PAPR Reduction in OFDM using Reduced Complexity Selective Mapping Technique

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Abstract **– Orthogonal Frequency Division Multiplexing (OFDM) is the most promising technique available and is most commonly used due to its advantages like very high data rate, noise immunity and efficient bandwidth utilization. One of the major drawback of OFDM is its high Peak to Average Power Ratio (PAPR). In this paper Selective mapping is used to perform PAPR reduction and same time reducing its complexity so that its implementation uses less floor area and on chip requirements. Results shows that PAPR reduction is similar to Conventional SLM but new technique is less complex than original one in terms of IFFT blocks used and Multipliers used in the process.**

Keywords - Orthogonal frequency division multiplexing (OFDM), Peak to average power ratio (PAPR), Selective Mapping (SLM), Bit Error Rate (BER), Digital Subscriber Line (DSL), Partial Transmit Sequence (PTS).

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is a digital transmission Technique developed to meet the increasing demand of higher data rates in wireless and wired communications. Due to its high data rate handling capacity, it is most often used in high speed networks like Digital Video Broadcasting (DVB), Digital Subscriber Line (DSL) and in wireless communication[3][12]. The main disadvantage in using OFDM is its high Peak to Average Power Ratio (PAPR). Such a high PAPR causes the linear amplifier to have large dynamic range which is difficult to accommodate[8].

Thus it becomes necessary to reduce the PAPR to keep the High Power Amplifier (HPA) in linear range. There are numerous techniques available for PAPR reduction. These are categorized as Signal Distortion Techniques and Signal Scrambling Techniques. Distortion Techniques causes signal distortion and Bit Error Rate (BER) to grow after certain point, whereas Signal Scrambling techniques causes no harm to the OFDM signal. The only disadvantage in using signal scrambling techniques is their increased system complexity[3][6].

This paper is organized as follows: Section I describes OFDM system. Section II describes PAPR in OFDM system. Section III describes Improved SLM as PAPR reduction techniques. Section IV describes simulation results and Section V describes conclusion.

II. PAPR IN OFDM SIGNAL

Let the input data block of length N be represented by block $X_S = [X_1, X_{2,} X_3 \ldots X_{N-1}]$, Thus OFDM symbol can be written as:

$$Z(s) = \sum_{k=1}^{N-1} X_S e^{j2\pi k f_0 t} \qquad (1)$$

Where Z(s) is the OFDM symbol, X_S is the input data block and N is the number of symbols in input data block.

PAPR is defined as the ratio of Peak to Average Power. Mathematically PAPR can be defined as following:

$$\text{PAPR}\{Z(s)\} = \frac{\max[Z(s)]^2}{E\{[Z(s)]^2\}} \qquad (2)$$

Where Z (s) is the OFDM signal, $\max[Z(s)]^2$ is the peak signal power, E $\{[Z(s)]^2\}$ is the average signal power[3].

III. SELECTIVE MAPPING

Selective Mapping is a Signal Scrambling technique to reduce PAPR in OFDM system. The advantage in using this technique is that it does not effects the system performance in terms of Bit Error Rate. The only disadvantage in using this technique is its high complexity. The basic concept behind this technique is the phase rotation of the modulated data before performing IFFT operation. After performing phase rotations, the signal with lowest PAPR is selected [2][8][4].

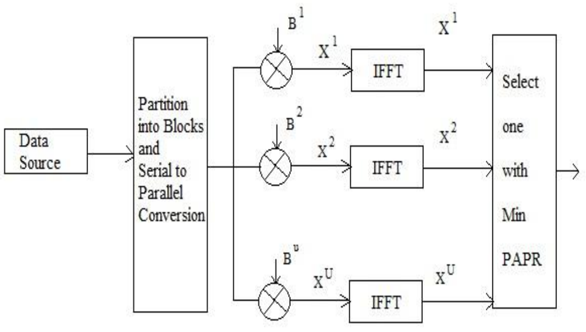

Fig. 1. Block diagram of SLM technique[2]

Let the input data block be represented as

$$X_S = [X_0, X_1, X_2 ... X_{N-1}]^T \quad (3)$$

And independent phase sequences are given by

$$B^U = [B_0^U, B_1^U .....B_{N-1}^U]^T, U = (1,2....U) \quad (4)$$

Where B^U is the phase sequence, U is the total no. of Phase sequences and T is the length of input data block.

After applying Phase rotation, IFFT is applied to obtain data block with different PAPR value and phase sequences[2].

$$X^U = [X_0^U, X_1^U, ...X_{N-1}^U]^T \quad (5)$$

Where X^U is the OFDM symbol generated after IFFT operation. After this the stream with lowest PAPR is selected for transmission. CCDF is used for PAPR representation. CCDF of PAPR in SLM can be represented as

$$P(PAPR > PAPR0) = (1-(1-e^{-PAPR0})^{\alpha.N})^U \quad (6)$$

Where α is the oversampling factor, N is no. of sub-carrier, U is total no. of independent phase sequences.

A. *IMPROVED SELECTIVE MAPPING*

The drawback in using Conventional Selective Mapping is its high Implementation complexity. The complexity of this technique increases exponentially upon increasing the number of phase sequence and number of subcarriers in OFDM system.

So, here a new and improved SLM technique is presented which is less complex than conventional SLM but the original concept remains intact and PAPR reduction is similar to Conventional SLM. This technique is modified to incorporate only one IFFT block and multiplier in place of multiple ones and replace the parallel processing with serial processing. Figure below illustrates the Single IFFT block SLM.

If the number of sub-blocks is M, then the data block can be expressed as:

$$X_M = \sum_0^{M-1} X \quad (7)$$

After serial to parallel conversion one data block can be represented as:

$$X = [X_0, X_1 \dots \dots \dots X_{N-1}] \quad (8)$$

Each of the sub-blocks is then multiplied with independent phase sequences and passed through an N-point IFFT block to obtain the corresponding SLM. Which is given by:

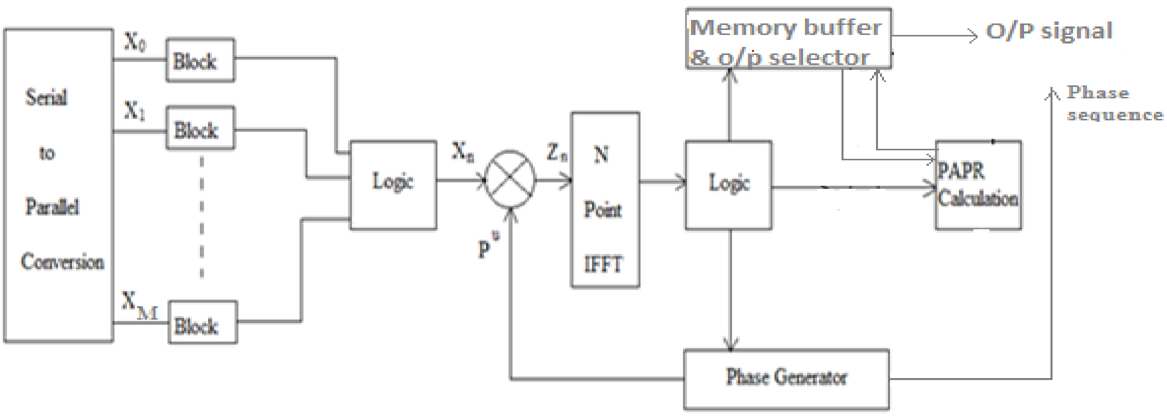

Fig. 2. Block diagram of proposed SLM

Let the Phase Sequences is represented by:

$$P^u = [p_0^u, p_1^u \dots p_{n-1}^u] \quad (9)$$

Where u is the no. of total phase sequences each of lenth n.The above Phase sequence is multiplied with data block to perform phase rotation.

$$Z_n = Xn * P^u \quad (10)$$

SLM output for first block in first phase sequence will be:

$$Y_n = IFFT[Z_n] \quad (11)$$

PAPR of this SLM rotated OFDM symbol can be calculated as:

$$\text{PAPR}[Y_n] = \frac{\max[Y_n]^2}{E[Y_n]^2} \quad (12)$$

Similarly, the input data block is rotated U number of times and is stored in Memory Buffer temporarily. The PAPR is calculated for each sequence and lowest one is selected for transmission. Similarly next data block enters the system and same steps are repeated for total number of data blocks.

Simple mathematical calculations have been done for both the techniques to find out the number of times these operations have to be performed. The values are enlisted in the following Table:

Table I. Shows quantative analysis

Process	**Original SLM**	**Single IFFT Block SLM**
N- point IFFT blocks required	M. U	M
Phase Multipliers required	M. U	M
PAPR calculations performed	M. U	M. U

Where M is the total no of input data blocks and u is the no. of phase sequences of length equal to n. Considering the number of phase sequences in SLM be 4 and input data block be 64, then quantitative analysis can be summarized as in following table:

Table II. Shows quantative analysis with example

Process	**Original SLM**	**Single IFFT Block SLM**
N- point IFFT blocks required	256	64
Phase Multipliers required	256	64
PAPR calculations performed	256	256

IV. SIMULATION RESULTS

It is observed that the results obtained from both the techniques are similar in PAPR reduction values but variation in time consumption of the two algorithms.

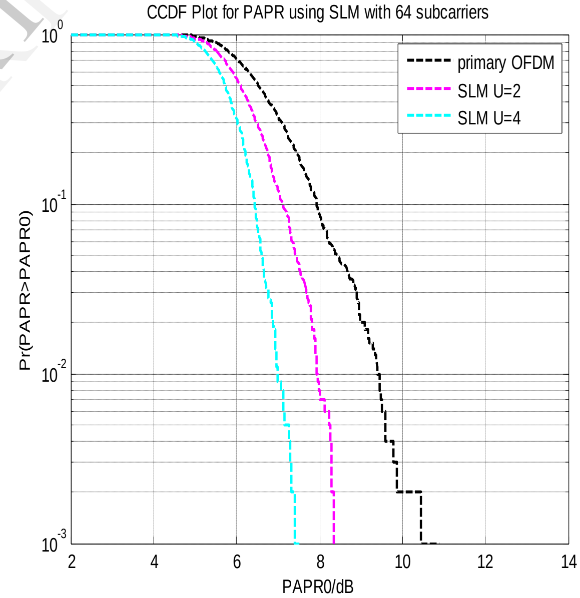

Fig 3. CCDF Plot of PAPR using proposed SLM for 64 sub-carriers with U=2,4.

In the above graph of proposed SLM for 64 sub-carriers , PAPR levels are reduced with the increase phase sequences(U).

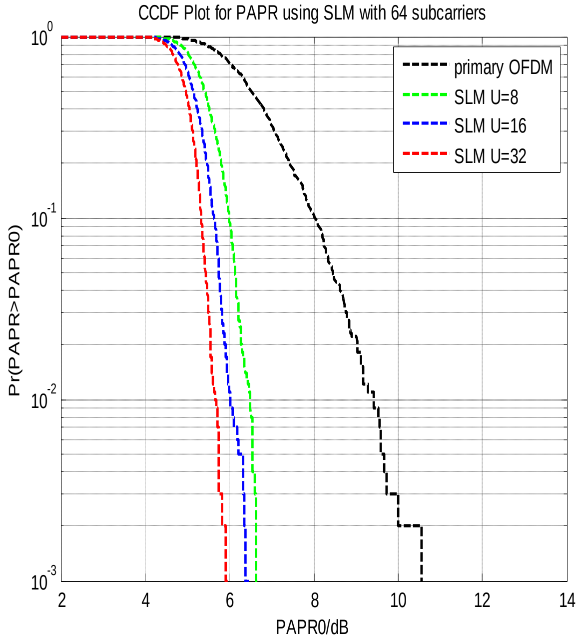

Fig. 4. CCDF Plot of PAPR using proposed SLM for 64 sub-carriers with U=8,16,32.

From the above graph of proposed SLM it is observed that PAPR levels keep on decreasing as Phase sequences are increased. but the margin of decrease in value of PAPR keeps on decreasing with the increase in value of U.

IV. CONCLUSION

In this paper, OFDM is studied and new SLM technique is implemented. This technique performs PAPR reduction similar to original SLM technique as shown in the graphs but implementation complexity is reduced to great extent. This technique does not cause out of band radiations or degrades BER performance. As in this technique hardware is reduced to great extent in terms of IFFT blocks and Phase multipliers used. But this technique reduces throughput of data as it takes large time for processing of data. So we can use this technique for less no. of phase sequences.

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