# An Overview of Various Techniques to Reduce PAPR in SFBC MIMO OFDM Systems

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**Abstract**

The multiple-input multiple-output (MIMO) orthogonal frequency division multiplexing (OFDM) system with space-frequency block coding (SFBC) is an attractive technique due to its robustness for time selective fading channels. SFBC MIMO-OFDM systems have a high computational complexity since the number of inverse fast Fourier transforms (IFFTs) required scales in direct proportion to the number of antennas at the transmitter. However, the SFBC MIMO-OFDM system also inherits from OFDM systems the drawback of high peak-to-average power ratio (PAPR) of the transmitted signal. In this paper, various PAPR reduction schemes have been discussed.

***Index Terms*** - Multiple-input multiple-output (MIMO), orthogonal frequency division multiplexing (OFDM), peak-to-average power ratio (PAPR), Space frequency block codes (SFBC).

## 1. Introduction

Multiple-input multiple-output (MIMO) orthogonal frequency division multiplexing (OFDM) with space-frequency block coding (SFBC) [1] has attracted increasing attention because it is robust to time selective fading channels. Orthogonal frequency-division multiplexing (OFDM) is a well known technique for transmission of high rate data over broadband channels [2] and it also improves the wireless system capacity. The combination of MIMO and OFDM (MIMO-OFDM) could exploit the spatial dimension capability of a wireless communication system to improve the wireless link performance and system capacity by employing multiple antennas at both the transmitter and receiver ends [3]. In MIMO-OFDM wireless systems, independent OFDM signals are simultaneously transmitted from multiple-transmit antennas to multiple-receive antennas. However, SFBC MIMO-OFDM systems also inherit disadvantages from OFDM techniques, e.g., signal-to-noise ratio, inter-channel interference, and high peak-to-average power ratio (PAPR). The literature presents a variety of PAPR reduction methods for OFDM systems, e.g., selected mapping (SLM) [2], [4], partial transmitted sequence (PTS) [5], [6], alternate multisequences scheme (AMS) [7], and polyphase interleaving and inversion (PII) [3].

### *1.1 SFBC MIMO OFDM System*

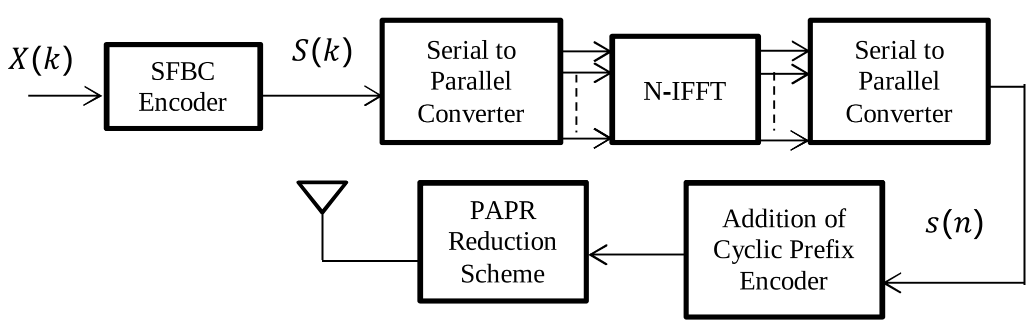


**Fig.1.** Fig. 1. Basic block diagram of SFBC MIMO-OFDM Systems.

SFBC (Space frequency block codes) are the frequency domain version of Space time block codes (STBC) in which in which data is encoded in frequency domain rather in time domain. STBC codes are also recognized as Alamouti codes [9].

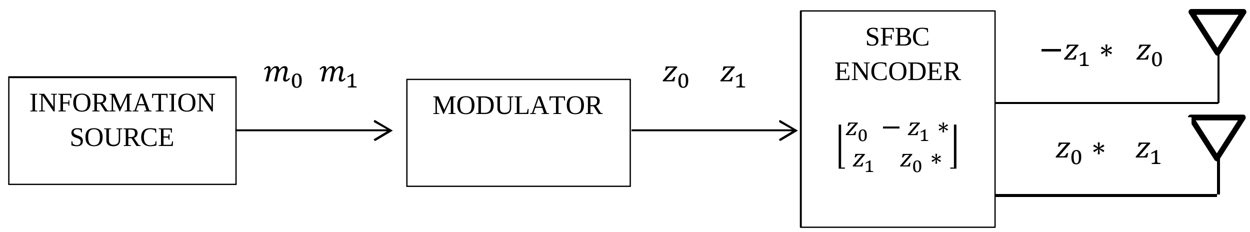


Fig. 2. Block diagram of implementation of Alamouti's SFBC.

The M-ary modulated symbols $m_0$ and $m_1$ are passed through the SFBC encoder and complex matrix Z is generated such that symbols $m_0$ and $m_1$ are coded through space and frequency. So, replicas of $m_0$ and $m_1$ for Alamouti coding are sent through two transmit antennas and over two frequency.

Complex matrix Z can be found by

$$Z = \begin{bmatrix} z_0 & -z_1* \\ z_1 & z_0* \end{bmatrix} \qquad \ldots.(1)$$

The frequency domain symbols from SFBC encoder are passed through serial to parallel converter and then these symbols are converted in to time domain samples of complex baseband OFDM signal is given by

$$s(n) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} S(k)\, e^{\frac{j2\pi nk}{N}} \qquad \ldots.(2)$$

where j = $\sqrt{-1}$ and n= 0,1,…..(N-1).

The peak to average power ratio (PAPR) of a signal is defined as the ratio peak amplitude of the signal to the average value of the signal. The PAPR of SFBC MIMO-OFDM system is defined by

$$PAPR(x) = \frac{max\{|s(n)|^2\}}{E\{|s(n)|^2\}} \qquad \ldots.(3)$$

where E{.} is the mathematical expectation.

Complementary cumulative density function (CCDF) for PAPR is given by

$$CCDF\left(PAPR\big(s(n)\big)\right) = P_r\left(PAPR\big(s(n)\big)\right) > PAPR_0 \qquad \ldots.(4)$$

### *1.2 Various techniques to reduce PAPR in SFBC MIMO-OFDM Systems*

#### *1.2.1 Alternate Multisequence Scheme (AMS)*

Alternative multisequence (AMS) scheme is used to reduce the PAPR of MIMO-OFDM signals. In AMS method, original data sequences at two antennas are divided into several couples of sub blocks, and each couple of sub blocks multiplies by different factors to get different pair of sub blocks. Then, the new sub blocks obtained are combined to get AMSs, which keep the structure and the diversity potentiality of the Alamouti's SFBC. Finally, the couple of alternative sequences with the smallest PAPR is chosen to be transmitted.

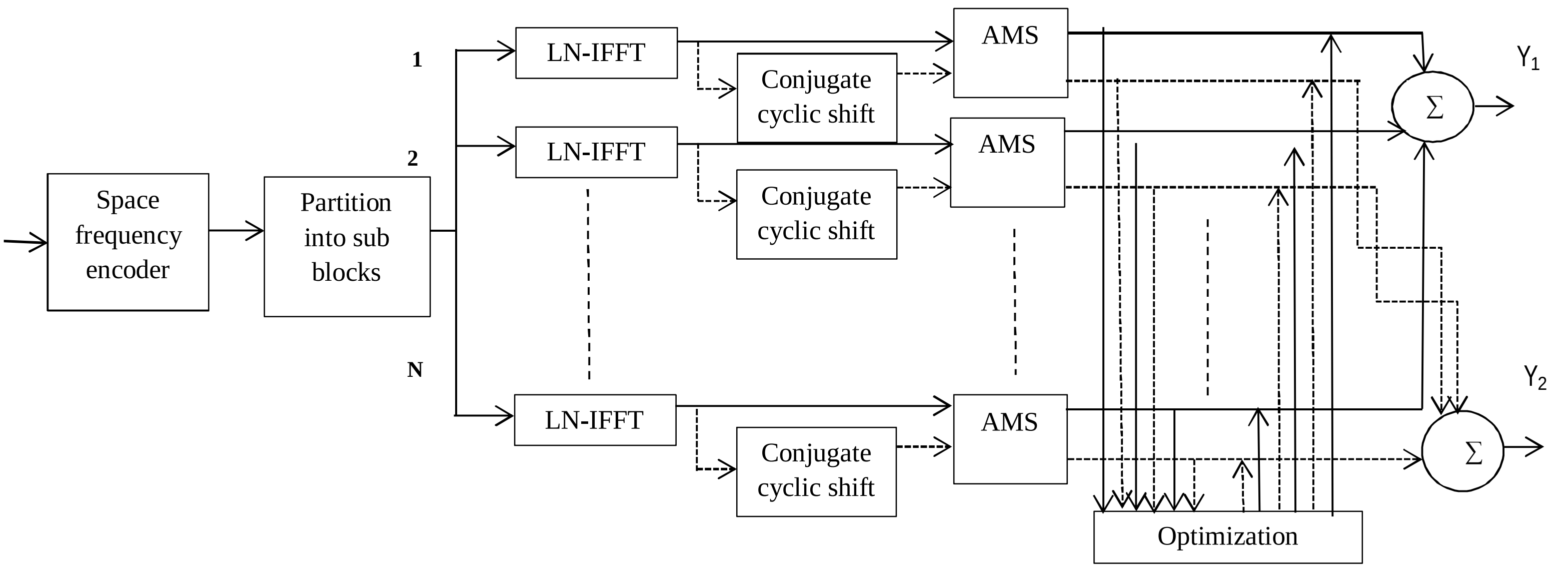


Fig. 3. Block diagram of AMS Scheme for PAPR reduction in SFBC MIMO-OFDM System.

*1.2.2 Selected Mapping (SLM)*

Selected Mapping (SLM) is the promising technique for reduction of the PAPR. The aim of this method is to generate many independent OFDM blocks from a single data block and then select one having PAPR. The independent OFDM sequences can be found with finding independent phase sequences. Let us consider M number of phase sequences with the sequence length of N (i.e. the number of subcarriers). Then the *nt* point of *mt* phase sequence is given as

$$D^m(n) = e^{(j\Phi^m(n))} \qquad \dots.(5)$$

where $n \in 1,2, \dots N$ and $m \in 1,2, \dots M$.

To reduce complexity of the application of different phase sequences, often, phases $\Phi^m(n)$ are randomly chosen from $\{0, \pi\}$ and this means $\Phi^m(n) \in \{\pm 1\}$, and it is enough to change the sign of the symbols before IFFT operation [2].

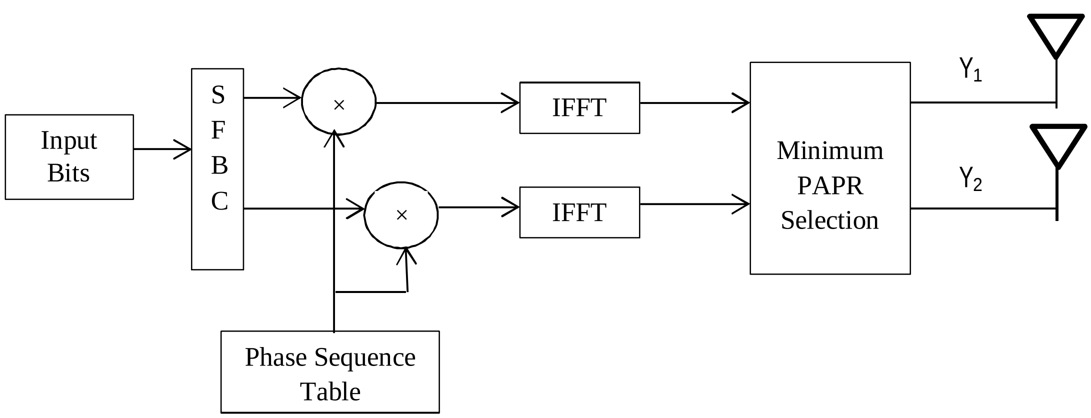


Fig. 3. Block diagram of SLM Scheme for PAPR reduction in SFBC MIMO-OFDM System.

**2. Polyphase Interleaving and Inversion (PII)**

In the PII scheme, a single data vector, $Y = [Y_0, Y_1, \ldots \ldots Y_{N-1}]$, is first partitioned into M disjoint carrier sub blocks $Y(m), m = 1,2, \ldots \ldots, M$.

Thus, the original sequence is

$$Y = \sum_{m=1}^{M} Y(m) \quad \ldots\ldots(6)$$

Consider the first sub block, $Y(1) = [Y_0, Y_1, \ldots \ldots Y_{\frac{N}{m}-2}, Y_{\frac{N}{m}-1}, 0, 0 \ldots, 0]$, which can be decomposed into two polyphase sequences $Y'(1)$ and $Y''(1)$, where

$$Y'(1) = \left[Y_0, 0, Y_2, 0, \ldots \ldots\ Y_{\frac{N}{M}-2}, 0, 0, \ldots \ldots .0\right] \quad \ldots\ldots(7)$$

$$Y''(1) = \left[Y_1, 0, Y_3, 0, \ldots \ldots\ Y_{\frac{N}{M}-1}, 0, 0, \ldots \ldots .0\right] \quad \ldots\ldots(8)$$

After this the above sequence is passed through N-point IFFT operation where the frequency domain signal is converted in the time domain signal.

Integrating the phase factors, $d_m \in W = \{\pm 1\}$ i.e. inversion and the rotation factors, $r_m \in \{0,1\}$, i.e. polyphase interleaving, for $m^{th}$ sub block, the resultant vector in time domain becomes,

$$y_i' = \sum_{m=1}^{M} d_m y_i^{(r_m)}(m); \quad i = 1,2 \quad \ldots\ldots(9)$$

**3. Partial transmit sequence (PTS)**

The partial transmit sequence (PTS) is an attractive technique because of good PAPR reduction performance and no restriction to the number of subcarriers [6]. In this scheme, the coming input bits are divided into smaller disjoint sub blocks. Input from each partitioned sub block converted from frequency domain to time domain by using N-point inverse fast fourier transform (IFFT).

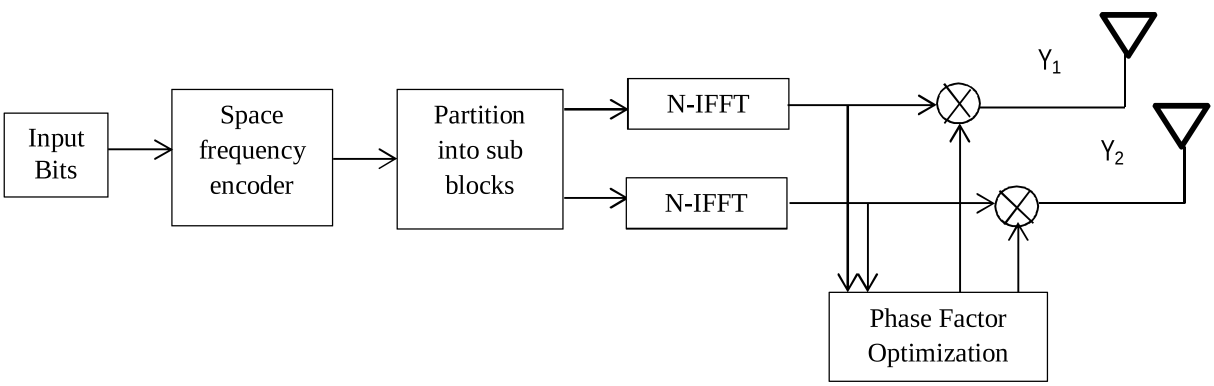


Figure 4: Block Diagram of PTS Scheme for PAPR reduction in SFBC MIMO OFDM System.

The time domain sequences are multiplied by rotating phase factors, $z = [\, z_1\, z_2 \ldots z_m]^T$, to minimize PAPR and then these sequences are then added to form the OFDM symbol for transmission.

The resulting time domain signal,

$$x'(z) = \sum_{m=1}^{M} z_m . x_m \quad \ldots . (10)$$

Allowable phase factor,

$$z_m = e^{j\Phi_m} \qquad \ldots . (11)$$

$x_m$ is the time domain sequence and $\Phi_m$ can take the value between (0 ,2π).
The main aim of this scheme is to design an optimal phase factor for each sub block set that minimizes the PAPR.

## 4. CONCLUSION

Orthogonal frequency division multiplexing (OFDM) is a very attractive technique for wireless communications due to its spectrum efficiency and channel robustness. One of the major drawbacks of in MIMO-OFDM systems is that the transmitted signal exhibits a high PAPR when the input sequences are correlated. In this paper, various crucial aspects is discussed, as well as a mathematical analysis is provided, including the distribution of the PAPR, in MIMO-OFDM systems. Four distinctive techniques to reduce PAPR have been analyzed, all of which have the potential to provide significant reduction in PAPR at the cost of decrease in data rate, increase in transmitted signal power, bit error rate performance is degraded, computational complexity is increased, and much more.

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