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Hadamard Matrix based Selected Mapping Hybridized with Clipping Technique for Peak to Average Power Ratio Reduction in OFDM System using Several Sub-carriers

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Abstract

High Peak to Average Power Ratio (PAPR) introduces distortion in the information when MultiCarrierModulation (MCM) technique like Orthogonal Frequency Division Multiplexing(OFDM) is used. OFDM is generally preferred when higher data rates are required. So it has become a requirement for the system which is using OFDM to diminish PAPR problem. So, in this paper we are proposing a novel technique in which we are using Selected Mapping (SLM) with clipping technique under Hadamard matrix based phase sequence designed in frequency domain. In the conventional SLM technique which uses multiple phase sequence possessing same length as that of the data sequence in order to diminish PAPR. Therefore, it is highly demanded that we have to propose a technique by which we can design phase sequence in frequency domain easily and can optimized the results in time domain. So, we have implemented an algorithm which design phase sequence in frequency domain conveniently and after transformation through inverse Fast Fourier Transform (IFFT) optimize in time domain accordingly. Along with this, we have hybridized clipping technique in time domain so that if in any case PAPR problem is found to be greater than certain threshold then it can clip it in the time domain sequence domain itself. Simulation results clearly provide the justification and efficiency of proposed algorithm as compared with conventional OFDM, SLM and Clipping technique. Proposed novel algorithm attains a significant gain (dB) of 2.85,2.65,2.35,2.05,2.60 and 2.70 in comparison with conventional OFDM system considering several number of sub carriers (N)=32,64,128,256,512 and 1024 respectively.

Keywords: Complementary Cumulative Distribution Function (CCDF), Orthogonal Frequency Division Multiplexing (OFDM), Peak to Average Power Ratio (PAPR), Selected Mapping (SLM)

1. Introduction

Orthogonal Frequency Division Multiplexing (OFDM) is the most promising technique for many applications like Digital Audio Broadcasting (DAB), Digital Video Broadcasting (DVB) etc. In [1]However, there exists a problem known as high Peak to Average Power Ratio (PAPR) due to which High Power Amplifier (HPA) has to work in non-linear region henceforth introducing distortion in the information. Several techniques have been proposed like Partial Transmitted Sequence (PTS)[2,3] in which partial sequence is passed through IFFT then data is optimized in time domain and finally sequence which generates minimum PAPR is considered for transmission. Selected

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Mapping (SLM)[4–8] technique is the attractive technique for the PAPR reduction because it optimizes the data in frequency domain and hence reduces complexity drastically as compared with PTS. Hence SLM technique has been widely adopted for compensating PAPR. There exists an important technique known as Hadamard phase based SLM[9]. This technique came into picture because it reduces the problem of phase generation and requires very less side information as compared with conventional SLM. Clipping[10,11] technique is also used to reduce PAPR by clipping the sequence. Coding scheme[12] is used to diminish the PAPR problem but it requires large look up tables. So there exist a trade-off between the performance and complexity in generating large look up tables. In this paper, a technique based on Hadamard based SLM hybridized with clipping which work remarkably well in reducing PAPR is presented.

This paper is organized as follows; mathematical expression related to OFDM, PAPR, CCDF, Hadamard phase sequence, and clipping are presented in Section 2. In Section 3, proposed algorithm methodology has been presented along with block diagram (Figure 1). In Section 4, parameters which are considered during simulation have been shown along with various simulation graphs under different sub-carriers and finally, conclusion has been presented in Section 5.

2. OFDM System, PAPR, CCDF, Walsh Hadamard Matrix and Clipping

In OFDM system[2] frequency domain sequence D(K) is converted into corresponding time domain sequence d(n) after passing through IFFT and is represented as,

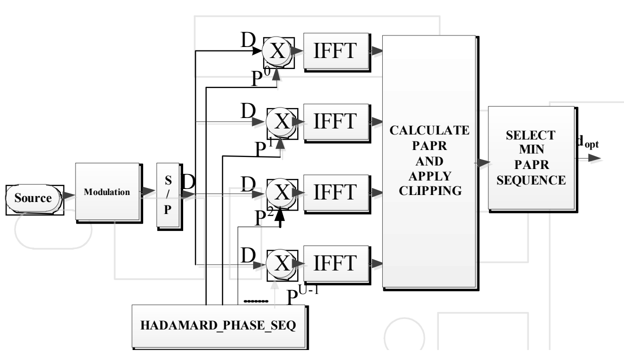

Figure 1. Block diagram of proposed selected mapping hybridized with clipping algorithm.

$$d(n) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} D(k) e^{\frac{j2\pi kn}{N}} \qquad n \in [0, N-1] \tag{1}$$

where k and n are frequency and time indices, respectively.

Peak to average power ratio (PAPR)[2] is defined as the ratio of maximum power to the average power and is given as,

$$PAPR(d[n]) = \frac{\max(|d[n]|^2)}{E[d[n]^2]} \tag{2}$$

Complementary cumulative distribution function (CCDF)[2] is defined as the probability that PAPR is found to be greater than certain threshold,

$$CCDF(PAPR(d[n])) = Pr(PAPR(d[n] > PAPR_0)) \tag{3}$$

where Pr= Probability, $PAPR_0$=threshold

Walsh Hadamard matrix9 can be constructed easily by recursive methodology of Selvester. Henceforth matrix rows can be used as phase sequence for SLM technique. This leads to drastic reduction in the complexity for designing phase sequence,

$$H_{2N}^{W} = \begin{bmatrix} H_N^W & H_N^W \\ H_N^W & -H_N^W \end{bmatrix} \quad and \; H_N^W = \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \tag{4}$$

In clipping technique, the information signal after passing through IFFT (converted into time domain) is clipped after certain threshold, i.e., if found possessing high PAPR and is represented as,

$$d_c(n) = \begin{Bmatrix} A & ; |d(n)| > A \\ d(n) & ; |d(n)| \le A \end{Bmatrix} \tag{5}$$

where d(n)= time domain information signal, A= predefined clipping level, $d_c(n)$=clipped time domain information signal.

3. Hadamard based SLM Hybridized with Clipping Technique for PAPR Reduction Algorithm

1. Data sequence after passing through modulator is represented by,

$$D = [D_0, D_1, .., D_{N-1}]^T \tag{6}$$

where, N is number of sub-carriers,

2. Phase sequence of Hadamard matrix for the optimization and reduction of PAPR is represented as,

$$P^v=[P^v_{0,} P^v_1,\ldots\ldots\ldots P^v_{N-1}]^T,\ 1 \leq v \leq U \tag{7}$$

where U is number of rows of hadamard matrix.

3. Element-wise product of modulated data and phase sequences is obtained and is defined as

$$D^v=[D_0{}^* P^v_0,\ D_1{}^* P^v_1,\ldots\ldots,\ D_{N-1}{}^* P^v_{N-1}]^T \tag{8}$$

4. Time domain transformation of D^v is performed with the help of IFFT and is represented by,

$$d^v=IFFT(D^v) \tag{9}$$

5. Now, value of PAPR is obtained by equation (2) and if it is greater than clipping level then it will be clipped in time domain sequence in order to reduce PAPR.
6. Repeat the steps (2–5) for the U different phases.
7. At last choose the sequence that generates minimum PAPR; i.e., d_{opt} for the transmission based upon phase sequence and clipping level.

4. Simulation Results and Deliberations

MATLAB simulations have been used for the proposed OFDM system considering numbers of sub-carriers (N) = 32, 64, 128, 256, 512, 1024, phase sequence (U) = [32], modulation scheme = 32-PSK (Phase Shift Keying). Clipping level (CL)=0.90, up-sampling factor (L)=4, number of OFDM symbols=5000, and Complementary Cumulative Density Function (CCDF) has been used for calculation of PAPR of OFDM system.

Figure 2, at CCDF=.1% depicts PAPR (dB) levels for conventional OFDM system, clipping, SLM, and SLM-clipping hybridized for N=32 sub-carriers as 10.10, 9.65, 8.10, and 7.25. Hence, it can be inferred that highest PAPR reduction is achieved, i.e., 7.25 (dB) from the proposed SLM-clipping algorithm which is the least PAPR among all.

Figure 3, at CCDF=.1% depicts PAPR (dB) levels for conventional OFDM system, clipping, SLM and SLM-clipping hybridized for N=64 sub-carriers as 10.15, 9.71, 8.20, and 7.50. Hence proposed SLM-Clipping algorithm is highly efficient in reducing PAPR as compared with other algorithms.

Figure 4, at CCDF=.1% depicts PAPR (dB) levels for conventional OFDM system, clipping, SLM and SLM-clipping hybridized for N=128 sub-carriers as 10.40, 9.80, 8.80, and 8.05. With the increase in the number of sub-carriers PAPR problem increases but proposed algorithm is best again for PAPR reduction.

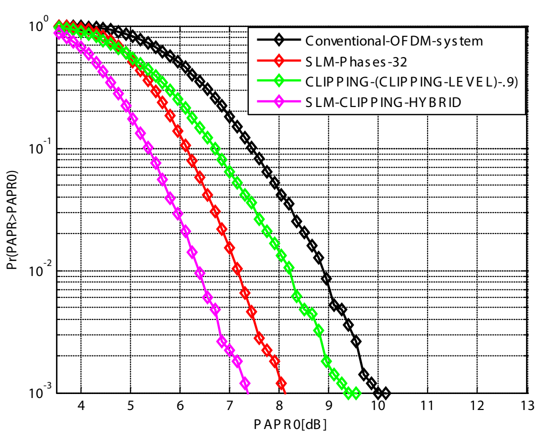

Figure 2. Comparison of conventional OFDM system, SLM, clipping and SLM-clipping hybrid for N=32.

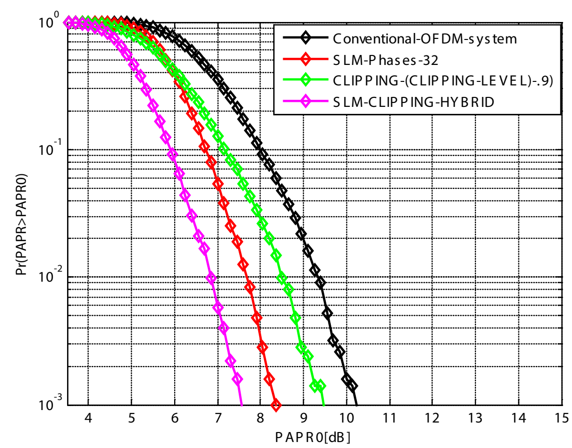

Figure 3. Comparison of conventional OFDM system, SLM, clipping and SLM-clipping hybrid for N=64.

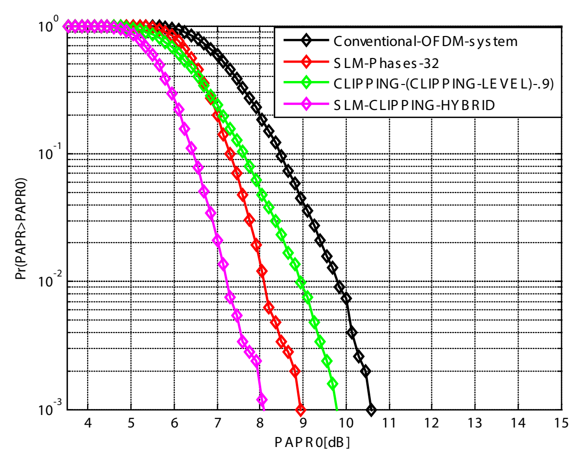

Figure 4. Comparison of conventional OFDM system, SLM, clipping and SLM-clipping hybrid for N=128.

Figure 5, at CCDF=.1% depicts PAPR (dB) levels for conventional OFDM system, clipping, SLM and SLM-clipping hybridized for N=256 sub-carriers as 10.45, 9.90, 9.10, and 8.40. So, in this case, PAPR (dB) is reduced up to 8.40 (dB) which is best among all. Hence, the proposed scheme suits this platform as well.

Figure 6, at CCDF=.1% depicts PAPR (dB) levels for conventional OFDM system, clipping, SLM and SLM-clipping hybridized for N=512 sub-carriers as 11.10, 10.20, 9.20, and 8.50. Hence, remarkable PAPR (dB) reduction of 8.50 dB is achieved by the proposed scheme.

Figure 7, at CCDF=.1% depicts PAPR (dB) levels for conventional OFDM system, clipping, SLM and SLM-clipping hybridized for N=1024 sub-carriers as 11.50,

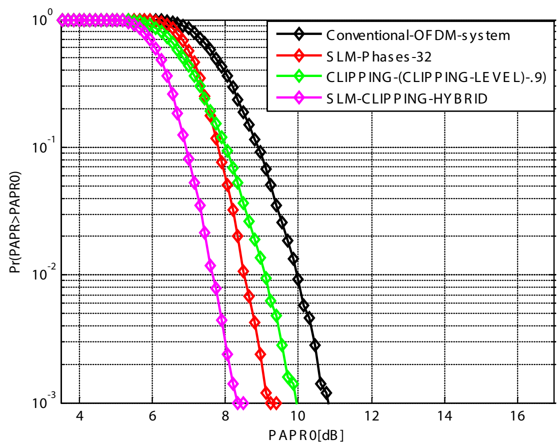

Figure 5. Comparison of conventional OFDM system, SLM, clipping and SLM-clipping hybrid for N=256.

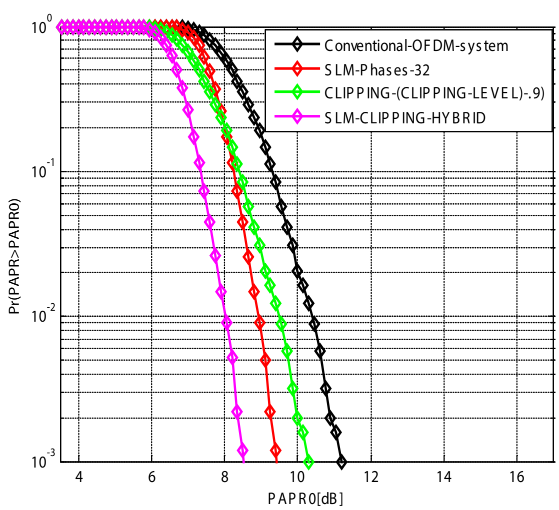

Figure 6. Comparison of conventional OFDM system, SLM, clipping and SLM-clipping hybrid for N=512.

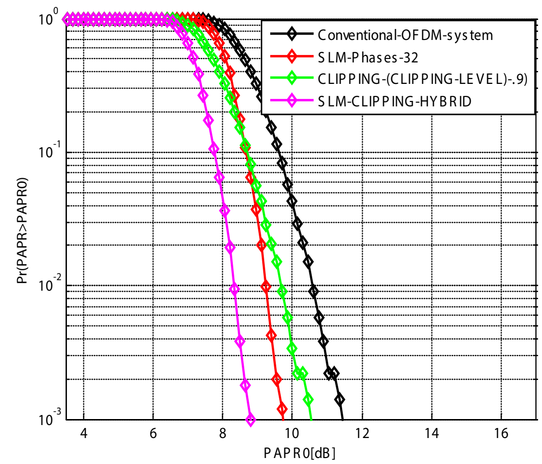

Figure 7. Comparison of conventional OFDM system, SLM, clipping and SLM-clipping hybrid for N=1024.

Table 1. Comparison of several algorithms with respect to PAPR reduction in decibels under various sub-carriers

Sr. No.	No. of Sub-carriers	Conventional OFDM system	Clipping	SLM	SLM and Clipping
1	32	10.10	9.65	8.10	7.25
2	64	10.15	9.71	8.20	7.50
3	128	10.40	9.80	8.80	8.05
4	256	10.45	9.90	9.10	8.40
5	512	11.10	10.20	9.20	8.50
6	1024	11.50	10.50	9.60	8.80

10.50, 9.60, and 8.80. So after analyzing PAPR (dB) with 1024 sub-carriers, it has been found that what so ever be the sub-carrier value remarkable PAPR reduction is achieved by proposed Hadamard based SLM hybridized with clipping technique (Table 1).

5. Conclusion

This paper proposed Hadamard based SLM hybridized with clipping technique for the reduction of PAPR problem of OFDM system. Simulation results presentedthrough CCDF curve for different sub-carriers like 32, 64, 128, 256, 512, and 1024 clearly depict that the proposed technique work well under each sub-carrier. Although PAPR reduction is there with each of the already existing techniques but efficient PAPR reduction is achieved through proposed technique. Since the proposed algorithm is excellent in performance and requires very-less side information, so futuristic goal can be of complete reduction of side information as well.

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