Simultaneous Reduction of Complexity and PAPR of OFDM Signals using Additive Mapping SLM Scheme

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Abstract- The selected mapping (SLM) scheme is one among the most widely used Peak-to-Average Power Ratio (PAPR) reduction schemes used for the improvement of Orthogonal Frequency Division Multiplexing (OFDM) based systems. Several Low-Complexity SLM schemes have been proposed but most of them reduce only the PAPR and the Computational Complexity remains same as in the previous schemes. So, in this paper, an Additive Mapping SLM scheme is proposed, in which the alternative signal sequences are generated by adding the Additive Mapping Sequences (i.e. multiplying some of the pre-selected OFDM signal sequences with their phases) to an original OFDM signal sequence. The proposed scheme simultaneously reduces computational complexity and achieves the PAPR reduction performance. This scheme requires an additional memory for saving the additive mapping signal sequences with quadrature amplitude modulation (QAM) and quadrature phase shift keying (QPSK). Also, this Additive Mapping SLM scheme can be applied to Multi-Input Multi-Output (MIMO) OFDM systems using Space-Frequency Block Code (SFBC) technique.

Keywords- *Additive Mapping SLM scheme, Computational Complexity, Orthogonal Frequency Division Multiplexing (OFDM), Peak-to-Average Power Ratio (PAPR), Selected Mapping (SLM).*

I. INTRODUCTION

Orthogonal frequency division multiplexing (OFDM) is a very useful technique in wireless communications and it is a method of encoding digital data on multiple carrier frequencies. The advantages of OFDM are high reliability and high data rate in the frequency selective fading channel environments so; it is named as a high speed communication system. These OFDM signals show high peak-to-average power ratio (PAPR) in the time domain, which causes in-band distortion and out-of-band radiation when an OFDM signal passes through nonlinear devices such as high power amplifier (HPA). Several schemes have been proposed for reducing the high PAPR of OFDM signals. Clipping is used to reduce the peak signal power of the OFDM signals to that of the threshold power. In the Companding scheme, the high power signals are suppressed and the low power signals are expanded .Tone reservation (TR), tone injection (TI), and active constellation extension (ACE) change constellation points for some subcarriers to reduce the PAPR. In both the selected mapping (SLM) and Partial Transmit Sequence (PTS) schemes several alternative signal sequences are generated by multiplying the OFDM signal sequence with its respective phase and selects the signal with the minimum PAPR among them. More alternative signal sequences increase the possibility to improve the PAPR reduction performance, but computational complexity increases as well.

There are many schemes to reduce the computational complexity of SLM. Inverse discrete Fourier transform (IDFT) to generate alternative signal sequences is replaced by a conversion matrix in the time domain whose elements are composed of $\{0, +1, -1\}$. This scheme reduces only the Computational Complexity. Also it modifies discrete Fourier transform (DFT)- shaping the SLM Scheme such that by using a pre-computed and windowed sparse matrix, a candidate alternative signal sequence with lower PAPR is selected and DFT-shaping scheme is applied only to this sequence. This scheme shows better PAPR reduction as well as lower computational complexity but needs additional memory and computations at the receiver. In [1] and [2], alternative signal sequences are generated at the intermediate stage of fast Fourier transform (FFT) in decimation-in-time [1] or decimation-in-frequency [2]. These schemes have a trade-off for PAPR and Complexity. In [3], through linear combinations of alternative signal sequences, additional alternative signal sequences are generated. Therefore, the computational complexity due to the inverse Fourier transform (IFFT) operations can be reduced while achieving the PAPR reduction performance similar to that of the conventional SLM scheme.

The proposed scheme simultaneously reduces the computational complexity and also achieves the PAPR reduction performance. Also, this scheme can be applied to the multi-input multi-output (MIMO) OFDM system using space-frequency block coding (SFBC) technique [4]. Although the proposed scheme is similar to the partial bit inverted SLM (PBISLM) scheme in [5], in the sense that the alternative symbols undergo the change of both amplitude and phase.

This paper contains the following sections. Section II, III and IV, PAPR, its effects and some reduction techniques are reviewed. Conventional and Partial bit inverted SLM schemes are also viewed in section V. Alternative symbol sequences are expressed by using additive mapping sequences in Section VI and a new low-complexity SLM scheme using additive mapping sequences is proposed in Section VII. Application of this scheme to MIMO-OFDM is explained in section VIII. The analysis of complexity and its evaluation are given in sections IX and X. The conclusion and future work are given in Sections XI and XII.

II. PEAK TO AVERAGE POWER RATIO

It is defined as the ratio of maximum peak power to that of the average power for a baseband signal s (t) i.e.

$$PAPR\{s(t)\} = \frac{\max|s(t)|^2}{E|s(t)|^2} \quad ---- \quad (1)$$

III. EFFECT OF HIGH PAPR

When an OFDM signal is passed through a non-linear device such as a high power amplifier (HPA) at the transmitter side then the Q-point will not operate in the linear region as in case of linear devices and it is affected with high PAPR. Due to this high PAPR, the Q-point moves to the saturation region which causes in-band distortion and out-of band radiation. In order to keep the Q-point in the linear region the dynamic range of the high power amplifier should be increased which in turn reduces its efficiency and enhances the cost.

IV. PAPR REDUCTION TECHNIQUES

Several techniques have been proposed for the reduction of PAPR. Some among them are Clipping, Companding, Partial Transmit Sequence, Selected Mapping, Tone Reservation, Tone Injection and Active Constellation Extension. We opt for the Selected Mapping (SLM) technique because it can reduce both the PAPR and Complexity simultaneously.

V. CONVENTIONAL AND PARTIAL BIT INVERTED SLM SCHEMES

In the conventional SLM scheme, a transmitter generates U distinct alternative signal sequences which represent the same input symbol sequence and selects the one with the minimum PAPR for transmission. By using U different phase sequences of length N, U alternative symbol sequences U, are generated by $\mathbf{X}(u)=\mathbf{A}\otimes\mathbf{P}(u)$ where $\otimes$ denotes the component wise multiplication. The first phase sequence P(0) is usually the all-1 sequence to include an input symbol sequence among alternative symbol sequences. Then, the one with the minimum PAPR among the alternative signal sequences $x^{(u)} = Q^H X^{(u)}$ is finally selected for transmission where Q is the Hermiton Matrix.

In the PBISLM scheme, alternative signal sequences are generated by multiplying the pre-selected input signal sequences with their corresponding phase sequences and they are represented as,

$$X_{k,j}^{(u)} = \begin{cases} A_{k,j} P_k^{(u)} & , \ j \in S \\ A_{k,j} & , \ j \in S^C \end{cases} \quad ----- \quad (2)$$

VI. ADDITIVE MAPPING SEQUENCES

Additive Mapping Sequences are introduced in this section which is used for generating the alternative signal sequences. An example of PBISLM with 16-QAM can be explained in the figure below. So according to this figure, the kth alternative symbol of the uth alternative symbol sequence for the phase sequence $p_k^{(u)} = \{+1,-1\}$ can be expressed as,

$$X_k^{(u)} = A_k + D_k^{(u)} \quad ------ \quad (3)$$

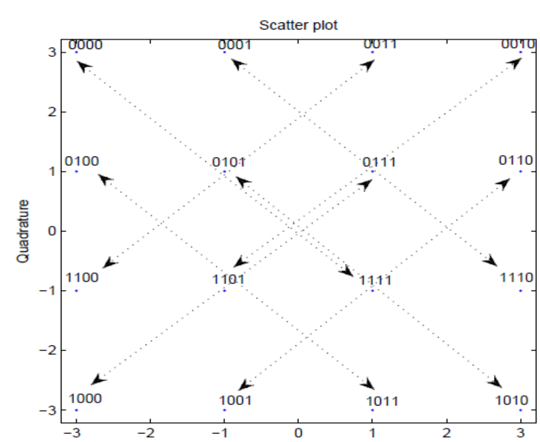


Fig.1: An example of PBISLM with 16-QAM

VII. NEW PROPOSED SLM SCHEME

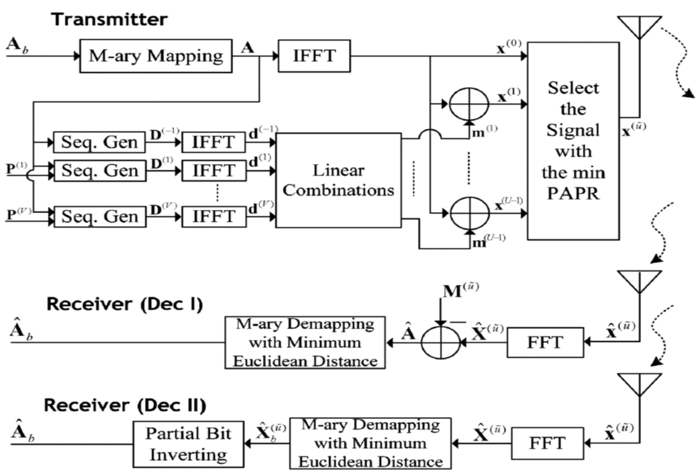
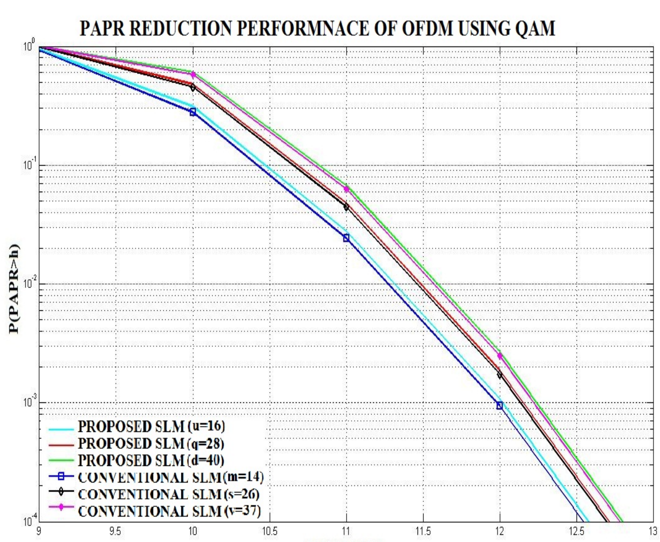


Fig.2: Block diagram of a transmitter and two receivers for the Proposed SLM Scheme.

In this section, an Additive Mapping SLM scheme is developed to generate the alternative symbol sequences by adding the additive mapping sequences to the original OFDM symbol sequence. Therefore, from the above figure, we can generate 16 numbers of alternative signal sequences and select the signal with the minimum PAPR according to the equation given by,

$$x^{(u)} = a + m^{(u)} \qquad \text{------ (4)}$$



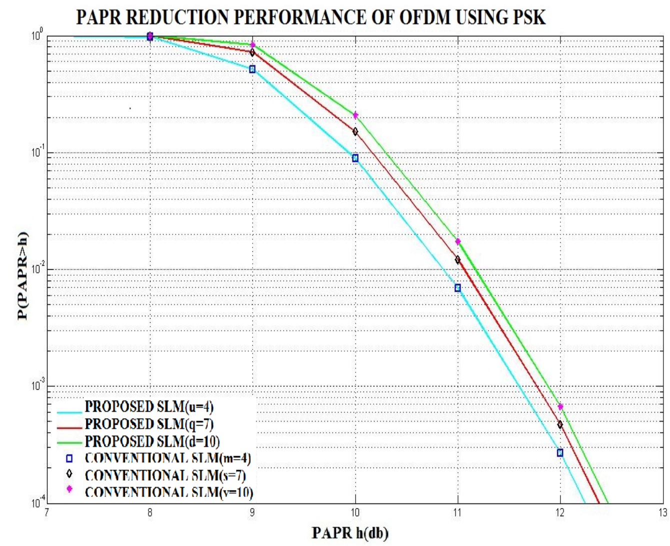


Fig.3: Results for PAPR reduction performance of OFDM using QAM and QPSK.

VIII. APPLICATION TO MIMO-OFDM

The Additive Mapping SLM scheme proposed can be extended to the MIMO-OFDM system. First, the proposed scheme can be applied to the MIMO-OFDM system with space-time block code (STBC) in which each antenna transmits independent OFDM signal sequence during one symbol block period and thus the proposed SLM scheme can be independently used for each antenna. However, in SFBC-OFDM system, data symbols are encoded in the frequency domain and a PAPR reduction scheme applied to one antenna affects the signals from other antennas. Therefore, when a PAPR reduction scheme is used in SFBC-OFDM system, the encoding schemes for all antennas should be considered to keep the orthogonality among them.

In this paper, we consider the Alamouti SFBC-OFDM system [4], where an input symbol sequence is encoded to two different symbol sequences and again they are sub-divided into even and odd carries and finally they are applied as input for two transmit antennas. The process is same as that in the case of the OFDM system.

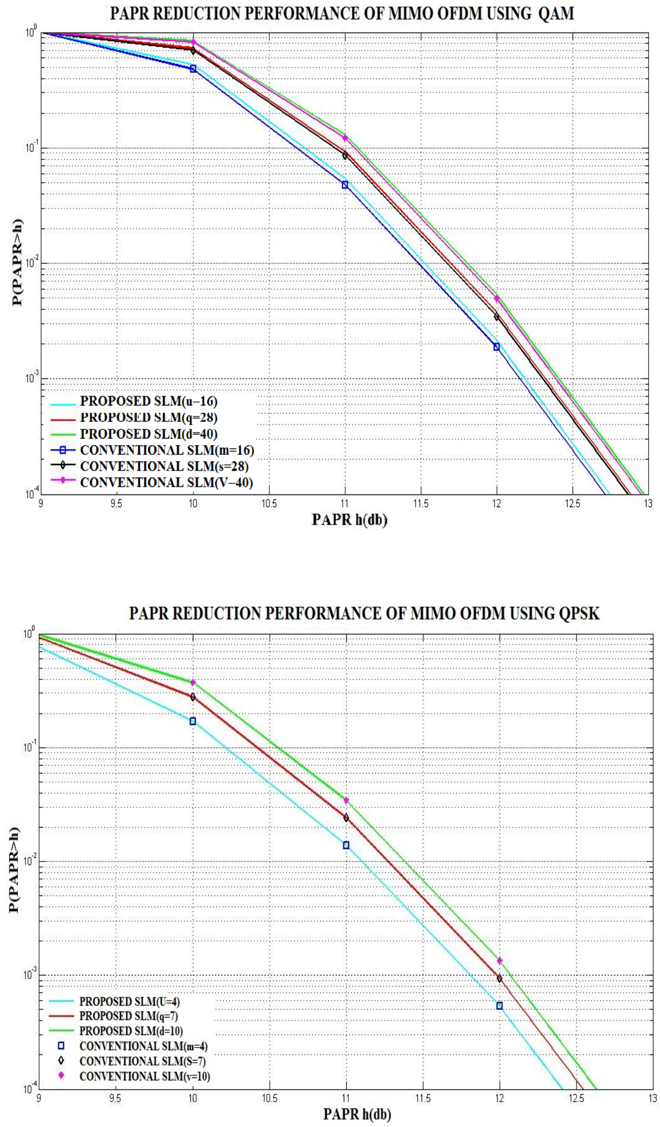


Fig.4: Results for PAPR reduction performance of MIMO-OFDM using QAM and QPSK.

IX. ANALYSIS OF COMPLEXITY

In this SLM technique the complexity arises with increasing the number of alternative OFDM signals (i.e. increasing the value of U) the PAPR is being reduced. Figure3 shows this analysis with consideration of 64 number of subcarriers and oversampling factor J = 4. However the number of alternative OFDM signals is same as the number of IFFT blocks. As we know that for N point IFFT the number of complex multiplications and additions are N/2log2N and Nlog2N respectively.

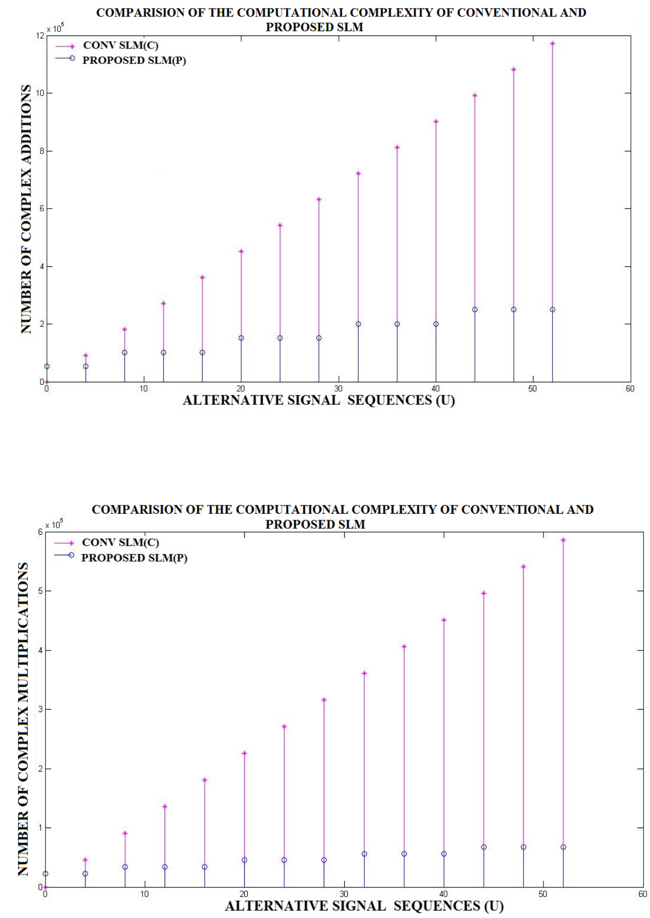


Fig.5: Number of Complex Multiplications and Additions of the Conventional and the Proposed SLM Schemes.

X. NUMERICAL ANALYSIS

In this section, the PAPR reduction performance of the conventional SLM and the proposed SLM schemes are compared. The rows of cyclic Hadmard matrix are used as phase sequences [7] and the oversampling factor J is set to 4.

The computational complexity reduction ratio (CCRR) of the proposed SLM scheme over the conventional SLM scheme defined as,

$$CCCR=\left(1-\frac{Complexity\ \ of\ \ the\ \ proposed\ \ SLM}{Complexity\ \ of\ \ the\ \ conventional\ \ SLM}\right)\times 100\% \quad \text{----(5)}$$

TABLE 1: COMPARISON OF COMPLEXITY OF DIFFERENT SLM SCHEMES

	Total number of complex multiplications	Total number of complex additions
Conventional SLM	$\frac{U}{2} JN \log_2(JN)$	$UJN \log_2(JN)$
SLM in [16]	$\sum_{b=1}^{v-1} 2^{b-1}\left(\frac{JN}{2^b}-1\right) + U\sum_{b=v}^{S} 2^{b-1}\left(\frac{JN}{2^b}-1\right)$	$JN\left[v + U(S-v)\right]$
SLM in [17]	$\frac{\sqrt{U}JN}{2}\log_2(JN) + JN\left(U-\sqrt{U}\right)$	$\sqrt{U}JN\log_2(JN) + JN(U-\sqrt{U})$
Proposed SLM with M-QAM	$\left(2+\lceil\frac{U-4}{12}\rceil\right)\frac{JN}{2}\log_2(JN)$	$\left(2+\lceil\frac{U-4}{12}\rceil\right)JN\log_2(JN) + \left(13\lceil\frac{13U-4}{12}\rceil+4\right)JN - 2\left(\lceil\frac{U-4}{12}\rceil+1\right)$
Proposed SLM with M-PSK	$\left(1+\lceil\frac{U-1}{3}\rceil\right)\frac{JN}{2}\log_2(JN)$	$\left(1+\lceil\frac{U-1}{3}\rceil\right)JN\log_2(JN) + 4\lceil\frac{U-1}{3}\rceil JN - 2\lceil\frac{U-1}{3}\rceil$
Conventional SLM (SFBC)	$\frac{U}{2}JN\log_2(JN) + \frac{U}{2}JN$	$UJN\log_2(JN) + UJN$
Proposed SLM with M-QAM (SFBC)	$\left(2+\lceil\frac{U-4}{12}\rceil\right)\frac{JN}{2}(\log_2(JN)+1)$	$\left(2+\lceil\frac{U-4}{12}\rceil\right)JN\log_2(JN) + \left(9+26\lceil\frac{U-4}{12}\rceil\right)JN - 2\left(1+\lceil\frac{U-4}{12}\rceil\right)$
Proposed SLM with M-PSK (SFBC)	$\left(1+\lceil\frac{U-1}{3}\rceil\right)\frac{JN}{2}(\log_2(JN)+1)$	$\left(1+\lceil\frac{U-1}{3}\rceil\right)JN\log_2(JN) + \left(1+8\lceil\frac{U-1}{3}\rceil\right)JN - 2\lceil\frac{U-1}{3}\rceil$

TABLE 2: COMPUTATIONAL COMPLEXITY REDUCTION RATIO OF THE PROPOSED SLM SCHEME OVER THE CONVENTIONAL SLM SCHEME FOR N=512 AND J=4.

	single-antenna OFDM						Alamouti SFBC-OFDM					
	M-QAM			M-PSK			M-QAM			M-PSK		
U	16	28	40	4	7	10	16	28	40	4	7	10
CCRR for complex multiplication (%)	81	86	88	50	57	60	81	86	88	50	57	60
CCRR for complex addition (%)	72	76	78	41	47	49	65	69	70	35	40	42

XI. CONCLUSION

In conclusion, a new low-complexity SLM scheme for the reduction of PAPR of OFDM signals is proposed, which generates alternative signal sequences by simply adding mapping signal sequences to an original OFDM signal sequence in the time domain. The proposed SLM scheme shows similar PAPR reduction performance as the conventional SLM scheme while reducing the computational complexity. Although our work is focused on the single-antenna OFDM and the Alamouti SFBC-OFDM, the proposed SLM scheme can be applied to any kind of SFBC-OFDM systems if the input symbol sequence of one transmit antenna can be represented by linearly transforming the input symbol sequence of another transmit antenna.

XII. FUTURE WORK

The application of this Additive mapping SLM scheme can also be verified in the OFDMA system. The sending of SI index in case of the Riemann matrix should be avoided by performing required analysis. Further reduction of the computational complexity for the proposed technique can be forestalled.

XII. REFERENCES

[1] D.-W. Lim, J.-S. No, C.-W. Lim, and H. Chung, "A new SLM OFDM scheme with low complexity for PAPR reduction," *IEEE Signal Process. Lett.*, vol. 12, no. 2, pp. 93–96, Feb. 2005.

[2] A. Ghassemi and T. A. Gulliver, "Partial selective mapping OFDM with low complexity IFFTs," IEEE Comm. Let., vol. 12, no. 1 , pp 4–6, Jan. 2008.

[3] S.-J. Heo, H.-S. Noh, J.-S. No, and D.-J. Shin, "A modified SLM scheme with low complexity for PAPR reduction of OFDM systems," *IEEE Trans. Broadcast.*, vol. 53, no. 4, pp. 804–808, Dec. 2007.

[4] K. F. Lee and D. B. Williams, "A space-frequency trasmitter

diversity technique for OFDM systems," in *Proc. IEEE GLOBECOM'00*, Nov. 2000, pp. 1473–1477.

[5] H.-B. Jeon, K.-H. Kim, J.-S. No, and D.-J. Shin, "Bit-based SLM schemes for PAPR reduction in QAM modulated OFDM signals," *IEEE Trans. Broadcast.*, vol. 55, no. 3, pp. 679–685, Sep. 2009.

[6] H. V. Sorensen, D. L. Jones, M. T. Heideman, and C. S. Burrus, "Real-valued fast Fourier transform algorithms," *IEEE Trans. Acoust., Speech, Signal Process.*, vol. assp-35, no. 6, pp. 849–863, Jun. 1987.

[7] D.-W. Lim, S.-J. Heo, and J.-S. No, "On the phase sequence set of SLM OFDM scheme for a crest factor reduction," *IEEE Trans. Signal Process.*, vol. 54, no. 5, pp. 1931–1935, May 2006.

[8] *IEEE Trans. Signal Process.*, vol. 54, no. 8, pp. 3159–3165, Aug. 2006, G. T. Zhou and L. Peng, "Optimality condition for SLM in OFDM,".

[9] J. Yang and K. Cheun, "Low complexity implementation of Alamouti space-time coded OFDM transmitters," *IEEE Comm. Lett.*, vol. 8, no. 4, pp. 229–231, Apr. 2004.

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