



# PAPR Performance of OFDM System Using Modified SLM Approach

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**Abstract-** In the era of modern wireless technology Multicarrier communication is one of the more suitable and reliable communication techniques. Orthogonal Frequency Division Multiplexing (OFDM) is used as modulation technique in multicarrier communication. OFDM has numerous advantages over single carrier communication but in spite of the advantages it suffers from one major drawback that is OFDM signal has high Peak Power – to – Average Power ratio (PAPR) . In this paper PAPR performance is simulated using conventional approach of Selective Mapping (SLM) technique and Modified SLM technique for different types of modulation techniques like QPSK, QAM and DPSK. The modified SLM technique is a probabilistic approach to reduce PAPR of OFDM system. This uses Linear Block Code (LBC) that is Extended Hamming Code where the different code having same information and by using selection criteria one of the codes having less PAPR is selected. Modified approach reduces system PAPR to a great extent as well as it reduces cost and complexity of the system. From simulated results it shows that the modified SLM approach is more suitable for practical implementation.

## I. INTRODUCTION

In advance wireless communication techniques, need for high speed communication has become an at most priority [1]. Orthogonal Frequency Division Multiplexing (OFDM) is adopted as modulation technique in many advance wireless communication technologies because of its advantageous like robustness to the multi-path fading, inter-symbol interference and high data rate. Especially, OFDM has been adopted for various wireless communication systems such as wireless local area networks (WLANs), wireless metropolitan area networks (WMANs), digital audio broadcasting (DAB), and digital video broadcasting (DVB) [2].

Apart from its advantages OFDM still have few drawbacks. One of the major drawbacks in OFDM is high Peak Power-to-Average Power Ratio (PAPR) of transmitted OFDM signal. High PAPR impair the system performance due to which complexity in design of Digital to Analog converter (ADC) and High Power Amplifier (HPA), which introduces In-band and out-of- band distortion in the OFDM signal [3].

Several techniques have been proposed in the literature to reduce the PAPR. These techniques can mainly be categorized in to signal scrambling techniques and signal distortion techniques. Signal scrambling techniques are all variations on how to scramble the codes to decrease the PAPR. Coding techniques can be used for signal scrambling. Golay complementary sequences, Shapiro-Rudin sequences, M sequences, Barker codes can be used efficiently to reduce the PAPR. However with the increase in the number of carriers the overhead associated with exhaustive search of the best code would increase exponentially. More practical solutions of the signal scrambling techniques are block coding, Selective Level Mapping (SLM) and Partial Transmit Sequences (PTS). Signal scrambling techniques

with side information reduces the effective throughput since they introduce redundancy [6].

The signal distortion techniques introduce both In-band and Out-of-band interference and complexity to the system. The signal distortion techniques reduce high peaks directly by distorting the signal prior to amplification. Clipping the OFDM signal before amplification is a simple method to limit PAPR. However clipping may cause large out-of band and in-band interference, which results in the system performance degradation [3].

This paper is organized as follows. In Section II, Brief introduction of PAPR in system, In Section III, Conventional SLM technique and proposed modified SLM technique presented in Section IV, In Section V, Simulation result is given to compare performance of system. In Section VI, given concluding remark.

## II. INTRODUCTION OF PAPR

OFDM signal is addition of all the independent sub carriers which are in the form of sinusoidal signal. When N subcarrier added up coherently they produce peak power which is greater than average power. It cause signal distortion and clipping of signal at the time of digital to analog conversion and High power amplification [4].

The PAPR of OFDM is defined as the ratio between the maximum power and the average power, The PAPR of the OFDM signal  $X(t)$  is defined as

$$PAPR = \frac{P_{peak}}{P_{average}} \quad (1)$$

With above assumption PAPR can be written as

$$PAPR = \frac{\max |X_n|^2}{E[|X_n|^2]}$$

(2)

Where  $X_n$  = An OFDM signal after IFFT (Inverse Fast Fourier transform)

$E[.]$  = Expectation operator, it is an average power. The complex baseband OFDM signal for N subcarriers represented as [5]

$$X(t) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_n e^{j2\pi n \Delta f t} \quad , \quad 0 \leq t \leq NT$$

(3)

PAPR is calculated in decibels (dB) which is given by

$$PAPR \text{ in dB} = 10 \log_{10} (PAPR)$$

(4)

### III. Conventional SLM Technique

The conventional SLM scheme is one of the well-known PAPR reduction schemes for the OFDM system, which does not cause the in-band distortion and the out-of-band radiation. In selective mapping (SLM) technique the actual transmit signal lowest PAPR is selected from a set of sufficiently different signals which all represents the same information. SLM Technique is very flexible as they do not impose any restriction on modulation applied in the subcarriers or on their number [4][5].

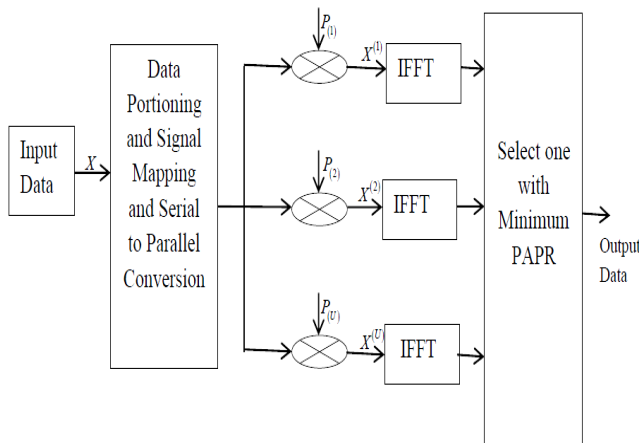


Fig. 1. Block diagram of Conventional SLM Technique

This Technique has few practical limitations like; the Selected Mapping technique requires explicit side information in order to recover the original data sequence. The transmitter must send the phase sequence information of the transmitted signal so that receiver can easily recover the original data sequence. Because of side information transmission degrades performance of the system. As Phase Sequence  $U$  increases, the amount of PAPR reduction for the

OFDM signal sequence becomes larger and System gives better performance. But, for large  $U$ , the computational complexity becomes too high mainly due to the  $U$  IFFTs. Because of  $U$  phase rotated data the number of IFFTs computation increases. Hence due to increase in computational complexity of IFFTs the system cost also affected [3][7].

### IV. MODIFIED SLM TECHNIQUE

The standard array of a linear block code is a basic tool for its minimum distance decoding. The standard array of an  $[n, k]$  binary linear code  $C$  is an  $M \times N$  array, shown in Table I.

Where  $M = 2^{n-k}$  ,  $N = 2^k$  .

In this array, there are M rows, and each row is a coset.  $c$  denotes the codeword.  $e$  denotes the error in transmission. The first element of each coset is called coset leader.

Since  $c \cdot H^T = 0$  for any codeword  $c \in C$ , where  $H$  is the parity-check matrix, any vector  $x \in c + e$  has the same syndrome as  $e$ , that is

$$Hx^t = H(e + c)^t = He^t \quad (5)$$

Syndrome table decoding can also be described using the standard array. The standard array of a group code  $C$  is the coset decomposition of Function with respect to the subgroup  $C$  [4][6].

- The first row is the code  $C$ , with the zero vectors in the first column.
- Every other row is a coset.
- The  $n$ -tuple in the first column of a row is called the coset leader—usually the most plausible (such as smallest weight) error pattern.

TABLE I  
 STANDARD ARRAY OF A  $[n, k]$  LINEAR BLOCK CODE [4]

$e_1 = c_1$	$c_2$	$c_3$	.....	$c_N$
$e_2$	$c_2 + e_2$	$c_3 + e_2$	.....	$c_N + e_2$
$e_3$	$c_2 + e_3$	$c_3 + e_3$	.....	$c_N + e_3$
$\cdot$	$\cdot$	$\cdot$	.....	$\cdot$
$\cdot$	$\cdot$	$\cdot$	.....	$\cdot$
$\cdot$	$\cdot$	$\cdot$	.....	$\cdot$
$e_M$	$c_2 + e_M$	$c_3 + e_M$	.....	$c_N + e_M$

The core of Modified SLM Technique is choosing a vector with low PAPR in each coset of a linear block codes as its coset leader, instead of the weight vector in conventional technique. Compared with conventional SLM, STA-SLM

requires only the relation between the syndromes and the coset leaders to decode the received signal, and therefore no side information needs to be transmitted.

The block diagram of modified SLM is shown in Figure 2. However, the transmitted sequence is chose after IFFT in STA-SLM. There are  $M$  IFFT blocks at the transmitter and  $M$  FFT blocks at the receiver. There will be only one IFFT block at the transmitter if the sequence which is most likely to yield the lowest PAPR can be find out by a decision algorithm before IFFT. The key of this decision algorithm is how to judge from a sequence itself that it's the best sequence, the sequence with the best randomness [6].

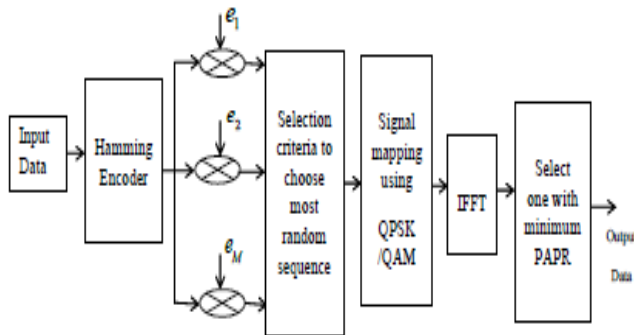


Fig. 2. Block diagram of Modified SLM Technique

Some methods to judge the randomness of a sequence proposed in [10] can be taken for reference. The decision criteria are designed by observing the randomness of the sequence, number of runs in a sequence and short cycle sequence. Therefore, the decision criterion is defined as [5]

$$Z = U_n^2 + V_n^2 + W_n^2 \quad (6)$$

The transmitted sequence can be chosen based on this criterion.

The operation of the modified technique is as follows.

As the first step, a binary information sequence is divided into blocks of 4 bits. Each information block is encoded into a codeword  $c$  which is 7 bits by a [7, 4] hamming encoder. Then a control bit which verifies all the symbols is added to the codeword  $c$  to construct an extended hamming code  $\hat{c}$  of 8 bits [6][10].

The second step, constructing the standard array  $\hat{H}$  by using syndrome  $S$  and If the parity-check matrix of [7, 4] hamming code is  $H$ , the parity-check matrix of [8, 4] extended hamming code  $\hat{H}$

$$\hat{H} = \begin{bmatrix} & & & \mathbf{0} \\ & & & \cdot \\ & & & \cdot \\ & & \mathbf{H} & \mathbf{0} \\ \mathbf{1} & \mathbf{1} & \mathbf{1} & \end{bmatrix} \quad (7)$$

According to the formula  $S = E \cdot \hat{H}^T$ , the syndromes which are corresponding to the non-error and one error patterns could be obtained. And other seven two errors patterns could be obtained from the other syndromes. So, the standard array of  $\hat{C}$  is constructed.

At last, sixteen vectors are constructed as  $\hat{c} + e_1, \hat{c} + e_2, \hat{c} + e_3, \dots, \hat{c} + e_{16}$ , where  $e_1 = \mathbf{0}$  and  $e_1, e_2, e_3, \dots, e_{16}$  are properly selected as the coset leaders of the standard arrays in terms of their PAPR. Then the foregoing criterion is used for each scrambled codeword to calculate the value of  $Z$ . Finally, the scrambled codeword with the minimum  $Z$  is selected and then transformed to an OFDM signal by constellation mapping and IFFT.

At the receiver, the received signal is converted into a codeword  $r$  by FFT and constellation demapping. The syndrome calculated from  $r$  is used for estimating the coset leader  $e$  chosen at the transmitter. The codeword  $c$  is obtained by calculating  $e + r$  and then is converted into an information sequence of  $k$  bits.

A modified version of SLM in which the transmit signal is selected as a signal with minimum PAPR from differently scrambled signals of the information by a number of random sequences [8]. Compared with conventional SLM, our scheme requires only the relation between the syndromes and the coset leaders to decode the received signal because the coset leaders are used for scrambling, and therefore no side information on the choice of the transmit signal needs to be transmitted [9]. Furthermore, both the encoder and decoder in our scheme can be easily implemented.

## V. SIMULATION AND RESULTS

The simulation parameters used for simulation is as follows

TABLE II  
 SIMULATION PARAMETERS

Number Of Subcarriers	900
FFT Size	64
Coding Techniques	Linear Block Code
Error Correcting Code	Extending Hamming Code
Modulation Techniques	QPSK\DPSK\QAM
Constellation Mapping	256
Decision Criteria	$Z=U_n^2+V_n^2+W_n^2$

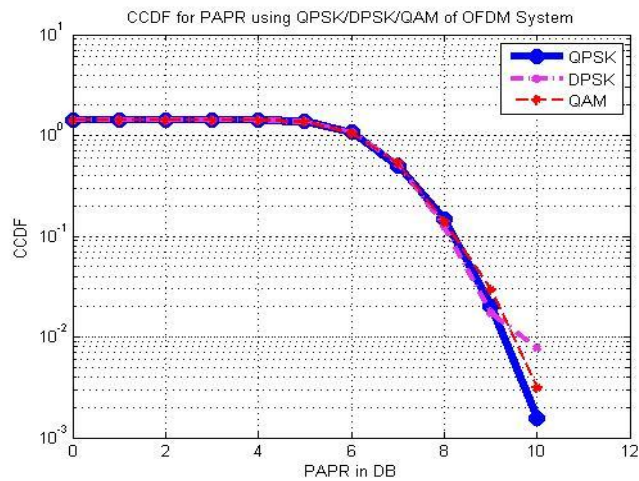


Fig. 3. CCDF of PAPR for OFDM System using QPSK/QAM/DPSK

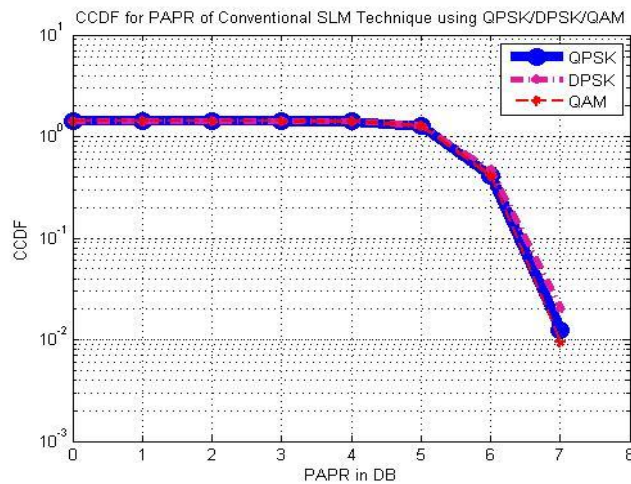


Fig. 4. CCDF of PAPR for Conventional SLM Technique using QPSK/QAM/DPSK

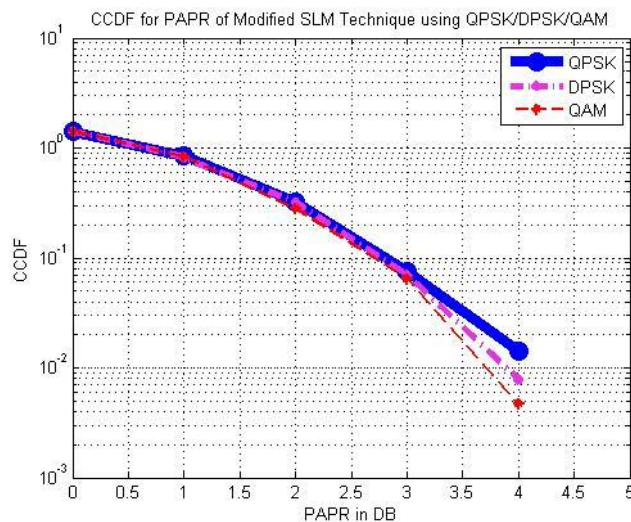


Fig. 5. CCDF of PAPR for Modified SLM Technique using QPSK/QAM/DPSK

The following table shows result of OFDM system by using different modulation techniques with and without SLM technique and modified SLM technique.

TABLE III  
 RESULTS OF OFDM SYSTEM WITH AND WITHOUT SLM

Modulation Technique	Maximum PAPR in dB		
	OFDM without SLM System	OFDM system with SLM	OFDM system with Modified SLM
QPSK	10.4209	7.2257	4.6826
DPSK	10.4869	7.9063	4.6021
QAM	10.8451	7.9284	4.5155

## VI. CONCLUSION

The technique proposed in this paper gives improved result in terms of PAPR and System Complexity of OFDM. From simulation results fig. 3, fig. 4 and fig. 5 PAPR performance of OFDM System for different modulation schemes like QPSK, DPSK, and QAM it shows that the modified SLM technique gives better performance than the conventional SLM technique. The PAPR can be reduced by using modified SLM system which is nearly equal to 4.51 dB.

On the other hand, here system doesn't need to send side information hence system overhead reduces because no side information needs to be transmitted and the only one IFFT block is needed at the transmitter. Both of these two advantages reduce the complexity and cost of the system. Hence Modified SLM is a simple and feasible scheme for PAPR reduction of OFDM system. With the rising demand for efficient frequency spectrum utilization, OFDM proves invaluable to next-generation communication systems. Hence Modified SLM is possible to implement practically.

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