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Performance Improvement of Orthogonal Frequency Division Multiplexing System by Reducing Peak to Average Power Ratio using FDCSS (Frequency Domain Cyclic Shift Sequence) Combined with SLM and Clipping Technique

Prabal Gupta[1*], R. K. Singh[2], Maniraguha Fidele[1], Balpreet Singh[1] and B. Arun Kumar[1]

[1]School of ECE Lovely Professional University, Jalandhar-Delhi, G.T. Road, National Highway 1, Phagwara, Jalandhar – 144411, Punjab, India; prabal.gupta9@gmail.com, manifils@gmail.com, balpreet.15731@lpu.co.in, arun.16518@lpu.co.in

[2]Department of ECE, Guru Nanak Dev Engineering College, Gill Park, Ludhiana - 141006, Punjab, India; rajivinbhu@gmail.com

Abstract

Orthogonal frequency division multiplexing (OFDM) undergoes a problem known as peak to average power ratio (PAPR). Selected mapping (SLM) and clipping are the efficient techniques to diminish the PAPR. Hence, in this paper, a frequency domain cyclic shift sequence (FDCSS) based scheme combined with SLM and clipping technique is proposed for the reduction of PAPR. Careful selection of the shifting values, clipping level, and phase sequence reduces PAPR and improves the performance OFDM system. The results of this novel scheme are validated through Matlab simulations under various phase sequences, sub-carriers and shifting values.

Keywords: FDCSS (Frequency Domain Cyclic Shift Sequence), Orthogonal Frequency Division Multiplexing (OFDM), Peak to Average power Ratio (PAPR)

1. Introduction

Orthogonal frequency division multiplexing technique (OFDM) is the most promising and efficient multiplexing technique which helps in attaining high data rate due to a specific characteristic known as orthogonality among sub-carriers[1]. Due to this, it has been adopted by several communication system such as wireless local area network (WLAN), digital audio broadcasting (DAB), digital video broadcasting (DVB), etc. Besides all these advantages, OFDM has the predominant PAPR problem which degrades system performance. Hence, it is highly desirable that PAPR should be diminished by applying efficient algorithm.

A cyclic shifted scheme (CSS) presented by Kee-Hoon Kim[2] which improves OFDM system performance by reducing its PAPR by cyclically shifting OFDM signals and by adding partial cyclic shifted sequence and finally selecting the sequence which generates minimum PAPR.

Recently a technique has been proposed by Woo. Jun-Young et. al.[3] in which class-III SLM scheme was presented in which only one inverse fast Fourier transform (IFFT) was being used for the generation of time domain OFDM signal and it was emphasized to randomly select cyclic shifting values. Hill. G. et.al.[4,5] depicts cyclic shift and time inversion for partial transmitted sequence (PTS) OFDM signal for the reduction of PAPR.

Coding technique[6,7] is also used for the reduction of PAPR but its large look-up table requires huge amount of memory. Another important distortion-less technique is called as partial transmitted sequence (PTS)[8]. In this technique, frequency domain sequence is divided into

* Author for correspondence

several partial sequences after time domain conversion using inverse fast Fourier transform (IFFT). These sequences are then added and hence sequence which generates minimum PAPR is selected for transmission. Also, selected mapping (SLM)[9-14] is the most important distortion-less technique for the PAPR reduction which uses various phase sequences in frequency domain where elementary multiplication of these phase sequences take place with data sequence and after that time domain transformation takes place through inverse fast Fourier transform and finally, the sequence which generate minimum PAPR is selected for the transmission. Clipping[15,16] technique is used for the reduction of PAPR; it clips the sequence which generates very high instantaneous power by making use of a certain clipping level threshold. Henceforth, in this paper, a technique is being proposed which uses frequency domain cyclic shift sequence (FDCSS) selected mapping (SLM) combined with clipping techniques under multiple phase sequences, clipping level and right circular shift. This paper is organized as follows: Section-I represents introduction about OFDM, its application and problems associated with it; Section-II presents mathematical equations associated to OFDM, complementary cumulative distribution function (CCDF) and PAPR; Section-III presents proposed work, i.e., FDCSS combined with SLM and clipping technique along with its block diagram shown in Figure 4; Section-IV shows parameters, various simulations for validating output of proposed work; Section-V represents conclusion.

2. OFDM, PAPR and CCDF

In OFDM, frequency domain sequence[6] X(k) passed through inverse fast Fourier transform (IFFT) gets converted into its corresponding time domain sequence x(n) as,

$$x(n) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X(k) e^{\frac{j(2\Pi n k)}{N}} \quad n \in [0, N-1] \tag{1}$$

where N, n and k are Number of sub-carriers, time and frequency indices, respectively .

In OFDM system, all the sub-carriers are orthogonal to each other and this orthogonality among sub-carriers is created by the above mentioned IFFT equation (1).

Peak to average power ratio is explained as the ratio of peak power to that of average power of time domain signal generated by IFFT and is represented as follows[6],

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

Above depicted equation is applicable after generation of time domain signal from equation (1) in order to calculate PAPR from equation (2) so that appropriate measure should be taken in order to diminish this problem.

Complementary cumulative distribution function (CCDF) is explained as the probability that the PAPR of time domain sequence is found to be larger than specific threshold as[6],

$$\mathbf{CCDF(PAPR(x[n])) = Pr(PAPR(x[n] > PAPR0))} \tag{3}$$

where Pr= Probability and PAPR0 is specified threshold.

After calculating PAPR of time domain OFDM signal by equation (2) it is mandatory to statistically analyze the time domain conventional OFDM signal or proposed algorithm based OFDM system in order to clarify and compare the efficiency of conventional OFDM system and proposed algorithm based OFDM system.

3. Proposed FDCSS Combined with SLM and Clipping Technique

Proposed scheme is detailed as under:

- Information in frequency domain is defined as follows, $\mathbf{X = [X(0), X(1), X(2) \ldots\ldots\ldots X(N-1)]}$ which is generated from source and passed through 8-PSK modulator and the modulated data is represented as $\mathbf{X_m}$ where **N** is the number of sub-carriers used is depicted as,

$$\mathbf{X_m = [X_m(0), X_m(1), X_m(2) \ldots X_m(N-1)]} \tag{4}$$

- Modulated data $\mathbf{X_m}$ passed through FDCSS block and circular right shifting block leads to the generation of **q** different circular right shifted data rows represented as $\mathbf{X^s}$.

$$\mathbf{X^s} = \begin{bmatrix} \mathbf{X^1(0), X^1(1), X^1(2) \ldots\ldots\ldots\ldots X^1(N-1)} \\ \mathbf{X^2(0), X^2(1), X^2(2) \ldots\ldots\ldots\ldots X^2(N-1)} \\ \mathbf{X^3(0), X^3(1), X^3(2) \ldots\ldots\ldots\ldots X^3(N-1)} \\ \ldots\ldots \quad , \ldots\ldots \quad , \ldots\ldots\ldots, \quad \ldots\ldots\ldots\ldots \quad , \ldots\ldots\ldots \\ \mathbf{X^q(0), X^q(1), X^q(2) \ldots\ldots\ldots\ldots X^q(N-1)} \end{bmatrix} \tag{5}$$

where $1 < s \leq q$.

- Phase sequence defined below is used for optimization, $\mathbf{P^v = [P^v(0,)P^v(1), P^v(2), P^v(3) .... P^v(N-1)]}$ ∈{-1, +1, -j, +j} (where $1 \leq v \leq U$) is used for elementary multiplication in frequency domain with data sequence generated through FDCSS block results,

$$\mathbf{X^v = [X^s(0) * P^v(0), ...X^s(N-1) * P^v(N-1)]} \tag{6}$$

Now considering v=1 and s=1 to 5 which results in,

$$\mathbf{X^1} = \begin{bmatrix} \mathbf{X^1(0) * P^1(0), ...X^1(N-1) * P^1(N-1)} \\ \mathbf{X^2(0) * P^1(0), ...X^2(N-1) * P^1(N-1)} \\ \mathbf{X^3(0) * P^1(0), ...X^3(N-1) * P^1(N-1)} \\ \mathbf{X^4(0) * P^1(0), ...X^4(N-1) * P^1(N-1)} \\ \mathbf{X^5(0) * P^1(0), ...X^5(N-1) * P^1(N-1)} \end{bmatrix} \tag{7}$$

- After defining frequency domain sequence and applying IFFT equation (1) to generate time domain signal henceforth, PAPR for the above time domain generated sequence represented by x^v is calculated by equation (2) and minimum PAPR sequence after U times repetition is stored which is shown as,

$$\mathbf{x = [x^1, x^2, x^3, x^4, ...x^q]} \tag{8}$$

where $1 < s \leq q$

- If time domain sequence generates very high PAPR values, clipping is applied using specific threshold as,

$$x_{clip}(n) = \begin{Bmatrix} B\ ; \ |x(n)| > B \\ X(n);\ |x(n)| \leq B \end{Bmatrix} \tag{9}$$

where $x(n)$=time domain signal, **B**=Clipping level, $x_{clip}(n)$=clipped signal

- Finally, all the FDCSS sequence from **1 to q** are stored, and ultimately the sequence which generates minimum PAPR is selected for the transmission from the transmitter side.

$$\mathbf{x = \min[x_{clip}{}^1, x_{clip}{}^2, x_{clip}{}^3, x_{clip}{}^4, ...x_{clip}{}^q]} \tag{10}$$

4. Simulations, Results and Discussion

Simulations generated from Matlab have been used for the proposed frequency domain cyclic shift sequence (FDCSS) based selected mapping (SLM) combined with clipping technique where sub-carriers N=32, 64, and 128; phase sequences=6, and 11; clipping threshold=0.85; digital modulation technique=8-PSK, up-sampling=4, OFDM blocks=5000, circular right shift= 20 has been used.

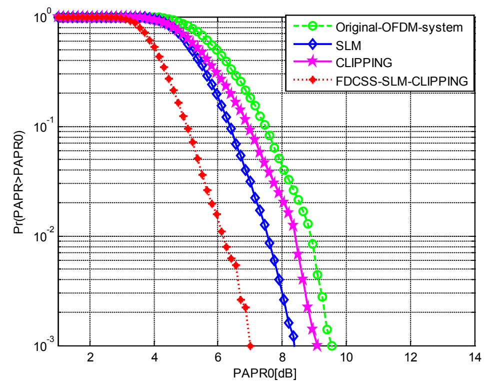

Figure 1. Comparative analysis of original OFDM system, SLM, clipping, and FDCSS-SLM-clipping under N=32, phase sequence=6, circular shift= 20, and clipping level=0.85.

In Figure 1, simulation results at CCDF=10^{-3} shows PAPR(dB) levels for Original OFDM system, SLM, clipping and FDCSS-SLM-clipping at N=32, number of phase sequence=6, clipping level=0.85 and right circular shift=20 are 9.55, 8.35, 9.1 and 7 respectively. Therefore, it can be concluded that maximum PAPR reduction is achieved by the proposed work FDCSS-SLM-clipping.

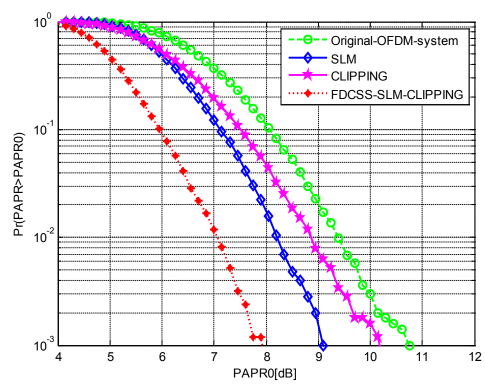

Figure 2. Comparative analysis of original OFDM system, SLM, clipping and FDCSS-SLM-clipping under N=64, phase sequence=6, circular shift= 20, and clipping level=0.85.

In Figure 2, simulation results at CCDF=.001 shows PAPR (dB) levels for original OFDM system, SLM, clipping, and FDCSS-SLM-clipping at N=64, number of phase sequence=6, clipping level=0.85 and right circular shift=20 are 10.75, 9.10, 10.15, and 7.9 respectively. Therefore, it can be concluded that maximum PAPR reduction is achieved by the proposed work FDCSS-SLM-clipping.

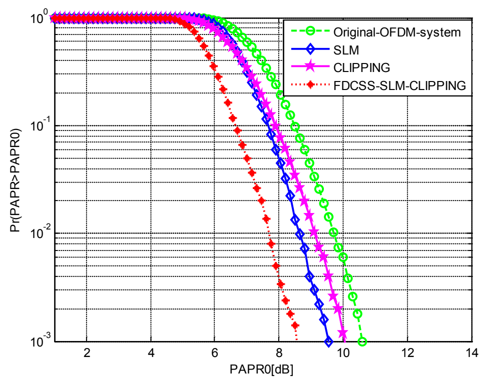

Figure 3. Comparative analysis of original OFDM system, SLM, clipping and FDCSS-SLM-clipping under N=128, phase sequence=6, circular shift=20, and clipping level=0.85.

In Figure 3, simulation results at CCDF=.001 shows PAPR (dB) levels for original OFDM system, SLM, clipping and FDCSS-SLM-clipping at N=128, number of phase sequence=6, clipping level=0.85 and right circular shift=20 are 10.60, 9.55, 10.0, and 8.5 respectively. Therefore, it can be concluded that maximum PAPR reduction is achieved by the proposed work FDCSS-SLM-clipping.

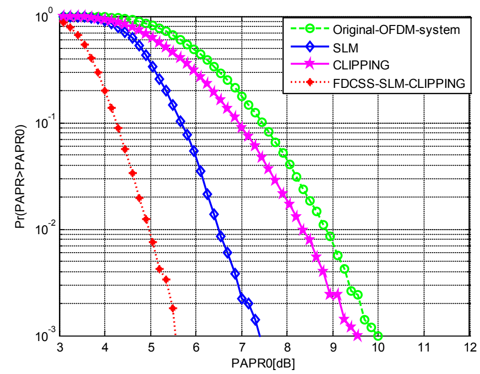

Figure 5. Comparative analysis of original OFDM system, SLM, clipping and FDCSS-SLM-clipping under N=32, phase sequence=11, circular shift= 20, and clipping level=0.85.

In Figure 5, simulation results at CCDF=.001 shows PAPR (dB) levels for original OFDM system, SLM, clipping, and FDCSS-SLM-clipping at N=32, number of phase sequence=11, clipping level=0.85 and right circular shift=20 are 10, 7.3, 9.55, and 5.6 respectively. Therefore, it can be concluded that maximum PAPR reduction is achieved by the proposed work FDCSS-SLM-clipping.

In Figure 6, simulation results at CCDF=.001 shows PAPR (dB) levels for original OFDM system, SLM, clipping and FDCSS-SLM-clipping at N=64, number of phase sequence=11, clipping level=0.85and right circular shift=20 are 10.15, 8.05, 9.7 and 6.55 respectively. Therefore, it can be concluded that maximum PAPR

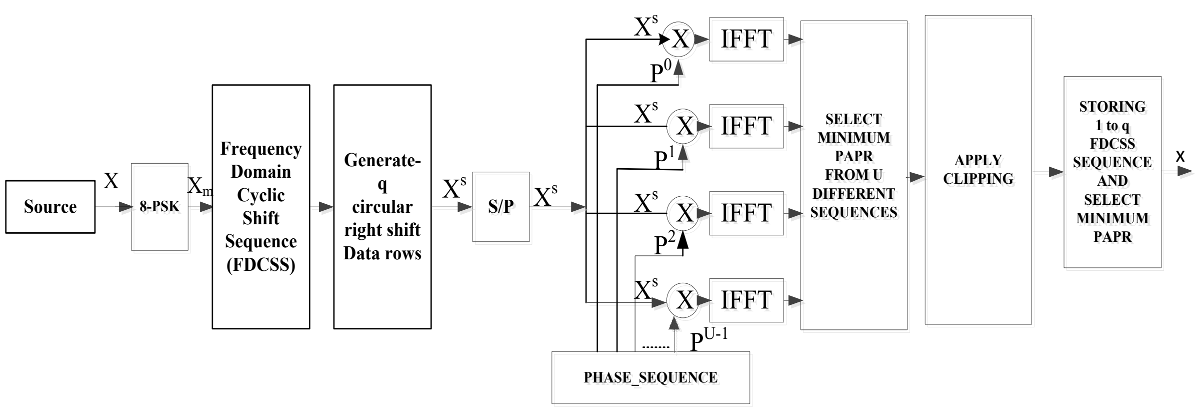

Figure 4. Block diagram of proposed frequency domain cyclic shift sequence (FDCSS) combined with selected mapping (SLM) and clipping techniques.

reduction is achieved by the proposed work FDCSS-SLM-clipping.

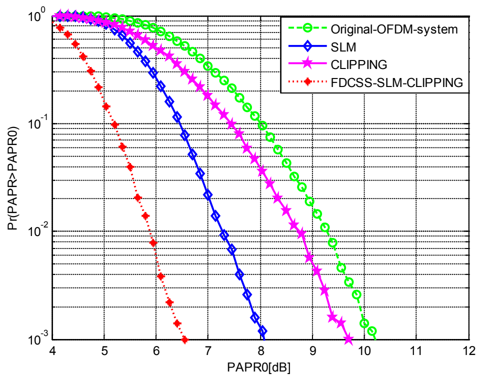

Figure 6. Comparative analysis of original OFDM system, SLM, clipping and FDCSS-SLM-clipping under N=64, phase sequence=11, circular shift=20, and clipping level=0.85.

In Figure 7, simulation results at CCDF=.001 shows PAPR (dB) levels for original OFDM system, SLM, clipping and FDCSS-SLM-clipping at N=128, number of phase sequence=11, clipping level=0.85 and right circular shift=20 are 11.05, 8.25, 10.45 and 7.01 respectively. Therefore, it can be concluded that maximum PAPR reduction is achieved by the proposed work FDCSS-SLM-clipping.

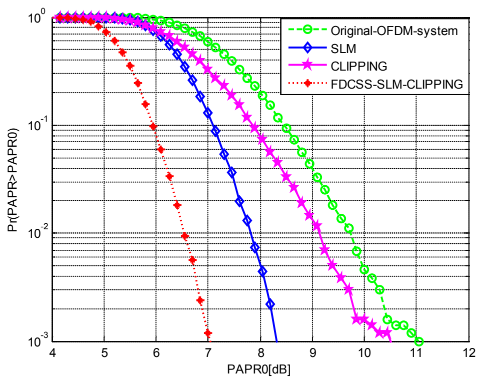

Figure 7. Comparative analysis of original OFDM system, SLM, clipping and FDCSS-SLM-clipping under N=128, phase sequence=11, circular shift=20, and clipping level=0.85.

5. Conclusion

Frequency domain cyclic shift sequence (FDCSS) based selected mapping (SLM) combined with clipping technique for diminishing PAPR of OFDM is proposed in this paper. Total number of phases 6 and 11 under 32, 64, and 128 sub-carriers with 20 right circular shifts has been used. Each simulation result clearly depicts the remarkable performance of proposed algorithm. Significant gain is achieved in all the above mentioned cases shown by corresponding CCDF simulation results. Thus, proposed algorithm is much more significant in reducing PAPR as compared with original OFDM, SLM, and clipping.

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7. References

1. Tao Jiang, Yiyan Wu. An overview Peak-to-Average Power Ratio Reduction Techniques for OFDM Signals, Broadcasting. IEEE Trans, 2008 June; 54:257-68.
2. Kee-Hoon Kim. On the Shift value Set of Cyclic Shifted Sequence for PAPR Reduction in OFDM Systems. IEEE Transactions on Broadcasting. 2016; 62:496-500.
3. Woo Jun-Young, Joo Hyun Seung, Kim Kee-Hoon, No Jong-Seon, Shin Dong-Joon. PAPR Analysis of Class-III SLM Scheme Based on Variance of Correlation of Alternative OFDM Signal Sequences. IEEE Communication Letters. 2015; 19:989-92.
4. Hill G, Faulkner M, Singh J. Cyclic shifting and time inversion of partial transmit sequence to reduce the peak to average power ratio in OFDM. 2000; 2:1256-59.
5. Hill G, Faulkner M, Singh. Reducing the peak to average power ratio in OFDM by cyclically shifting partial transmitted sequence. 2000; 36:561-61.
6. Gupta P, Kumar BA, Jain SK. Peak to average power ratio reduction in OFDM using higher order partitioned PTS sequence and Bose Chaudhuri Hocquenghem Codes. Proc. IEEE Conf. SPACES-2015. 2015 Jan; p. 443-47.
7. Li L, Qu D, Jiang T. Partition Optimization in LDPC-Coded OFDM Systems With PTS PAPR Reduction. Vehicular Technology, IEEE Trans. 2014 Oct; p. 4108-13.
8. Gupta P, Kumar, Arun Kumar B, Jain SK, Singh B. An Improved and Efficient PAPR Reduction Method in OFDM System Using Modified Partial Transmitted Sequence. Proc. Conf. EBAS-2014. 2014 Nov; p. 261-64.
9. Lingyin Wang, Ju Liu. Partial phase weighting selected mapping scheme for peak-to-average power ratio reduction in orthogonal frequency division multiplexing system. IET Communications. 2015 Jan; 9(2):147-55.
10. Bauml RW, Fischer RFH and Huber JB. Reducing the peak to average power ratio of multicarrier modulation by selected mapping. Electron. Lett. 1996 Oct; 32:2056–57.

11. Le Goff SY, Kien Khoo Boon, Tsimenidis CC and Sharif BS. A novel selected mapping technique for PAPR reduction in OFDM systems. IEEE Trans. Comm. 2008 Nov; 56(11):1775-79.
12. Peng Cheng, Xiao Yue, Dan Lilin and Li Shaoqian. Improved SLM for PAPR reduction in OFDM System. Proc. Conf. IEEE PIMRC-2007. 2007 Sept; p. 1-5.
13. Jizeng Wang, Luo Jingyu and Zhang Yanlong. A new phase sequence for SLM in MC-CDMA system. Proc. Conf. IEEE WiCom-2007. 2007 Sept; p. 938-41.
14. Peng Cheng, Yue Xiao, Lilin Dan, Shaoqian Li. Optimized phase sequence set for SLM-OFDM Communications. Proc. Conf. ICCCAS. 2007 July 11-13; p. 284-87.
15. Deepa T, Swetha K, Kumar R. A joint clipping and logarithmic based companding for the reduction of peak-to-average power ratio in OFDM system. Proc. IEEE Conf. ICICES-2013. 2013 Feb; p. 655-59.
16. Sharma C, Sharma PK, Tomar SK, Gupta AK. A modified Iterative Amplitude clipping and filtering technique for PAPR reduction in OFDM systems. Proc. Conf. ET-NCC-2011. 2011 April; p. 365-68.