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Performance Analysis of Selected Mapping Scheme for Minimization of Peak to Average Power Ratio in OFDM Systems

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Abstract: Minimization of Peak to Average Power Ratio (PAPR) has remained a challenging problem for researchers. Many methods have been proposed to reduce the PAPR. The Selected Mapping (SLM) method is a competent method for reducing the high PAPR of Orthogonal frequency Division multiplexing (OFDM) signal. One drawback of the SLM is the high computational complexity. To reduce the complexity of the SLM, the real and imaginary parts of the OFDM signal are treated separately. The even and odd sequences of the real and imaginary parts are obtained using the Fourier Transform properties. More candidates are generated by the different combination of all the subsequences. This paper provides an analysis of the SLM method for minimization of PAPR in OFDM. The method has been described in detail and its advantages over other methods have been highlighted. Simulation based analysis has been carried out in MATLAB environment. It has been demonstrated that the SLM method is a suitable method for the minimization of PAPR.

Keywords: Orthogonal Frequency Division Multiplexing, High Power Amplifier, Peak-to-average power ratio , Slected Mapping.

1. INTRODUCTION

A promising technique that can be used for fast transmission of data is OFDM, since it has high spectral efficiency and is robust to interference that might occur in the multi-path channels (Jiang*et al.,* 2007). Also OFDM has been widely adopted for use in current and planned mobile broadband wireless communication systems (Gouba, andLouët, 2013). Despite the many advantages of the OFDM system, unfortunately, one downside of OFDM systems is that they have a large transmit signal PAPR, which can significantly increase system cost (Halepoto *et al.,* 2013). High peak signals may be clipped in digital to analog converters (DAC) or fall in the saturation region of the Radio Frequency Power Amplifier (RFPA) used in an OFDM system. This leads to nonlinear distortions such as in band distortion and High Power Amplifier (HPA) which is used in OFDM systems to generate sufficient power of the transmitted signal. The characteristics of the HPA mean that we need to operate it around the saturation point to get the necessary maximum output power efficiency.

The HPA output is dependent of the varying input signal strength, since these signals exhibit a large PAPR; the output has inter-modulation between the subcarriers of the OFDM signal. Thus, this high PAPR results in interference which in-turn increases the Bit Error Rate (BER) and therefore it is required that the HPA characteristics be linearized so as to use it in its linear region having a high dynamic range. Regrettably, these amplifiers have poor efficiency and high cost and since power efficiency is of utmost importance in wireless communication systems since issues like area coverage need to be addressed, using less power and allowing for small sized terminates etc. We aim for efficient operation of the non-linear HPA while trying to limit the back-off values to its lowest possible and work to formulate solutions to get- rid of the interference. An example of such approaches is the reduction of the PAPR of the transmitted OFDM signals by manipulating it before transmission.

Furthermore, high PAPR signals require a high dynamic range DAC to be able to cater to the large peaks of the input OFDM signal. These qualities are present in some high quality DACs which can reduce PAPR while maintaining low quantization noise but these are very costly due to the high sampling rate requirement of the system. On the other hand, if a DAC having low precision is used, the cost issue is addressed but the Signal to Noise Ratio (SNR) gets degraded due to the high quantization noise and the low dynamic range of the DAC which needs to be increased in proportion with the high PAPR of the signal. A large number of OFDM subcarriers demonstrate a Gaussian distribution which means that the peak value does not occur frequently and therefore uniform quantization is not suitable. In such a scenario, using clipping will give rise to band distortion and out of band radiation (adjacent channel interference). It can be said then that PAPR reduction of the signal before it is passed on to the HPA and the DAC would be well suited for this problem.

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There have been numerous methods proposed as yet to minimize PAPR (Lim, *et al.*, 2009),which can be categorized into two classes: distortion-bearing and distortion less. The distortion bearing class includes clipping techniques (Zhu, *et al.*, 2013), (Shiragapur, *et al.*, 2013), tone reservation (TR) (Tao *et al.*, 2014), and active constellation extension (ACE) (Jing *et al.*, 2013). Even though the method with the lowest computational complexity is among distortion less schemes is TR, this is gained with a loss in bandwidth efficiency (Abro *et al.*, 2015). The overall signal degradation is increased when the nonlinear behavior of the Power Amplifier is factored. The distortion less schemes involved coding based techniques (Daiming, *et al.*, 2014), partial transmit sequence (PTS)(Jun 2011) and SLM (Chackocha., 2011) (Tao, 2013)(Lin, *et al.*, 2014). For coding based techniques, a problem which is faced is the difficulty in keeping the coding rates to an acceptable level in OFDM systems having many subcarriers. Phase rotation vectors are not same which results in a considerable increase in the BER. Furthermore, the low-complexity techniques, which use time domain symbol processing to generate multiple candidate symbols and choose the symbol with the lowest PAPR, were presented in (Chackocha., 2011) (Tao, 2013).

This paper also focuses on the useof the SLM techniquein an OFDM system**.**Contrary to Offset Selected Mapping (OSLM)techniquein which selective mapping method is utilized for data that is real valued while considering all OFDM symbols that overlap each other. Our paper is arranged as follows. In section 2, we review the basics of an OFDM system and the PAPR problem algorithm is presented. In section 3, we brief our motivation for SLM scheme. In section 4 we propose our improved SLM technique for use in OFDM systems, in section 5 contains the simulation results and.Insection 6, we give a brief conclusion where as in section 7, acknowledgement is given.

2.OFDM SYSTEM MODEL & PAPR PROBLEM

2.1 OFDM System Model

An OFDM system is shown in **(Fig. 1).** As can be seen in the figure, the incoming bit stream is formed in to a constellation of points using carrier weightsS[k]. These are then transformed from a serial stream to separate parallel data for the Inverse Discrete Fourier Transform (IDFT) operation. LetN and $S[k], 0 \le k \le N-1$, be the number of subcarriers and the complex modulated symbols in the frequency domain respectively. The output $s[t]$ of the *N*-point IDFT of S[k]can be mathematically written as

$$s[t] = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} S[k]\, e^{j2\pi kn/N}, \qquad 0 \le t \le N-1 \qquad (1)$$

The PAPR of the transmitted OFDM symbol $s[T],\ n = 1, \dots, N-1$is defined as PAPR

$$PAPR[s(t)] = \frac{P_{max}}{P_{av}} = \frac{\max_{0 \le t \le NT} [|s(t)|^2]}{E\{|s(t)^2|\}} \qquad (2)$$

where*E* stands for the expectation operator.

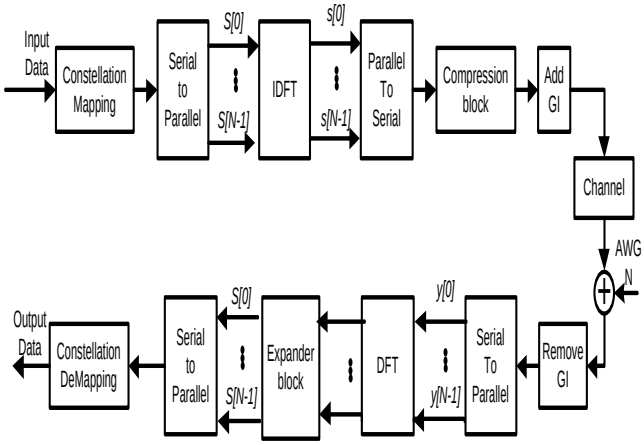


Fig. 1. A typical OFDM system model

Using this technique, the signal with high PAPR in the time domain passes through a block used for compression which is appended to the IDFT block at the transmitter as illustrated in Fig.1. The expansion at the receiver end is performed by a dedicated expander block which is also performs the required DFT operation. A time domain OFDM signal for baseband communication can be composed as in equation (3).

$$s(n) = \sum_{y=\infty}^{+\infty} \sum_{x=0}^{X-1} u_{x,y}\, e^{j\emptyset_{x,y}}, e^{j2\pi x a_0 t} h(-y\tau_0), \qquad (3)$$

with X being the number of sub-carriers which is an even quantity, $u_{x,y}$the real- valued symbol conveyed by the sub-carrier of index xduring the symbol time of indexy, h the pulse shape, $q_0$the subcarrier spacing and τ_0 the time offset between the adjacent real part and imaginary part of an OFDM symbol.$a_0 = 1/T_0 = 1/2\pi_0$,with$T_0$the duration of the complex valued symbols. $\emptyset_{x,y}$is an additional phase term given by

$$\emptyset_{x,y} = \emptyset_0 = \frac{\pi}{2}(x+y)(\text{mod } \pi), \qquad (4)$$

Where $\emptyset_0$ can be arbitrarily chosen.

Perfect reconstruction of real symbols for a distortion-free channel can be achieved according to the following real orthogonal condition.

$$\Re\{\langle h_{x,y}|h_{v,w}\rangle\} = \Re\{\int h_{x,y}(n)h_{v,w}^{*}(n)\} = \delta_{x,v}\delta_{y,w} \quad (5)$$

where$\Re\{\bullet\}$is the real part operator. $\delta_{x,v} = 1$,if$x = v$and $\delta_{x,v} = 0$ if $x \neq v$.

From equation (3) we can see thats(n), which is the transmitted signal is the sum over all subcarriers which are statistically independent, consequently, for a large number of subcarriers X, s(n) has varies over a large range.

2.2 Basics of PAPR

Primarily PAPR is most essential variable to calculate the sensitivity for transmission schemes by nonlinear amplification, which having non constant envelop. Now in discrete time domain version the PAPR of the OFDM signal is define as under:

$$\text{PAPR}_{s_c(t)} = \frac{\max|s_c(t)|^2}{E\{|s_c(t)^2|\}} \qquad 0 \le t \le T, \quad (6)$$

The nonlinear distortion in the HPA happens in the analog domain whereas the digital domain is used to implement methods for the reduction of PAPR. Generally, the analog and digital domain PAPR is not the same. PAPR is represented in both the digital and the analog domain utilizing the oversampled signal domain as a close approximation. An oversampling factor of L=4 is usually enough to get an approximation of the analog domain PAPR.Then, the OFDM signal PAPR can be given as:

$$\text{PAPR} = \frac{\max|x(n)|^2}{E\{|x(n)^2|\}} \qquad 0 \le n \le LN, (7)$$

The PAPR has a large value as a result of the summation of the inverse discrete Fourier transform (IDFT) process. In time domain OFDM signal or signal envelop variation or the Crest Factor (CF) is expressed as in equation (8).

Where;

$$\text{PAPR} = CF^2 \quad (8)$$

In dBs, the PAPR of the transmitted OFDM signal can be defined as.

$$\text{PAPR(dB)} = 10\log_{10}\frac{\max_{k\in\{0,\cdots,X-1\}}\{[s_k]^2\}}{E\{|s_k|^2\}} \quad (9)$$

The factor PAPR is utilized as random variable considering OFDM based system. The main idea of this computation is to determine the probability which crosses a predefined threshold δ(dB)and the Complementary Cumulative Distribution Function (CCDF) provides this probability for every δ. It can be mathematically presented as:

$$\text{CCDF} = P\{\text{PAPR} > \delta\} \quad (10)$$

3. MOTIVATION FOR USING SELECTED MAPPING

SLM is arguably the most popular PAPR reduction scheme which can be used for OFDM. The main benefit of SLM is the guarantee of achieving a smaller PAPR providing that the mapping sequences were pre-selected in an optimal manner. Another important motivation for using SLM is that it does not cause distortion, which means that the SNR of the transmitted signal remains the same. It must be mentioned here that SLM does require the knowledge of scrambling sequences at the receiver end, but this can be communicated via $\log_2(Z)$ bits, where Z represents the number of SLM sequences in used.

4. THE SLM METHOD FOR OFDM

A promising scheme for reducing PAPR in OFDM is selected mapping. Within this scheme, data blocks which are statistically independent are generated by means of different phase sequences with the lower one being utilized and transmitted. This scheme has the potential to reduce the probability of a major PMEPR (Peak-to-Mean Envelope Power Ratio) for multicarrier transmission scheme. Our goal is to perform a change of phase on the modulated symbols (before IFFT) in order to reduce the probability of constructive interference between the subcarriers (after IFFT) has been computed. A block diagram of SLM is represented in **(Fig. 2).**

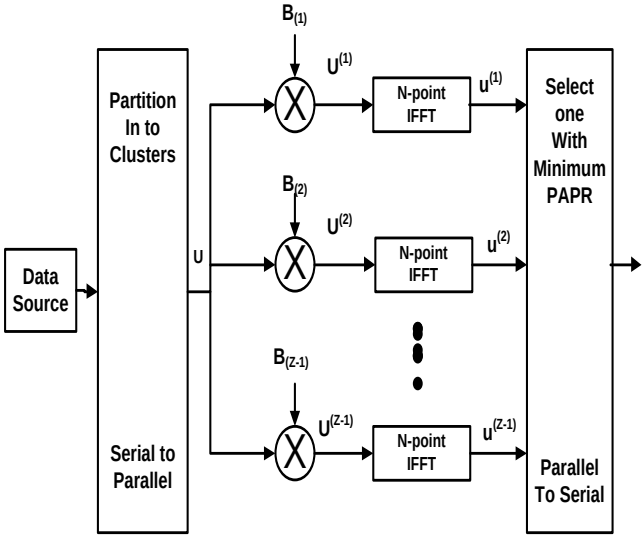


Fig. 2. Block Diagram for SLM Scheme for OFDM System

Each block of data is multiplied with phase rotator Z for different length N.

$$B^z = [b_z, 0, b_Z, 1, \dots, b_Z, N-1]^T, Z = 1,2, \dots, Z-1$$

Table.1 PAPR Levels in dBs for OFDM Symbol Candidate Combinations

Fig #	OFDM Symbol Candidates	Phase Sequences	Over Sampling Factors	Sub band	PAPR level in (dB)
Fig. 3	C=8	4	4	64	3.7
Fig. 4	C=16	4	4	64	4.3
Fig. 5	C=32	4	4	64	4.7
Fig. 6	C=64	4	4	64	5.0
Fig. 7	C=128	4	4	64	5.3
Fig. 8	C=256	4	4	64	5.5

Resulting in Z different data blocks, so the z^{th} phase sequence after multiplying is given as:

$$U^Z = \left[U_1 b_{Z,1}, U_2 b_{Z,2}, \dots, U_{N-1} b_{Z,N-1}\right]^2, (z = 1, 2, \dots, Z-1).$$

Therefore, OFDM signal becomes as given in equation (11).

$$u^z(t) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} U_n b_{z,n} e^{j2\pi fnt} \quad \text{where } 0 \le t \le NT, \\ = 1,2, \dots, U. \qquad (11)$$

Among the data blocks $U^{(z)}(z = 0, 1, \dots, Z-1)$ only one of the modified data block,that has the lowest PAPR value is chosen to be sent. After that the data is transmitted along with the phase sequences as side information. The opposite operation is performed at the receiver to recover the original signal. The SLM technique requires Z IFFT operations to be performed to use it in OFDM signals and the quantity of bits used as side data is $\lceil \log_2(Z) \rceil$ for each block of information. This methodology is calculable with a wide range of modulation and the number of sub carriers. It can be then said that the performance of SLM in terms of PAPR reduction is dependent on the number of phase factors Z and the design of the phase components.

5. SIMULATION RESULTS

By closely observing the graphical analysis, it is inferred that the PAPR reduction in terms of dB in CCDF for OFDM system is shown with dotted(---)line and without SLM solid (___) line. The graphical analysis and simulation results of PAPR reduction SLM methodology can be utilized for OFDM based system. From Fig. 3 to Fig. 8, SLM technique uses different number of OFDM Symbol candidates (C), with 4 phase sequences, 64 number of sub band, and L=4 (Oversampling factor). This combination can reduce the PAPR of an OFDM signal at different level in dB. But, Fig 9 shows the reduction approximately about 5.7 dB by using number of OFDM symbol candidates C=256, 4 different phase sequences, 64 number of sub band, L=4 (Oversampling factor). Table-1 summarizes the results presented in **figures** 3 to 8.It is observed that SLM with increasing number of OFDM symbol candidate improves the PAPR performance and no BER increases. This also decreases the system complexity.

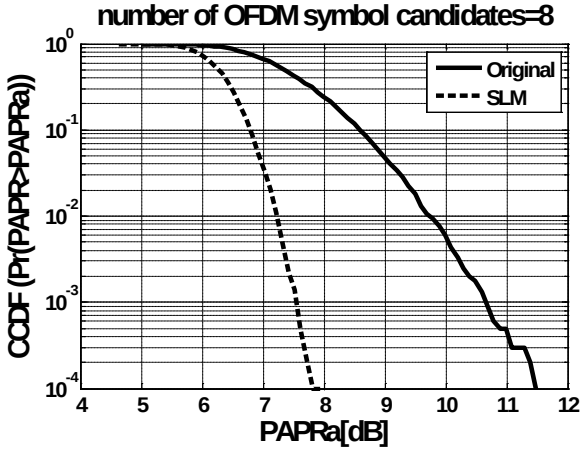


Fig. 3. CCDF graph for PAPR of OFDM with and without SLM

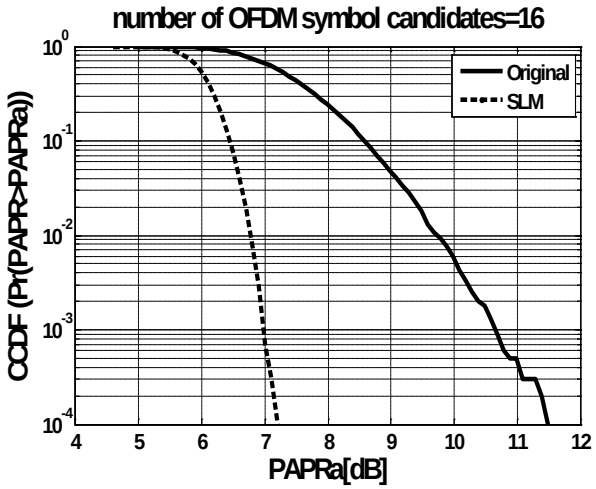


Fig. 4. CCDF graph for PAPR of OFDM with and without SLM

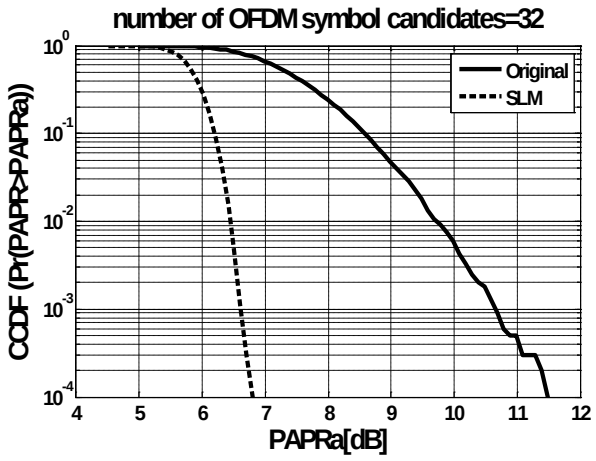


Fig. 5.CCDF graph for PAPR of OFDM with and without SLM

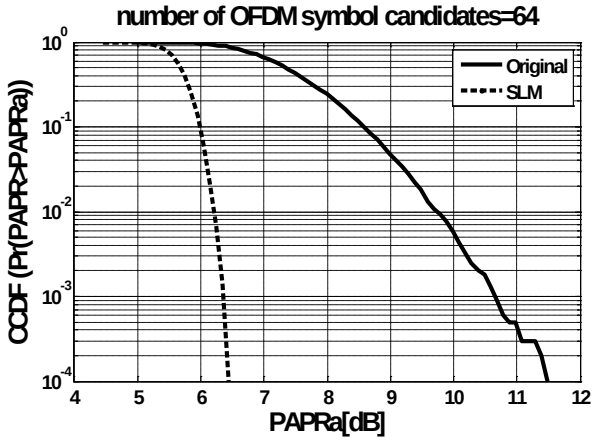


Fig. 6. CCDF graph for PAPR of OFDM with and without SLM

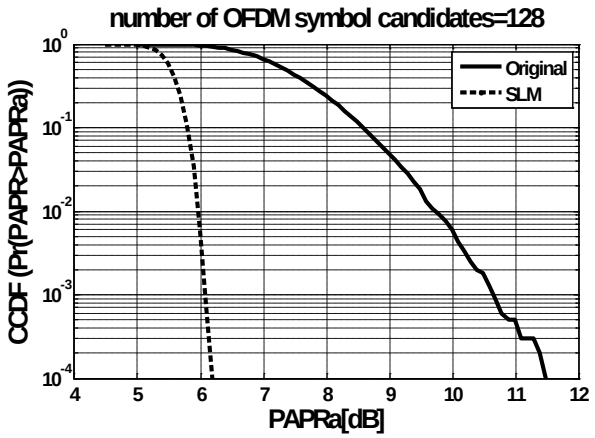


Fig. 7. CCDF graph for PAPR of OFDM with and without SLM

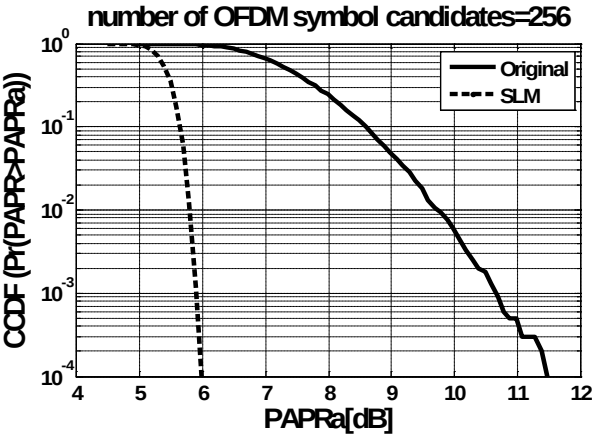


Fig. 8. CCDF graph for PAPR of OFDM with and without SLM

6. CONCLUSIONS

The major aim of this paper is to reduce the PAPR by using the SLM methodology. The proposed methodology can be utilized for the OFDM based system. One workable solution is SLM which is an easy way to mitigate the effect of PAPR by means of undistorted processing. This is done by increase the number of OFDM symbol candidate with 4 different phase sequences, 64 number of sub band, L=4 (Oversampling factor), combinations can reduce the PAPR of an OFDM signal by about 5.7 dB. This is quite enough. Furthermore it makes no BER degradation, no interference to different subcarriers and does not require any extra processing at the receiver. The potential of the research is quite evident from the simulation results presented. Further work can be carried out to reduce the complexity. It can be seen that the SLM scheme is very useful and offers advantages over the other techniques to reduce the PAPR efficiently.

7. ACKNOWLEDGEMENT

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REFERECES:

Abro, F.R., S. McGrath, T.J.Khanzada, andM.A. Hashmani, (2015). A novel approach to minimize Peak-to-Average Power Ratio in OFDM using Tone Reservation methodology. *Sindh University Research Journal - SURJ (Science Series), 47* (2), 355-360.

Chackochan, R., and H. Soni. (2011). Peak to Average Power Ratio (PAPR) reduction in OFDM for a WLAN network using SLM technique. *IEEE International Conference on Communications, 3* (1), 57-59.

Daiming, Qu., L. Li, andT. Jiang, (2014) . Invertible Subset LDPC Code for PAPR Reduction in OFDM systems with low complexity. *IEEE Journals and Magzines, 13*(4), 2204–2213.

Gouba, O. A.,andY. Louet. (2013). Adding signal for Peak-to-Average Power Reduction and predistortion in an Orthogonal Frequency Division Multiplexing Context. *IET Journal on signal processing, 7*(2),879-887.

Halepoto, I. A., W. Kumar, T.D.Memon, and I.A. Ismaili. (2013). Quantifying the effect of Look up Table Size and Coefficients Complexity for Non-Linearity Compensation in Power Amplifiers. *Sindh University Research Journal (Science Series), 45*(2), 447-452.

Jing H., andZ. Yan. (2013). Improving convergence rate of Active Constellation Extension algorithm for PAPR Reduction in OFDM. *IEEE Transaction on Broadcasting, 49*(3), 280–284.

Jiang., T., W. Xiang., H. H. Chen., and Q. Ni. (2007). Multicast broadcasting services support in OFDMA-based WIMAX systems. *IEEE Transaction on Communications Magazine, 45*(8), 78-86.

Jun H., J. Ge, andJ. Li. (2011). Peak-to-Average Power Ratio Reduction of OFDM Signals Using Partial

Transmit Sequences with Low Computational Complexity. IEEE Transaction on Broadcastings, 57(1). 143–148.

Lin, Y., J. H. Wu, andM.S.Yun, (2014). Swapped SLM Scheme for reducing PAPR of OFDM systems. *Electronics Letters on Wireless Communication, 50* (22), 1608-1609.

Lim, Dae-Woon.,H. Seok-Joong, andN. Jong-Seon. (2009). An Overview of Peak-to-Average Power Ratio Reduction Schemes for OFDM Signals",*IEEE Journals of Communication and Networks*, *11* (3), 229-239.

Shiragapur, B. K., U. Wali,andS. Bidwai. (2013). NovelTechnique to reduce PAPR in OFDM systems by clipping and filtering. *IEEE International Conference on Advance in Computing*, 1593–1597, 22-25 Aug. 2013.

Tao J., C. N. Chang, andX.Qi. (2014). Curve Fitting Based Tone Reservation Method with Low Complexity for PAPR Reduction in OFDM Systems.*IEEE Journal on Communications Letters*, *18*(5), 805-808.

Tao, J., C. Ni., andL. Guan. (2013). A Novel Phase Offset SLM Scheme for PAPR Reduction in Alamouti MIMO-OFDM systems Without Side Information. *IEEE Letters on Signal Processing, 20* (4), 383-386.

Zhu, X., P. Wensheng, L. Hong, andT.Youxi.(2013). Simplified Approach to Optimized Iterative Clipping and Filtering for PAPR Reduction of OFDM Signals. *IEEE Transaction on Communications,61*(5),1891–1901.