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Critical Analysis of PAPR Reduction for Better System Performance

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Abstract— **Man has an insatiable desire of having more and more. This applies to his needs in communication field as well. Better connectivity and high speed data is becoming the new trend. OFDM is the transmission technique having the potential to support this increasing demand. It is a spectrally efficient version of multicarrier modulation. But the high power peaks of OFDM signal leads to high PAPR. This high PAPR increases BER and degrades the system performance. In this paper, a critical review of various PAPR reduction techniques is given. In this paper, various techniques , for example, clipping-filtering, companding, selective mapping technique are used to reduce the PAPR of simple OFDM signal. A hybrid concept is proposed in which combination of SLM technique and clipping-filtering technique is used to reduce PAPR. The obtained results have shown a significant decrease in PAPR.**

Index Terms: **Cognitive Radio (CR), Orthogonal Frequency Division Multiplexing (OFDM), Peak to Average Power Ratio (PAPR), Partial Transmit Sequence (PTS), Selective Mapping (SLM)**

I. INTRODUCTION

With each passing day, higher speed data is becoming a common requirement. To supply high speed connectivity, better communication transmission techniques have been utilized. One of these advanced transmission techniques is OFDM, that is, Orthogonal frequency division multiplexing. Today, OFDM is used in many wireless applications, for example, WLAN standards, Wireless Metropolitan Area Networks (WMAN), Digital Video Broadcasting (DVB), 3GPP-LTE, Asymmetric Digital Subscriber Line (ADSL) etc. It is actually a multicarrier modulation technique having lower equalization complexity and better distortion mitigation capacity. OFDM is a transmission technique that divides the available spectrum into subcarriers, with each subcarrier containing a low rate data stream [1]. A large number of closely spaced orthogonal subcarriers are used to carry data. The main idea behind the OFDM is that since low-rate modulations are less sensitive to multipath, the better way is to send a number of low rate streams in parallel than sending one high rate waveform [2]. The orthogonality of the carriers means that each carrier has an integer number of cycles over a symbol period. Due to this integer number of cycles, the spectrum of each carrier has a null at the center frequency of each of the other carriers in the system that results in no

interference between the carriers, allowing them to be spaced as close as possible [3]. This overlapping of the subcarriers reduces the required bandwidth and increases the spectral efficiency. Thus, it can be said OFDM increases wireless capacity without increasing bandwidth [4].

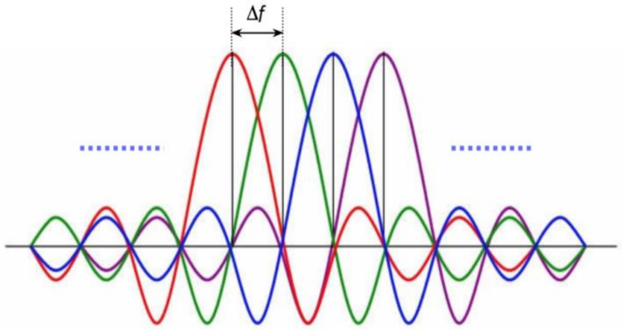

Figure1. Spectra of OFDM symbol

The literature is rich in the study of OFDM and its high PAPR. In [1], the authors have investigated many alternative modulation schemes which are actually variants of OFDM and have shown their potential to replace OFDM for radio systems. Considering their weak points, an improved FBMC/OQAM concept is proposed, which has proved to be able to maximize the benefits. In [2], the authors described CR systems and their requirements to have a flexible physical layer. The authors have investigated orthogonal frequency division multiplexing (OFDM) technique as a candidate transmission technology for CR. OFDM-based CR system block diagram is given and interaction among different layers is also discussed. Various challenges that arise from employing OFDM in CR systems are identified. The cognitive properties of some OFDM-based wireless standards are also discussed in this paper. In [3], the authors have presented a descriptive survey on OFDM for wireless communications with an intention to cover almost every aspect. The authors mentioned OFDM as a special form of multicarrier modulation (MCM) and gave a basic description of OFDM along with its use to deal with impairments in wireless systems, including channel estimation, timing-offset and frequency-offset estimation, ICI mitigation, and PAPR reduction. The authors also introduced related modulation and access schemes. The authors also

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summarized the MIMO techniques for OFDM and the wireless applications of OFDM. In [7], the authors have discussed that high peak-to-average power ratio of the transmit signal is a major drawback of multicarrier transmission (OFDM). This paper has described some of the important PAPR reduction techniques for multicarrier transmission including amplitude clipping and filtering, coding, partial transmit sequence, selected mapping, interleaving, tone reservation, tone injection, and active constellation extension. In [9], the authors have described that combining schemes with individual PAPR techniques have gained interest. The authors have used the combinations of SLM and clipping technique in this paper leading to lower clipping noise of combined scheme than that of single clipping technique. The performance of combined scheme is analyzed with various clipping ratios, phase sets for SLM, and modulation schemes over flat and frequency selective fading channels. In [10], the authors have discussed that PAPR is one of the main problems of OFDM system which arises due to the superposition of many subcarriers. This paper presented a new hybrid PAPR reduction technique, which combines a selective mapping method with the clipping method. The authors presented an analysis of the performance and advantages of the new technique and compared it with other existing methods.

In our paper, we have first described the PAPR and its need of reduction. After this, a critical analysis of various PAPR reduction techniques is given.

II. PEAK TO AVERAGE POWER RATIO

OFDM offers several advantages over other transmission technologies such as high spectral efficiency, robustness to fading channel, immunity to impulse interference, and capability of handling very strong multi-path fading and frequency selective fading without having to provide powerful channel equalization [3]. Despite of various advantages, it has a major potential drawback in the form of high Peak-to-Average Power Ratio (PAPR). OFDM signal is a sum of several individual signals modulated over a group of orthogonal subcarriers with equal bandwidths. Therefore, when added up coherently, the resultant signal has large peak, while the mean power remains low [4].

Let us consider a collection of data symbols X_n, n = 0,1,….., N-1 which is denoted by a vector $X = [X_0, X_1, \dots, X_{N-1}]^T$ which is called as data block. The complex baseband representation of a OFDM signal having N subcarriers is given by:

$$x(t) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_n . e^{j2\pi n\ t}$$

PAPR of the OFDM signal is given by

$$PAPR = \frac{\max_{0 \le t < NT} |x(t)|^2}{1/NT \int_0^{NT} |x(t)|^2 dt}$$

An approximation is made where only NL equidistant samples are considered.

Now the PAPR computed from L-times oversampled time domain signal samples is given as under

$$PAPR = \frac{\max_{0 \le k \le NL-1} |x_k|^2}{E\{|x_k|^2\}}$$

where E{.} denotes the expectation operator [7].

The cumulative distribution function (CDF) of PAPR is used as performance measure of PAPR reduction technique. In literature, complementary CDF (CCDF) is commonly used instead of the CDF itself. The CCDF of the PAPR denotes the probability that the PAPR of a data block exceeds a given threshold. The horizontal and vertical axes represent the threshold for the PAPR and the probability that the PAPR of a data block exceeds the threshold, respectively. Roughly speaking, the closer the CCDF curve is to the vertical axis, the better its PAPR characteristic [7].

III. NEED OF PAPR REDUCTION

OFDM, as a successful air-interface technique, has gained a lot of attention in the recent years. But spectral leakage due to large side lobes, large PAPR, sensitivity to frequency offsets etc. are some of the disadvantages of OFDM [4].

High PAPR is a crucial drawback as it deteriorates the whole system performance. We know that OFDM is actually the sum of several individual signals which are modulated over different orthogonal subcarriers. On constructive addition at the transmitter, the resulting power increases leading to a very high PAPR. This high PAPR decreases the SQNR (Signal-to-Quantization Noise Ratio) of ADC (Analog-to-Digital Converter) and DAC (Digital-to-Analog Converter) while degrading the efficiency of the power amplifier in the transmitter. High PAPR may saturate the power amplifiers and clipping might occur, which causes inband noise resulting in degradation of system performance. So, the dynamic range of the power amplifiers should be large enough to accommodate such large PAPR values. But the component cost of the D/A converters and power amplifiers increase with the increase in the dynamic range. Thus, if the average power of the signal is lowered then this will also lower the peaks that a power amplifier needs to handle. However reducing the average power of the signal will reduce the SNR at the receiver thus degrading performance. If we do not lower the average power of amplifier input signal and allow large peaks to pass through the amplifier, this will introduce nonlinearities into the transmitted OFDM signal. So, in order to overcome the problem of high Peak to Average Power Ratio, we have two solutions: Amplifier Linearization and PAPR Reduction. The amplifier linearization method is very much costly and high power consuming method because to achieve the linearized operation, the use of High Power Amplifier is required which require high power to operate. Thus, several PAPR reduction techniques have been proposed during the last decades with different levels of success and complexity.

IV. DIFFERENT PAPR REDUCTION TECHNIQUES

Umpteen techniques have been introduced for PAPR reduction and the research is still on. All these methods cannot be explained in this paper, but some widely known reduction methods are as under:

A. Clipping and Filtering

One of the simple and effective PAPR reduction techniques is clipping, which cancels the signal components that exceed some unchanging amplitude called clip level. In other words, clipping means the amplitude clipping which limits the peak envelope of the input signal to a predetermined value. Let x[n] denote the pass band signal and $x_c[n]$ denote the clipped version of x[n], which can be expressed as

$$x_c[n] = \begin{cases} A & x[n] \leq \; A \\ x[n] & |x[n]| < A \\ A & x[n] \geq A \end{cases}$$

where A is the pre-specified clipping level. Clipping is nonlinear process and causes inband noise and out-of-band noise distortion. The in band noise causes degradation in the performance of bit error rate (BER) and out-of-band noise imposes out-of-band interference signals to adjacent channels decreasing the spectral efficiency. This out-of-band radiation can be reduced by filtering. But this filtering of the clipped signal leads to the peak re-growth. This clipping and filtering technique leads to some sort of distortion during the transmission of data. But the technique of iterative clipping and filtering reduces the PAPR without spectrum expansion. However, the iterative signal takes long time and it will increase the computational complexity of an OFDM transmitter.

B. Companding

This technique introduces compression of the signal at the transmitter and expansion of the same signal at the receiver. We know clipping technique introduces distortions. Companding technique shows better performance than clipping because inverse companding (expanding) can be applied at the receiver end to reduce distortion. Companding can either be A-law companding, μ-law companding or exponential companding [20]. If the parameter A=1 in A-law companding or μ=0 in μ-law companding, then the characteristic is linear (no compression) corresponding to uniform quantization. A-law companding technique performs slightly better than μ-law companding. Actually, μ-law companding technique enlarges only small signal so that the average power increases. In exponential companding, both large and small signals are adjusted keeping the average power at same level. Exponential companding causes lesser sidelobe generation than μ-law companding [8].

C. Selective Mapping (SLM) method

This method is used for minimization of peak to average transmit power of multicarrier transmission system with selected mapping. In this technique, the transmitter generates a set of different data blocks, all representing the same information as the original block and selects the most favorable for transmission [4]. Actually, the input data is multiplied by random series and resultant series with the lowest PAPR is chosen for transmission. To allow the receiver to recover the original data, side information of the selected phase is needed to be sent to receiver. At the receiver, the reverse operation is performed to recover the original data [7]. This technique is quite popular but if number of phase rotation increases then complexity increases. The good side of selected mapping method is that it doesn't eliminate the peaks, and can handle any number of subcarriers. The drawback of this method is the overhead of side information that requires to be transmitted to the receiver of the system in order to recover information.

D. Partial Transmit Sequence

This proposed method is based on the phase shifting of sub-blocks of data and multiplication of data structure by random vectors. This method is flexible and effective for OFDM system. The main purpose behind this method is that the input data frame is divided into non-overlapping sub blocks and each sub block is phase shifted by a constant factor to reduce PAPR [4]. PTS is probabilistic method for reducing the PAPR problem. It can be said that PTS method is a modified method of SLM. PTS method works better than SLM method. The main advantage of this scheme is that there is no need to send any side information to the receiver of the system, when differential modulation is applied in all sub blocks [7] [12].

There are many issues to be considered before using the PAPR reduction techniques in a digital communication system. These issues include PAPR reduction capacity, power increase in transmit signal, BER increase at the receiver, loss in data rate, computational complexity increase and so on. A table is formulated below which gives a comparison of various PAPR reduction methods.

Table 1. Comparison of various PAPR reduction methods

Technique	**Distortion**	**Power**	**Data Loss**
Clipping & Filtering	Yes	Decreases	No Loss
Partial Transmit Sequence	No	Decreases	Loss
Selective Mapping	No	Decreases	Loss

Insipite of all the research, most of the techniques are not proficient to obtain a large reduction in PAPR with low coding overhead, with low complexity, without performance degradation and without transmitter and receiver symbol handshake.

V. Critical Analysis of PAPR Reduction using Various Techniques

A simple OFDM signal can be generated using DVB standard. This generated signal is shown below:

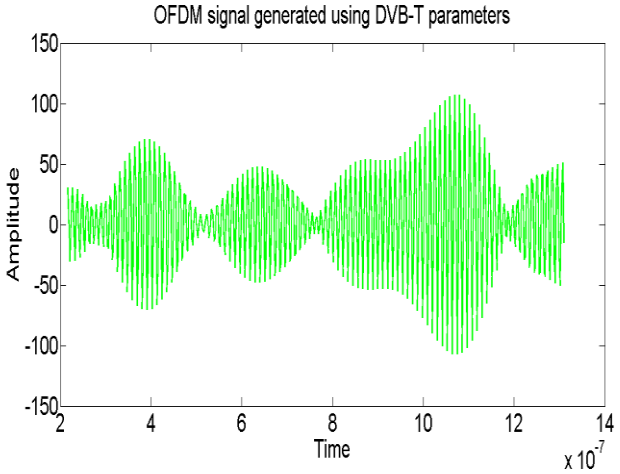

Figure 2. OFDM signal generated using DVB-T parameters

Here we reduce the PAPR of generated OFDM signal by using clipping-filtering technique, companding technique and SLM technique separately. In SLM technique, route numbers are varied to show its effect on PAPR. Further, a hybrid method is proposed where clipping-filtering technique is combined with SLM technique and the combination is applied to the generated OFDM signal. This combination exploits both the simplicity of clipping-filtering technique and the good performance of SLM method to reduce the PAPR.

First clipping-filtering in applied. It reduces the PAPR by approximately 2.6 dB. This technique, inspite of being simple, results to distorted signal transmission. So, a technique called as companding is used which not only adjusts the power levels of OFDM signal at the transmitter, but also adjusts the signal at the receiver too. From Figure 3, it is clear μ – law companding reduces PAPR by about 8 dB. A-law companding provide slightly better result than μ – law companding.

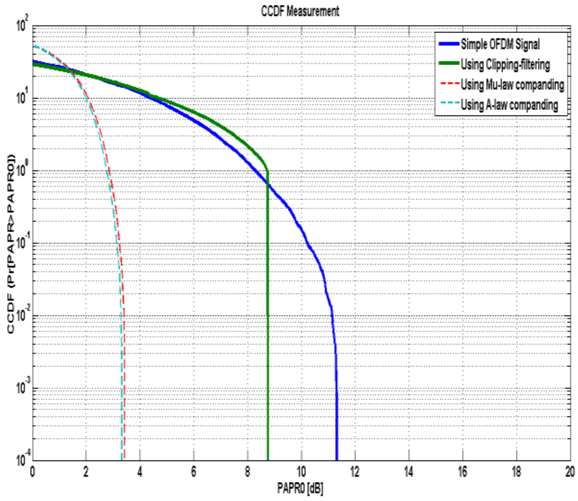

Figure 3. PAPR Reduction of OFDM signal using Clipping-filtering and Companding Techniques

We apply SLM on the generated OFDM signal and we vary the route numbers in order to have better results. From the Figure 4, it is clear that PAPR of signal is reduced from 12.3dB to about 8.5dB which is a quite significant change. Also increasing route numbers results in decrease in the PAPR.

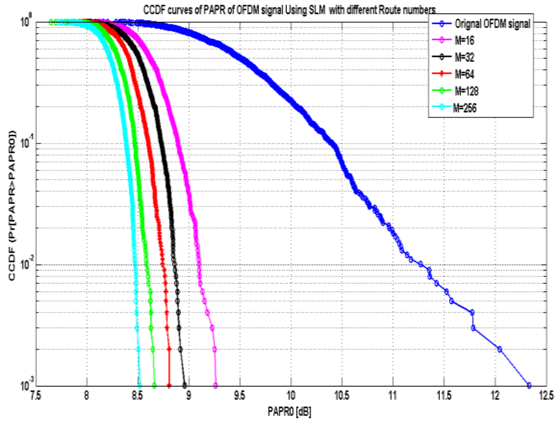

Figure 4. PAPR Reduction of OFDM signal Using SLM with Different Route Numbers

Now a hybrid method is proposed to reduce the PAPR of OFDM signal. This hybrid technique incorporates the idea of clipping-filtering in SLM. The OFDM signal is first clipped then filtered and after this, we use the SLM technique to reduce the PAPR of OFDM signal. The results are shown in figure 5.

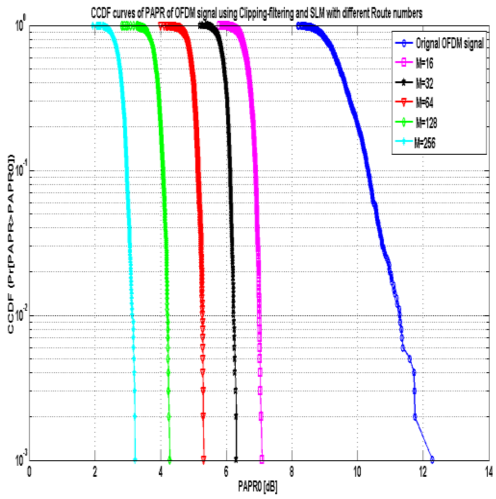

Figure 5 : PAPR of OFDM Signal using Hybrid Technique

The results of figure 4 and figure 5 can be summarized in the form of table as shown in table 2. PAPR of Original generated OFDM signal =12.3dB.

Table 2 Comparison of PAPR Values for Different Route Numbers

Different Route Numbers	PAPR (dB) values using SLM	PAPR (dB) values using Hybrid SLM and Clipping-filtering
M=16	9.25	7.1
M=32	8.95	6.3

M=64	8.8	5.3
M=128	8.65	4.3
M=256	8.5	3.2

The above results prove that the hybrid technique shows better results than individual techniques, but this is not true always. Here, hybrid technique showed significant improvement by reducing PAPR of OFDM signal to 3.2dB which is overall PAPR reduction of about 9.1dB.

VI. CONCLUSION

OFDM is a very attractive technique for high-speed transmission over a dispersive communication channel. The PAPR problem is one of the crucial issues to be addressed in developing multicarrier transmission systems. In this paper, we describe some PAPR reduction techniques. Various techniques are used to reduce the PAPR. Companding technique shows better results than clipping-filtering technique. Further, SLM technique is applied on generated OFDM signal showing better results with the increase in route numbers. In this paper, a hybrid technique is proposed where the concept of clipping-filtering technique and SLM technique are used together to reduce the PAPR of generated signal. This hybrid technique shows significant PAPR reduction of about 9dB with M=256. Thus, this combination tries to cover up the limitations of one another by combining their strong qualities together

All these techniques have the potential to provide substantial reduction in PAPR, but at the cost of loss in data rate, transmit signal power increase, BER increase, computational complexity increase etc. Thus, the PAPR reduction technique should be carefully chosen according to various system requirements. In practice, the effect of the transmit filter, D/A converter, and transmit power amplifier must be taken into consideration to choose an appropriate PAPR reduction technique.

VII. ACKNOWLEDGMENT

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REFERENCES

[1] Hao Lin and Pierre Siohan, "An Advanced Multi-carrier Modulation for Future radio Systems", *IEEE International Conference on Acoustic, Speech and Signal Processing (ICASSP)*, 2014

[2] Mahmoud H. , Yucek T. , Arslan H. , "OFDM for Cognitive Radio: Merits and Challenges", *IEEE Wireless Communications*, Vol.16, Issue. 2, pp.6-15, 2009

[3] Hwang T. , Yang C. , "OFDM and Its Wireless Applications: A Survey", *IEEE Transactions on Vehicular Technology*, Vol. 58, No. 4, May 2009

[4] Rohling H. , "OFDM: Concepts For Future Communication Systems", *Springer Publications*, 2011

[5] Navid Daryasafar "OFDM and its Applications in Multi-Antenna Systems: A Survey", *Journal of Basic and Applied Scientific Research*, 2(10)9950-9960, 2012

[6] Ulrich H. R. , "DVB-The Family of International Standards for Digital Video Broadcasting", *Proceedings of the IEEE*, Vol. 94, No. 1, January 2006

[7] Han S.H. , Lee J.H. , "An Overview of Peak-to-Average Power Ratio Reduction Techniques for Multicarrier Transmission", *IEEE Wireless Communications* , April 2005

[8] Yuan Jiang "New Companding Transform for PAPR Reduction in OFDM", *IEEE Communications Letters*, Vol. 14, No. 4, April 2010

[9] Moo B.L. , Kim Y. , Figueiredoet R. J. P., "Performance Analysis of the Clipping Scheme with SLM Technique for PAPR Reduction of OFDM Signals in Fading Channels", *Springer Journal on Wireless Personal Communications*, Vol.63, Issue 2, pp.331-334, 2012

[10] Cuteanu V. , IsarA. , "PAPR Reduction of OFDM Signals using Selective Mapping and Clipping Hybrid Scheme", *Proceedings of the 20th European Signal Processing Conference (EUSIPCO), IEEE Publications*, pp. 2551-2555, 2012

[11] Vinit V. Patel, R. N. Patil, "Comparison of Peak to Average Power Ratio Reduction Techniques in OFDM System", *IMACST*, Vol.4, No.1, May 2013

[12] Victor Cuteanu, Alexandru Isar, "PAPR Reduction of OFDM Signals using Partial Transmit Sequence and Clipping Hybrid Scheme", *AICT 2012 : The Eighth Advanced International Conference on Telecommunications*, Germany, June 2012.

[13] Fischer W.," Digital Video and Audio Broadcasting Technology: A Practical Engineering Guide", *Springer Publications.*

[14] Cho Y.S. , Kim J., Yang W.Y. , Kang C.G. ,"MIMO-OFDM Wireless Communications with MATLAB", *Wiley Publications*