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PAPR PERFORMANCE ANALYSIS FOR COMBINATION OF SELECTIVE MAPPING (SLM) AND EXPONENTIAL COMPANDING TECHNIQUE

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ABSTRACT
OFDM is a multicarrier transmission scheme that increase data transmission rate. However, OFDM has high PAPR problem which can cause signal distortion. A PAPR reduction scheme known as SLM-Exp was introduce in this paper to overcome high PAPR problem of OFDM. To evaluate the PAPR performance of SLM-Exp, SLM-Exp scheme along with SLM-Mu and Exponential were simulated in MATLAB for PAPR value at 1×10^{-3} of CCDF plot. PAPR performance of SLM-Exp was compare with SLM-Mu, and Exponential scheme as number of subcarrier, phase sequence and modulation scheme varied. The number of subcarrier concern in this project were 64, 128, 256, and 512. Number of phase sequence concern in this project were 8, 16 and 32. For modulation scheme, QPSK, 16 QAM, and 64 QAM were concern in this project. The result shows that PAPR value of SLM-Exp at 1×10^{-3} of CCDF plot was better than SLM-Mu by 0.53dB to 2.31dB and 0.10dB to 0.61dB for Exponential scheme as number of subcarrier varied. Result also shows that PAPR performance of SLM-Exp is better than SLM-Mu by 0.99dB to 1.63dB as number of phase sequence varied.

INDEX TERMS—SLM-Exp, SLM-Mu, Exponential companding, Mu law, SLM, PAPR reduction.

INTRODUCTION
OFDM is multicarrier transmission scheme used for both wireless and wired communication. In OFDM, the spectrum bandwidth is subdivided into carriers. Then, carriers are modulated with data and multiplex orthogonally. Since these carriers are orthogonal to each other, the carrier spectrum is null at the central frequency of another carrier. Hence, there is no interference between carriers and they can space close together. The advantage of using OFDM scheme are high spectral efficiency, multipath fading and co-channel interference resistance [1] [3].

Despite the advantages, there are some drawback in OFDM scheme. The first drawback of OFDM signal is high PAPR which cause signal distortion [1]. PAPR is the ratio of maximum power to the average power of the OFDM sample within the transmit symbol. An example of high PAPR is N times the average power occur when N signal which all has the same phase are added together. The high PAPR is sensitive to nonlinear amplifier and can cause signal distortion as amplifier operate in nonlinear region during high PAPR. The signal distortion further cause intermodulation and out of band radiation problem [4].

To overcome high PAPR problem, two categories of PAPR reduction technique has been introduced. The first category is signal distortion technique and the second category is data scrambling technique [2]. The examples of signal distortion technique are clipping and filtering (CF), peak cancelation, peak windowing, and commanding. Its disadvantage is BER degradation. For data scrambling technique, the examples are Selective Mapping (SLM), and Partial Transmit Sequence (PTS). Unlike signal distortion technique, data scrambling technique does not cause BER degradation, instead system complexity increases as iteration number and subcarriers of the system increase [2]. In [2] [5], both the signal distortion technique and data scrambling technique were combined to reduce PAPR.

The PAPR is the ratio of sample peak power to the sample average power in time domain. Hence, PAPR can be reduce if the peak power decrease or average power increase. In exponential companding, the PAPR is reduced by compress sample peak power [13]. In Mu law companding, the PAPR is reduced by increase the average power of the sample [10]. While in SLM, the PAPR is reduced by phase rotation which reduce peak power of the sample [11]. In [5], a combination scheme of SLM and Mu law is introduced and result shown that combination scheme has better PAPR performance than single scheme alone. However, Exponential scheme is not use in [5]. Since Exponential has better PAPR performance than Mu law [12], SLM-Exp has better PAPR performance than combination scheme of SLM-Mu, or SLM, Mu law, or Exponential scheme alone. In this project, combination scheme of SLM-Exp is propose. MATLAB 2016A is use to simulate the SLM-Exp scheme and only concern transmitter part. Thus, only PAPR performance is evaluate. The PAPR performance of the schemes is analyze using MATLAB, by plotting CCDF of PAPR with different parameters. The parameters are types of modulation scheme, number of subcarrier, and number of phases in SLM.

The section 2 of this paper discuss the background and related works of the scheme, while section 3 discuss the methodology of this project. Section 4 discuss the results obtained and section 5 is the conclusion.

BACKGROUND AND RELATED WORK

PAPR

PAPR is the ratio of maximum power to the average power of the sample in time domain. Its formula was given in equation 2.1 [4].

$$PAPR = \frac{\max\ |x(t)|^2}{E[|x(t)|^2]} \qquad (1)$$

A large PAPR can occur when subcarrier of OFDM signal add up coherently. For example, N signal which has the same phase, when added together produce peak power which was N times the average power of the signal. The high PAPR cause signal distortion as the amplifier force to work in nonlinear region [4]. One of the method to evaluate PAPR was by Complementary Cumulative Distributive Function. The CCDF was a plot of probability of maximum PAPR exceed the threshold value T. Its formula was given in Eq. 2 [6].

$$CCDF(T) = P(Max\ PAPR > T) \qquad (2)$$

To construct a CCDF plot, 1000 samples of PAPR are compute so that probability can be calculate from the samples.

PAPR Reduction Schemes

1) Selective Mapping (SLM)

In SLM, original input data in frequency domain with N size, for example D$\{D_0, D_1, D_2, \dots, D_{N-1}\}$is multiply with a set of independent phase sequence with M as number of phase sequence, for example P { $P_0, P_1, P_2, \dots, P_{M-1}$ }. The first phase sequence has zero phase to keep the original signal as one of the phase sequence. After input data is multiply with each phase in the phase sequence, it produces M number of alternative data sequence. Each alternative data sequence is shift by phases in phase sequence. Then, IFFT is apply to transform each alternative data sequence in frequency domain to time domain. The PAPR among these alternative data sequence is calculated and sequence with lowest PAPR is select to transmit [6] [7]. In SLM scheme, PAPR reduction is achieve by phase rotation of input data in frequency domain which reduce the chance of data with same phase [11]. In [6] [7], the PAPR reduction performance decrease as the number of subcarrier increase. In [6], the PAPR reduction performance improve as number of phase sequence increase.

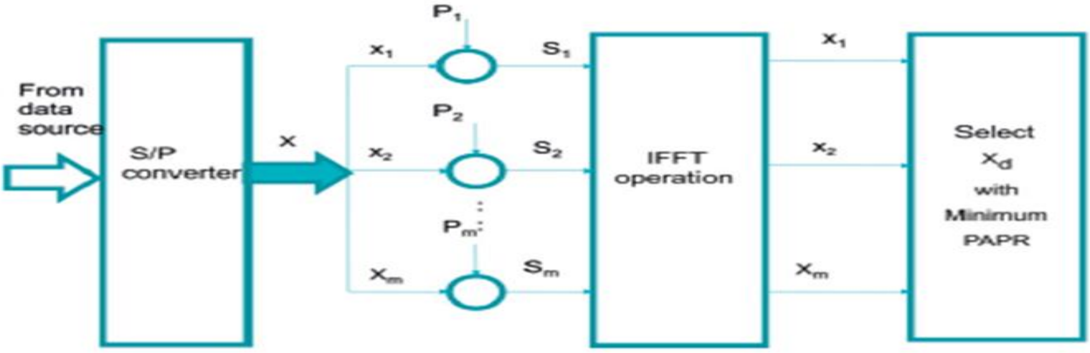

Figure 1. Block diagram of Selective Mapping [6]

2) Mu law

The formula for Mu law is shown in Eq. 3 [9]. The x_{max} is maximum amplitude of the input, µ is the Mu law constant where standard value is 255, $sgn(x)$ was the sign function of the input x [10]. Mu law reduce PAPR by increase average power of the signal [9].

$$Output(x) = x_{max}\frac{\log\left(1+\frac{\mu|x|}{x_{max}}\right)}{\log(1+\mu)}sgn(x)\ ;0 \le |x| < x_{max} \qquad (3)$$

3) Exponential Companding

The characteristic of exponential companding are peak signal compression and small signal expansion while maintain average power. This create uniform signal distribution without increase the average power of the signal like Mu law and A law [12] [13]. The formula for exponential companding is shown in Eq. 4 [14].

$$output(x) = sgn(x)\sqrt[d]{\alpha\left[1 - exp\left(-\frac{x^2}{\sigma^2}\right)\right]}$$

$$\alpha = \left[\frac{E[|s_n|^2]}{E\left[\sqrt[d]{\left[1 - \exp\left(-\frac{|s_n|^2}{\sigma^2}\right)\right]^2}\right]}\right]^{\frac{d}{2}} \qquad (4)$$

4) Combination of SLM and Mu law

In [5], a combination scheme of modified Selective Mapping (MSLM) and Mu law is proposed. Modified SLM (MSLM) reduce the number of IFFT require to perform which in turn reduce computational complexity [7]. In [5], coding technique is applied before the MSLM to improve BER performance. The parameter involve in this scheme are QPSK, DOPSK and 8 QAM modulation, 64 subcarriers, and 900 symbols. The block diagram of the combination scheme is shown in figure 2 where it is cascade of Modified Selective Mapping (MSLM) and Mu law technique. Although combination of SLM and Mu law is not shown directly in this paper, the combination of SLM and Mu law scheme is build and compare to the combination of MSLM and Mu law scheme for its PAPR performance. The result of this paper show that the combination scheme is better than Modified Selective Mapping (MSLM) and Mu law alone.

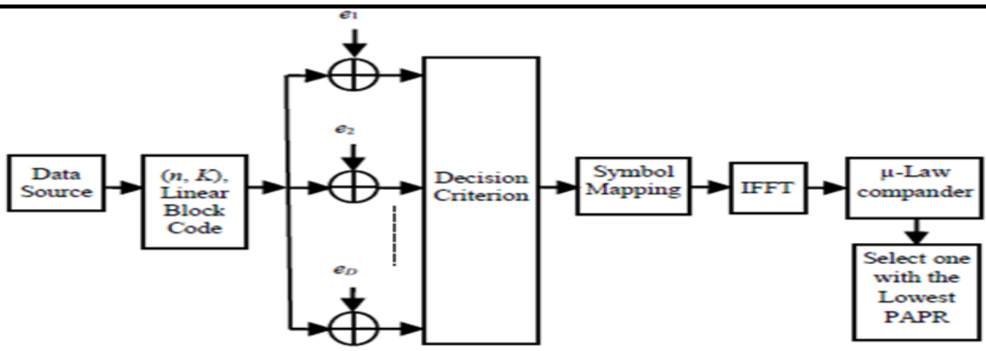

Figure 2. Block diagram of combination scheme [5]

The formula for Mu law is shown in Eq. 3 [9]. The x_{max} is maximum amplitude of the input, µ is the Mu law constant where standard value is 255, $sgn(x)$ was the sign function of the input x [10]. Mu law reduce PAPR by increase average power of the signal [9].

$$Output(x) = x_{max} \frac{\log\left(1+\frac{\mu|x|}{x_{max}}\right)}{\log(1+\mu)} sgn(x) \ ; 0 \leq |x| < x_{max} \qquad (3)$$

METHODOLOGY

There are 2 objectives in this project, to build SLM-Exp scheme and to evaluate PAPR performance of the SLM-Exp scheme. The SLM-Exp scheme is first build follow by CCDF plot to evaluate the performance of SLM-Exp scheme.

A. SLM-Exp scheme

For explanation purpose, the parameter is set to, 128 subcarriers, 16 phase sequences, 16 QAM modulation. Figure 3 show the block diagram of SLM-Exp scheme.

1) Data Source

There are 2 types of data generate at this block, data for transmission and phase sequence for SLM.

a) Data for transmission

The data values are generated randomly and are depend on type of modulation used. For example, QPSK data has random value range between 0 to 3, while 16 QAM data has random value range between 0 to 15. A total of 128 data are generated as system use 128 subcarriers.

b) Phase sequence for SLM

For phase sequence, phase 0, 90, 180 and 270 are randomly assign to phases in each phase sequence. Each phase sequence has 128 number of phases as there are 128 subcarriers.

2) QAM Modulation

The data are modulated according to types of data generated. QPSK data are modulated using QPSK modulator and 16 QAM data are modulated using 16 QAM modulator.

3) SLM

Modulated data are replicate 16 times as 16 phase sequences are used. Each replicated data is multiplied with its respective phase sequence to produce 16 alternate data sequences. Each alternate data sequence is convert to time domain via IFFT for PAPR calculation. Data sequence with lowest PAPR is then select to proceed for Exponential companding.

4) Exponential companding

Data sequence selected at SLM is undergo exponential companding operation in time domain.

5) PAPR

After exponential companding operation, PAPR of data sequence is calculated and recorded.

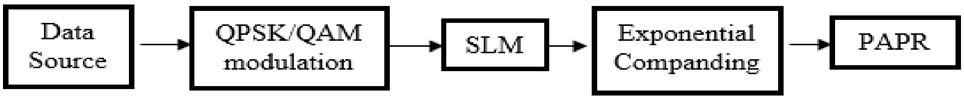

Figure 3. Block diagram of SLM-Exp scheme

B.Performance evaluation

To evaluate the performance of SLM-Exp scheme, CCDF of SLM-Exp and other scheme like SLM-Mu, Exponential, Mu law and SLM are computed and plotted on the same CCDF plot. Figure 4 show the flow chart of CCDF computation.

In order to compute CCDF plot, probability of PAPR greater than PAPR threshold is require to compute. Various schemes are simulated 1000 times to create data needed to compute the probability. From this probability, CCDF of PAPR for various scheme is plotted.

The process of CCDF computation is repeated with different parameter for performance evaluation of SLM-Exp under different parameter. The parameters involve in performance evaluation are types of modulation scheme, number of subcarrier, and number of phase sequence for SLM. Types of modulation scheme involve QPSK, 16 QAM, and 64 QAM. For number of subcarrier, there are 64, 128, 256, and 512 while for number of phase sequence, there are 8, 16 and 32.

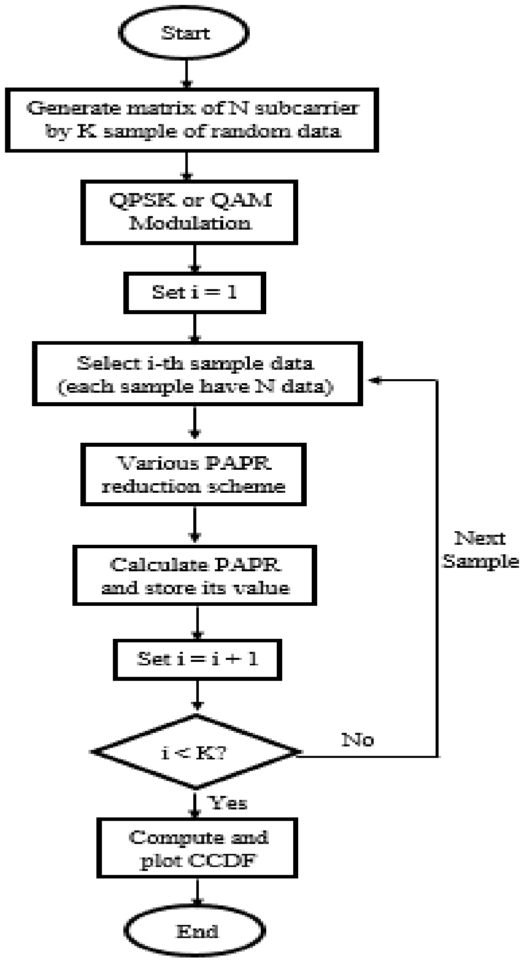

Figure 4. Flow chart of CCDF computation

RESULT AND DISCUSSION

A. Performance of SLM-Exp scheme

From figure 5, the CCDF plot shows that PAPR value of SLM-Exp scheme is 1.25 dB lesser than SLM-Mu scheme. This means that SLM-Exp perform better PAPR reduction than SLM-Mu scheme. This confirm the problem statement that Exponential companding which has better PAPR performance than Mu law can result in SLM-Exp better than SLM-Mu.

B.Performance of SLM-Exp scheme when number of subcarrier varied

The OFDM system use to obtain result in table I use 16 phase sequences for SLM. The parameter that varied are types of modulation, and number of subcarrier.

papr value in db obtained when number of subcarrier varied from 64, 128, 256, to 512.

Modulation	PAPR scheme	Number of subcarrier			
		64	128	256	512
QPSK	Exponential	3.83	3.54	2.90	2.56
	SLM-Mu	3.93	4.16	4.41	4.68
	SLM-Exp	3.22	2.97	2.65	2.48
16 QAM	Exponential	3.72	3.15	2.94	2.75
	SLM-Mu	3.92	4.19	4.38	4.67
	SLM-Exp	3.39	2.94	2.58	2.36
64 QAM	Exponential	3.88	3.43	3.09	2.66
	SLM-Mu	3.99	4.24	4.49	4.76
	SLM-Exp	3.32	2.86	2.56	2.56

From Table 1, PAPR performance of SLM-Exp is better than SLM-Mu by 0.53dB to 2.31dB as number of subcarrier increase from 64, 128, 256, to 512 for QPSK, 16 QAM and 64 QAM modulation. Table 1 also shows that PAPR performance of SLM-Exp was better than Exponential by 0.10dB to 0.61dB as number of subcarrier increase from 64, 128, 256, to 512 for QPSK, 16 QAM and 64 QAM modulation. The average different in PAPR value between SLM-Exp and Exponential scheme for 64, 128, 256, and 512 subcarriers are 0.50dB, 0.45dB, 0.38dB and 0.19dB respectively.

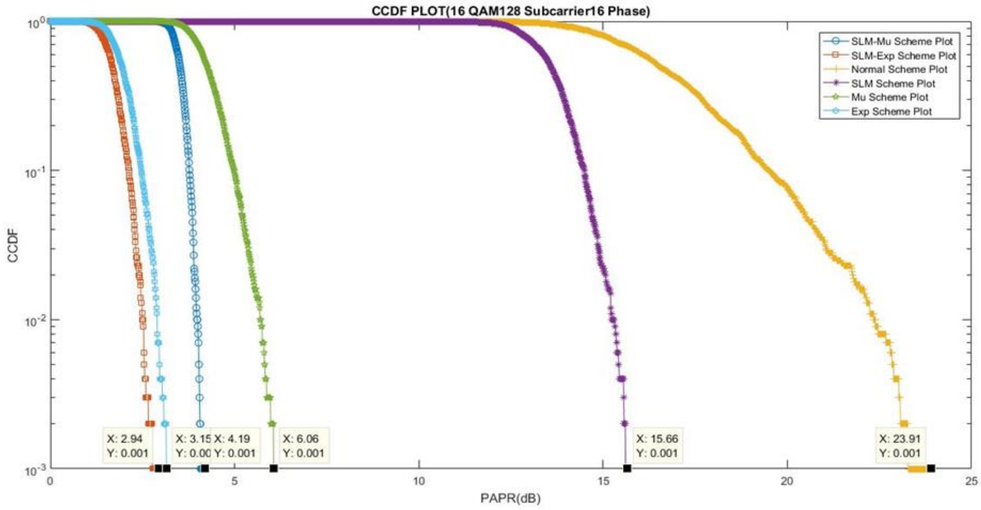

Figure 5. CCDF plot of various scheme with 16 QAM, 128 subcarriers, and 16 phase sequences

C. Performance of SLM-Exp scheme when number of phase sequence varied

The OFDM system use to obtain result in table II use 128 subcarrier. The parameter that varied are types of modulation, and number of phase sequence.

PAPR value in dB obtained when number of phase sequence varied from 8, 16, to 32.

Modulation	PAPR scheme	Number of phase sequence		
		8	16	32
QPSK	SLM	16.80	16.20	14.89
	SLM-Mu	4.39	4.21	4.13
	SLM-Exp	2.91	3.00	2.85
16 QAM	SLM	17.12	15.66	14.95
	SLM-Mu	4.44	4.19	3.93
	SLM-Exp	3.09	2.94	2.94
64 QAM	SLM	17.42	15.71	15.29
	SLM-Mu	4.54	4.24	4.04
	SLM-Exp	2.91	2.86	2.81

From Table 2, the PAPR value of SLM decrease as number of phase sequence increase. This means that PAPR performance of SLM increase with increase in number of phase sequence. However, the increase in PAPR performance of SLM as number of phase sequence increase has not much effect on both SLM-Exp and SLM-Mu scheme. PAPR performance of SLM-Exp was better than SLM-Mu by 0.99dB to 1.63dB as number of phase sequence increase from 8, 16, to 32, for QPSK, 16 QAM, to 64 QAM modulation.

CONCLUSION

A PAPR reduction scheme, SLM-Exp has been propose. The performance analysis shown that PAPR performance of SLM-Exp scheme was better than SLM-Mu scheme by 0.53dB to 2.31dB and 0.10dB to 0.61dB for Exponential scheme as number of subcarrier varied from 64, 128, 256, to 512 for QPSK, 16 QAM and 64 QAM modulation scheme. The performance analysis also shows that PAPR performance of SLM-Exp is better than SLM-Mu by 0.99dB to 1.63dB as number of phase sequence varied from 8, 16, to 32.

REFERENCES

1) C. Wu, Y. Lu, and G. Liu, “An improved clipping scheme based on TR for PAPR reduction in OFDM systems,” Proc. - 2012 IEEE 12th Int. Conf. Comput. Inf. Technol. CIT 2012, pp. 598–601, 2012.
2) G. S. Toor, H. Singh, and A. S. Bhandari, “PAPR reduction and BER improvement by using logrithmic companding hybrid with SLM technique in bit interleved COFDM system,” Proc. 5th Int. Conf. Conflu. 2014 Next Gener. Inf. Technol. Summit, vol. 2, no. 2, pp. 604–608, 2014.
3) J. Samuel, A. Emmanuel, I. Frank, N. Charles, and A. Bayonle, “Modeling of Orthogonal Frequency Division Multiplexing (OFDM) for Transmission in Broadband Wireless Communications,” J. Emerg. Trends Comput. Inf. Sci., vol. 3, no. 4, pp. 534–539, 2012.
4) A. Gangwar and M. Bhardwaj, “An Overview: Peak to Average Power Ratio in OFDM system & its Effect,” Int. J. Commun. Comput. Technol., vol. 1, no. 2, pp. 22–25, 2012.
5) B. K. Shiragapur and U. Wali, “Peak-To-Average Power Ratio Reduction Using Coding and Hybrid Techniques for Ofdm System,” ICTACT J. Commun. Technol., vol. 7, no. 1, pp. 1229–1234, 2016.
6) K. Mhatre and U. P. Khot, “Efficient Selective Mapping PAPR reduction technique,” Procedia Comput. Sci., vol. 45, no. C, pp. 620–627, 2015.
7) Y. Hassan and M. El-Tarhuni, “A comparison of SLM and PTS peak-to-average power ratio reduction schemes for OFDM systems,” IEEE, pp. 604–608, 2011.
8) P. P. Patil and V. . Malode, “BER with different modulation schemes in OFDM System,” Int. J. Adv. Res. Electron. Commun. Eng., vol. 3, no. 12, pp. 1906–1910, 2014.
9) H. Choubey and A. Kushwah, “Comparison of SLM technique of PAPR reduction in OFDM with Non-linear companding technique,” Int. J. Eng. Res. Appl., vol. 3, no. 4, pp. 821–826, 2013.
10) V. N. Sonawane and S. V. Khobragade, “Comparative Analysis between A- law & μ -law Companding Technique for PAPR Reduction in OFDM,” Int. J. Adv. Res. Comput. Commun. Eng., vol. 2, no. 5, pp. 2210–2214, 2013.
11) X. L. Zhao, S. M. R. Jones, and R. A. Abdul-Alhammed, “A FAIR COMPARISON PLATFORM FOR OFDM SYSTEMS WITH VARIOUS PAPR REDUCTION SCHEMES,” 5th Int. Conf. Commun. Comput. Appl., pp. 136–141, 2012.
12) A. N. Jadhav and M. V. Kutwal, “BER and PAPR Reduction Using Companding Algorithms in OFDM,” Int. J. Appl. or Innov. Eng. Manag., vol. 3, no. 1, pp. 188–192, 2014.
13) N. Dewangan and M. Singh, “Comparision of Exponential Companding Transform and CB-ACE Algorithm for PAPR Reduction in OFDM Signal,” Int. J. Sci. Res. Publ., vol. 2, no. 5, pp. 1–4, 2012.
14) T. Jiang, Y. Yang, and Y. H. Song, “Exponential companding technique for PAPR reduction in OFDM systems,” IEEE Trans. Broadcast., vol. 51, no. 2, pp. 244–248, 2005.