PAPR using ASM Based SFBC Technique in OFDM Systems

P. Sai Kiran Kumar¹ M. Nanda Kumar²
¹PG Scholar ²Assistant Professor
¹²Sreenivasa Institute of Technology & Management Studies, Chittoor, A.P, India

Abstract—In this paper, we recommend Alternative-Signal Scheme for PAPR reduction in OFDM Systems with Space Frequency Block Coding (SFBC). The key idea of the proposed scheme is keeping the advantage of the SFBC structure to generate some multi-sequences via combining the OFDM signals at different transmit antennas. The OFDM is used to mitigate the problem of inter symbol interference (ISI) and provides good protection against co-channel interference and noise. One of the major drawbacks of OFDM systems is that the transmitted signal exhibits a high PAPR when the input sequences are correlated. The space frequency block coding based Alternative-Signal schemes have been used to reduce peak to average power ratio (PAPR) orthogonal frequency division multiplexing (OFDM) system with space frequency block coding (SFBC). The Alternative-Signal scheme reduces the computational complexity and when Alternative-Signal scheme is used with quadrature amplitude modulation (QAM). Theoretical analysis and simulation results validate that the proposed scheme has the ability to provide large PAPR reduction, low bit error rate and low computational complexity without side information in SFBC MIMO-OFDM systems.

Key words: OFDM, SFBC, PAPR, ASM-I, ASM-J, ASM-S

I. INTRODUCTION

As a promising candidate multicarrier modulation practice for Long-Term Evolution Advanced (LTE-A) and other future wireless standards, orthogonal frequency-division multiplexing with offset quadrature amplitude modulation (OFDM/OQAM) has drawn more and more attention due to its high spectrum efficiency. In OFDM/OQAM systems, the OFDM/OQAM signal is obtained by summing over M time-shifted OFDM/OQAM symbols, each of which is obtained by letting N QAM symbols pass through a prototype filter and be modulated with N orthogonal subcarriers. Compared with traditional OFDM systems, the OFDM/OQAM systems own some noticeable advantages: 1) The cyclic prefix is no longer required and 2) the sidelobe of its power spectrum density is very low. The main advantages of OFDM/OQAM are the heavier computation cost due to the extra filtering operations and the more complex channel equalization. For the multicarrier modulation systems (including both the OFDM and OFDM/OQAM), one of the critical issues for implementations is their relatively high peak-to-average power ratio (PAPR). Peak-to-average power ratio (PAPR) is proportionally related to the number of subcarriers used for OFDM systems. When the different subcarriers are in phase with each other. At each instant of time they are different with respect to each other with different phase values. When sub-carriers are added coherently, this will cause the output envelope to abruptly shoot up which gets a ‘peak’ in the output envelope. Large PAPR of a system makes the implementation of digital-to-analog converter (DAC) analog-to-digital converter (ADC) difficult. The complexity increases in the design of RF amplifier, if PAPR is high.

II. PEAK TO AVERAGE POWER RATIO

The Peak to Average power Ratio is the ratio of the maximum power of a sample in a given OFDM transmitted to the average power of that same OFDM symbol. In multicarrier modulation scheme uses more number of sub-carriers. When the different sub-carriers are in phase with each other. At each instant of time they are different with respect to each other with different phase values. When sub-carriers are added coherently, this will cause the output envelope to abruptly shoot up which gets a peak in the output envelope. Due to using of large number of independently modulated subcarriers in an OFDM system, the peak value of the OFDM system can be very high as compared to the average value of the whole system. This ratio of the peak power to the average power value is named as “Peak-to-Average Power Ratio”.

The PAPR is defined by:

\[ \text{PAPR} = \frac{\max(x(t))^2}{E[|x(t)|^2]} \]  \hspace{1cm} (1)

Where \( E[.| \) denotes expectation. The complementary cumulative distribution function (CCDF) of the PAPR is one of the parameter most frequently used to performance measures for PAPR reduction techniques. The CCDF of the PAPR denotes the probability that the PAPR of a data block exceeds a given threshold.

A. Cumulative Distribution Function:

The Cumulative Distribution Function (CDF) is one of the most regularly used parameters, which is used to measure the efficiency of any PAPR technique. Normally, the Complementary CDF (CCDF) is used instead of CDF, which helps us to measure the probability that the PAPR of a certain data block exceeds the given threshold.

By implementing the Central Limit Theorem for a multicarrier signal with a large number of sub-carriers, the real and imaginary part of the time domain signals have a
mean of zero and a variance of 0.5 and follow a Gaussian distribution.

The CDF of the amplitude of a signal sample is given by:
\[ F(z) = 1 - \exp(-z) \]

The CCDF of the PAPR of the data block is desired is our case to compare outputs of various reduction techniques. This is given by:
\[ P(\text{PAPR} > z) = 1 - P(\text{PAPR} \leq z) = 1 - (1 - \exp(-z))^N \]

### III. PAPR FORMULATION FOR OFDM/OQAM SYSTEM MODEL

![Fig. 2: Typical OFDM/OQAM Transmitter.](image)

The OFDM/OQAM transmitter structure is shown in Fig. 2, which consists of \( N \) subcarriers. After the QAM modulation, the input QAM symbols are first serial-to-parallel converted to data matrix \( X \), which is defined as
\[ X = [X_0, X_1, \ldots, X_{M-1}] \]  
where \( M \) is the number of data blocks, and \( X_m \) is the \( m \)th data block, which is defined as
\[ X_m = [X_0^m, X_1^m, \ldots, X_{N-1}^m] \]
with denoting the transpose and \( X_m^k \) denoting the \( k \)th QAM symbol on the \( m \)th subcarrier, which is defined as
\[ X_m^k = e^{\text{Re}^*} + j d_m^k \]
where \( e^k \) and \( d_m^k \) denote the real and imaginary parts of \( X_m^k \), respectively.

![Fig. 3: Structure of the OFDM/OQAM Signal.](image)

The real and imaginary parts of \( X_m^k \) are staggered by \( T/2 \) and passed through the prototype filter to obtain
\[ x_m^k(t) = e_k^m h(t - mT) + j d_m^k h \left( t - \frac{T}{2} - mT \right) \]
where \( T \) denotes the symbol period [4], and \( h(t) \) is the response of the prototype filter satisfying the perfect reconstruction condition [5]. It is worth noting that the length of \( h(t) \) is \( KT \), with \( K \) being an even integer [4], [5]. Here we adopt \( K = 4 \), similar to [4] and [5]. Then, \( X^m k(t), k = 0, 1, \ldots, N - 1 \) are modulated with \( N \) orthogonal subcarriers to obtain
\[ s^m_k(t) = \left\{ e_k^m h(t - mT) + j d_m^k h \left( t - \frac{T}{2} - mT \right) \right\} e^{j k(2\pi t + \phi)} \]

Next, \( s^m_k(t) \) on all the \( N \) subcarriers are added up together to obtain the \( m \)th OFDM/OQAM symbol \( s^m(t) \)
\[ s^m(t) = \sum_{k=0}^{N-1} s^m_k(t), \quad mT \leq t \leq (m + K + \frac{1}{2}) T \]

Note that the length of each OFDM/OQAM symbol \( s^m(t) \) is \((K + 1/2)T\).

Finally, the desired OFDM/OQAM signal \( s(t) \) is obtained by summing over the \( M \) OFDM/OQAM symbols, i.e.,
\[ s(t) = \sum_{m=0}^{M-1} s^m(t), \quad 0 \leq t \leq (m + K + \frac{1}{2}) T \]

Thus, we show the structure of OFDM/OQAM signal in Fig 3. It is shown that the symbol rate is \( 1/T \), and the length of each OFDM/OQAM symbol is equal to \((K + 1/2)T\). Compared with \( s_0(t), s_m(t) \) is right-shifted with \( mT \). Obviously, \( s_m(t) \) overlaps with the next \( K \) OFDM/OQAM symbols. The OFDM/OQAM signal \( s(t) \) is obtained by summing over the \( M \) OFDM/OQAM symbols, and the length of \( s(t) \) is \((K + M - 1/2)T\).

In the conventional OFDM systems, the OFDM symbol is obtained by taking the inverse fast Fourier transform operation over the \( N \) QAM symbols, and the length of each OFDM symbol is \( T \). Since the OFDM symbol rate is \( 1/T \), there is no overlap between any adjacent OFDM symbols, and the PAPR of each OFDM symbol is defined as the ratio of the peak power to the average power [8]. Due to the special signal structure, the PAPR definition for the proposed OFDM/OQAM systems needs to be modified. OFDM/OQAM signal \( s(t) \) is first divided into \( M + K \) intervals, each of which is with length \( T \) (except the last one, with length \( T/2 \)). Thus, the PAPR for \( s(t) \) in the \( P \)th interval is defined as
\[ \xi^P = 10 \log_{10} \frac{\max_{0 \leq T \leq (p + 1) T} |s(t)|^2}{P_{\text{avg}}} \]
\[ P = 0, 1, \ldots, M + K - 2 \]
\[ \xi^P = 10 \log_{10} \frac{\max_{0 \leq T \leq (p + \frac{1}{2}) T} |s(t)|^2}{P_{\text{avg}}} \]
\[ p = 0, 1, \ldots, M + K - 1 \]

where \( P_{\text{avg}} \) is the average power of \( s(t) \).

We now summarize the notations that we have defined so far.
- \( X \) is the input data matrix.
- \( X_m \) is the \( m \)th data block.
- \( X^m_k \) is the \( m \)th QAM symbol on the \( k \)th subcarrier.
- \( s^m(t) \) is the \( m \)th OFDM/OQAM symbol.
- \( s(t) \) is the OFDM/OQAM signal.

### IV. DIFFERENT PAPR REDUCTION TECHNIQUES

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. The high Peak to Average Power Ratio (PAPR) or Peak to Average Ratio (PAR) or Crest Factor of the Orthogonal Frequency Division Multiplexing (OFDM) systems can be reduced by using various PAPR reduction techniques namely.

1) Exponential Companding Transform
2) Selective Mapping (SLM).
3) Partial Transmit Sequence (PTS).
4) Alternative Signal Method etc.

A. Exponential Companding Transform:
This method is used for reducing the one of the major drawback of the Orthogonal Frequency Division Multiplexing (OFDM) systems i.e., the high Peak-to-Average Power Ratio (PAPR), is named as the Exponential Companding Transform. It is also named as the Nonlinear Companding Transform.

The process of companding enlarges the small signal amplitudes, while the peaks of the signal remain unchanged. Therefore, the average powers are increased and now calculate the ratio of peak signal value to the average signal value is low. Thus the Peak-to-Average Power Ratio (PAPR) of the Orthogonal Frequency Division Multiplexing (OFDM) systems is reduced, which in turn helps in increasing the efficiency of the power amplifiers and also the complexity in Analog-to-Digital Converter (ADC) and Digital-to-Analog Converter (DAC) reduced.

The key idea of the Exponential Companding Transform in OFDM is transforming the statistics of the amplitudes of these signals into uniform distributed or companded signals. This can be obtained by compressing the peak value signals and expanding the small value signal. The Exponential Companding Transform can also eliminate the Out-of-Band Interference (OBI), which is a type of distortion made by clipping the original OFDM signals. This scheme has other advantage, i.e., it can maintain a constant average power level of the signal.

B. Selection Mapping Technique (SLM):
The CCDF of the original signal sequence PAPR above the threshold value PAPR₀ is can be written as \( P_r[PAPR > PAPR₀] \). For K statistical independent signals, CCDF can be written as \( [P_r[PAPR > PAPR₀]^K] \), so the probability of PAPR exceeds with the given same threshold [6]. The probability of PAPR of the signal, larger than a threshold Z can be written as

\[
P(\text{PAPR} < Z) = F(Z)^N = (1 - \exp(-z))^N \tag{11}
\]

Assuming that the M-OFDM symbols carrying the same information and that are statistically independent of each other. In this case of, the probability that the PAPR greater than Z is equals to the product of each every independent probability. This can be written as:

\[
P(\text{PAPR}_{\text{LOW}} > Z) = P(\text{PAPR} > Z)^M =((1 - \exp(-Z))^N)^M \tag{12}
\]

In selection mapping method, first assume the system containing M statistically independent sequences which are represents the same information that are generated. This results into M statistically independent data blocks. Which can write in the form

\[
S_m = [S_{m,0}, S_{m,1}, ..., S_{m,N-1}]^T.
\]

For \( m = 1,2, ..., M \) are then subjected into IFFT operation simultaneously. \( x_m = [x_{1}, x_{2}, ..., x_{N}]^T \) are in the form of discrete time-domain and then the PAPR of these independent M-vectors are calculated separately.

Finally, the sequences \( X_d \) with the smallest PAPR is selected for the final serial transmission. Figure 4 shows the basic block diagram of selection mapping technique for suppressing the high PAPR of the OFDM system.

C. Partial Transmit Sequence (PTS):
Partial Transmit Sequence (PTS) [15] algorithm is the technique for bettering the statistics of a multicarrier signal. The basic principle of partial transmit sequences algorithm is to divide the original OFDM sequence into so many sub-sequences and for each sub-sequences multiplied by different weights. For with different weights until an optimum value is getting.

For \( m = 1,2, ..., M \) are then subjected into IFFT operation simultaneously. \( x_m = [x_{1}, x_{2}, ..., x_{N}]^T \) are in the form of discrete time-domain and then the PAPR of these independent M-vectors are calculated separately.

Finally, the sequences \( X_d \) with the smallest PAPR is selected for the final serial transmission. Figure 4 shows the basic block diagram of selection mapping technique for suppressing the high PAPR of the OFDM system.

C. Partial Transmit Sequence (PTS):
Partial Transmit Sequence (PTS) [15] algorithm is the technique for bettering the statistics of a multicarrier signal. The basic principle of partial transmit sequences algorithm is to divide the original OFDM sequence into so many sub-sequences and for each sub-sequences multiplied by different weights. For with different weights until an optimum value is getting.
D. Alternative Signal Method:

In this alternative-signal (AS) method was used to reduce the PAPR of OFDM/OQAM signals. We first apply the traditional SLM scheme to the OFDM/OQAM systems to obtain the independent AS (AS-I) and joint AS (AS-J) algorithms. Specifically, AS-I reduces the PAPR of each OFDM/OQAM symbol independently, and AS-J applies joint PAPR reduction among M OFDM/OQAM symbols. AS-J intuitively should yield a better performance than AS-I. However, the computation complexity of AS-J exponentially increases with M, which is impractical. To balance the performance and the computation complexity, we propose a sequential AS (AS-S) algorithm, which adopts a sequential optimization procedure over time with the computation complexity linearly increasing with M. Simulation results will be provided to compare the performance among the three algorithms.

1) AS-I Algorithm:

Inspired by the SLM method, the AS-I algorithm reduces the PAPR by optimally choosing one phase rotation vector from a given set for each OFDM/OQAM symbol. Over different OFDM/OQAM symbols, the phase rotation vectors might be different. Denote the set of candidate phase rotation vectors as

$$\mathbf{B} = \{b_0^u, b_1^u, \ldots, b^{U-1}_u\}$$

where U is the size of B, and $b_u^0, 0 \leq u \leq U - 1$, is the uth phase rotation vector, which is defined as

$$b_u^k = \text{e}^{(2\pi k W)/U}, i = 0, 1, \ldots, W - 1 \text{ [10]}.$$  

Here we adopt the peak power as the design metric throughout this method. This is because the PAPR reduction should come from the peak power reduction rather than the average power increasing. Given the finite number of bits for the side information is equal to M log2(U). It is easier shown that the AS-I algorithm is simple but performs badly, whereas the AS-J algorithm performs well but bears high complexity. To balance the PAPR reduction performance and the complexity, the AS-S algorithm is proposed in the following.

2) AS-S Algorithm:

The main idea of the AS-S algorithm is shown in Fig 6, which shows that the AS-S algorithm adopts a sequential optimization procedure. In the mth block, by taking into account the previous OFDM/OQAM symbols, i.e., $s^0(t)$, $s^1(t)$, . . . , $s^{m-1}(t)$, the PAPR reduction problem could be formulated as

$$\begin{align}
\min_{b^{m,u}_k} & \max_{b^{m,u}_k} \left| \sum_{k=0}^{N-1} s_k^m(t) b_k^{m,u} \right|^2 \\
& \text{s.t. } b^{m,u}_k \in B.
\end{align}$$

Similarly, after is generated, as we did in the AS-I algorithm, the PAPR reduction problem could be formulated as

$$\begin{align}
\min_{b^{m,u}_k} & \max_{b^{m,u}_k} \left| \sum_{k=0}^{N-1} s_k^m(t) b_k^{m,u} \right|^2 \\
& \text{s.t. } b^{m,u}_k \in B.
\end{align}$$

In the zeroth block, we multiply $s_0(t)$ by different phase rotation vectors and choose the one with the minimum peak power, which is denoted as $s_0(t)$. Then, $s_0(t)$ is sent to the first block to solve the following problem:

$$\begin{align}
\min_{b^{1,u}_k} & \max_{b^{1,u}_k} \left| \sum_{k=0}^{N-1} s_k^1(t) b_k^{1,u} \right|^2 \\
& \text{s.t. } b^{1,u}_k \in B.
\end{align}$$

The optimal phase rotation vector is denoted as $b^{1,u}_k$, and the new generated symbol is cast as

$$s_1(t) = \sum_{k=0}^{N-1} s_k^1(t) b_k^{1,u}.$$  

Next, $s_1(t)$ and $s_0(t)$ are both sent to the second block to calculate the new symbol $s_2(t)$. We repeat the given procedure until the (M − 1)th block. Thus, AS-S is a sequential optimization procedure. Specifically, in the mth block, $m = 1, 2, \ldots, M - 1$, the optimization problem could be cast as follows:

$$\begin{align}
\min_{b^{m,u}_k} & \max_{b^{m,u}_k} \left| \sum_{k=0}^{N-1} s_k^m(t) b_k^{m,u} \right|^2 \\
& \text{s.t. } b^{m,u}_k \in B.
\end{align}$$

All rights reserved by www.ijsrd.com
Note that $\Gamma$ is a key parameter that significantly affects the PAPR reduction performance.

![Fig. 7: CCDF versus PAPR0 for Different Schemes](image)

![Fig. 8: CCDF versus PAPR0 for AS-S with different U values for k=256](image)

![Fig. 9: CCDF versus PAPR0 for AS-S with different U values for k=128](image)

Fig. 10: CCDF versus PAPR0 for AS-S with different U values for k=64

V. PROPOSED MODEL

The proposed ASM Scheme for PAPR reduction in OFDM Systems with Space Frequency Block Coding (SFBC). The key idea of the proposed scheme is keeping the advantage of the SFBC structure to generate some multi-sequences via combining the signals at different transmit antennas. Specifically, when the proposed scheme is employed in SFBC OFDM systems with quadrature amplitude modulation (OQAM), one of the big advantages is that the side information does not need to be sent to the receiver. Theoretical analysis and simulation results validate that the proposed scheme has the ability to provide large PAPR reduction, low bit error rate and low computational complexity without side information in SFBC OFDM systems.

![Fig. 11: Block Diagram for SFBC Based ASM Model](image)

A. SFBC using ASM Method:

The most well-known transmit diversity technique was introduced by SFBC where the proposed orthogonal code ensures full diversity. As shown in , the Block code precoding can be implemented either as a SFBC or as a Space-Frequency Block Code (SFBC). In order to simplify the descriptions of our proposed method, we consider a SFBC System with two transmits and one receive antenna. For other systems with more transmit antennas, our proposed method can be easily extended.

If Space Time Coding (STC) is joined to multicarrier modulation, such as Orthogonal Frequency Division Multiplexing (OFDM), Space Frequency Block Coding (SFBC) can be performed as shown in Fig. 4.1.
Enhancement in Reduction of PAPR using ASM Based SFBC Technique in OFDM Systems

Space time coding is one of the main methods in order to exploit the capacity of Multiple Input Multiple Output (MIMO) channels. Since STC techniques use both time and spatial domains for coding data symbols, diversity and spatial multiplexing can be combined achieving robustness at the receiver with a higher data rate transmission.

As a result, STC techniques have been incorporated in many of the last generation wireless communications systems, including the new generation of terrestrial and mobile digital video broadcasting (DVB) standards. This way, codes words are fed into adjacent carriers of the two consecutive OFDM symbols, translated to the time domain and transmitted through several transmit antennas. This transmission scheme is usually combined with Bit Interleaved Coded Modulation (BICM) giving good diversity results in a wireless communication link.

Principle of the Proposed Technique:
The proposed technique follows these steps:

step 1: Multiply the original data X by independent phase sequences and obtain X_.

step 2: Each couple (X_ 2k, X_ 2k+1) will be encoded according to the pre-coder codebook M. The resulted sequence with the lowest PAPR will be kept and transmitted. Basically, this method uses a predefined set E of possible phases. This set E consists of two subsets: E1 leaves unchanged the OFDM signal constellation whereas E2 is the set of its rotated constellation with a specific _opt angle. If the constellation points (in set E) are very close, the rate of errors detection phase will be increased.

That is why we propose to calculate a minimum distance, d_min, separating two different types of constellation (E1 and E2): the selected one _opt is the one having the biggest d_min. Denote all possible combinations of the factors where V denotes the number of choices for the factor combinations. At the receiver is obtained after decoding of the SFBC. Then, a hard decision is made to each elements of X with the minimum distance of the constellation used at the transmitter, and the sequence X = {0, 1, ..., N - 1} without channel noise is obtained.

\[
\begin{align*}
Z_{v,2l}^m &= \frac{a_vX_{2l} - b_vX_{2l+1}}{a_v^2 + b_v^2}, \\
Z_{v,2l+1}^m &= \frac{b_vX_{2l} + a_vX_{2l+1}}{a_v^2 + b_v^2}, \\
0 &\leq \frac{v}{2} \\
1 &\leq \frac{v}{2}
\end{align*}
\]

Then the sequence X is divided into M sub blocks so for each sub block we could obtain (V + 1) alternative signalling scheme.

VI. PROPOSED MODEL RESULTS
Enhancement in Reduction of PAPR using ASM Based SFBC Technique in OFDM Systems

(IJSRD/Vol. 3/Issue 06/2015/226)

All rights reserved by www.ijsrd.com

Fig. 15: 256 Bit Process on Comparison between AS and SFBC-AS PAPR Reduction in OFDM Channel

<table>
<thead>
<tr>
<th>K values</th>
<th>Average PAPR</th>
<th>Min PAPR</th>
<th>Before SFBC using in ASM</th>
<th>After SFBC using in ASM</th>
</tr>
</thead>
<tbody>
<tr>
<td>256</td>
<td>4.8405</td>
<td>3.76</td>
<td>8.2db</td>
<td>6.32db</td>
</tr>
<tr>
<td>128</td>
<td>4.8405</td>
<td>3.76</td>
<td>7.9db</td>
<td>5.43db</td>
</tr>
<tr>
<td>64</td>
<td>4.8405</td>
<td>3.76</td>
<td>7.2db</td>
<td>4.85db</td>
</tr>
</tbody>
</table>

Table 1: Comparative study of PAPR for different carriers

VII. CONCLUSION

In this paper, we investigated an efficient PAPR reduction technique dedicated to OFDM systems using SFBC coding technique. The main feature of our proposed method is that it induces an embedded signalling through the advanced precoders codebook that leads to a powerful recovery of the transmitted signal and guarantees a very low failure decision rate. To further improve the decision process, we proposed an additional embedded signal that consists of a set of rotated and un-rotated QAM constellations and when used in the decision process (using a hard decision deduced from a Max-Log-MAP decoding), it significantly improves the OFDM system performances in terms of CCDF of the PAPR, SIER and BER. To overcome this issue, conceiving a soft decision process would be an appropriate solution: this is a research aspect that we are currently investigating.

REFERENCES

[8] S. H. Muller and J. B. Huber, OFDM with Reduced Peak to Average Power Ratio by Optimum Combination of Partial Transmit Sequences, IEE Electronics Letters, vol. 33, no. 5, pp.368–369,
Feb.,1997.