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Peak To Average Power Ratio (PAPR) Reduction In OFDM - OQAM Signals

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Abstract: **The Orthogonal Frequency Division Multiplexing (OFDM) is a type of modulation that is being used for many of the latest wireless, telecommunication and broadcasting standards. OFDM is considered to be complicated than other signals but also it possess high data rate transmissions with relatively wide bandwidths. The major disadvantage included in OFDM signal is Peak-to-Average Power Ratio (PAPR) in higher level and Sensitive to Carrier offset. Hence there were found to be many reduction techniques for PAPR have been proposed where in need to reduction in high PAPR and carrier sensitivity still more to make it efficient for future optical domain standards. This paper not only makes the OFDM system advantageous but also suitable for fast data transmission and reduces the complication at receiver side, because all the transmitting data are cleared out of signal noise, interferences, etc. The technique which is going to get implemented for PAPR reduction is Optimized Iterative Clipping and Filtering (OICF).The OFDM is provided with the subcarrier of N=256 and the modulation of Offset Quadrature Amplitude Modulation (OQAM). The OQAM-OFDM provides the higher spectral efficiency and also the inter-symbol interference is avoided since not using Cyclic Prefix (CP) in OQAM-OFDM signal. The main reason for reducing PAPR is that to avoid non- linearity at the receiving end in high speed wireless communication.**

Keywords: **OFDM, PAPR, S-PTS, OICF, OQAM, CCDF.**

I. INTRODUCTION

Transmitting voice and data using electromagnetic waves [1] in open space where the transfer of messages between two or more points that are not connected by an electrical conductor is the Wireless communication. Transmitters and Receivers are used to refer the telecommunication system where Radio waves are used to transfer the messages without using wires [9]. The short and long distances communication is used for transfer the information from one place to another. Transmitter, Receiver and Channel are the common wireless systems. There are several types of wireless communication is used.

Point-to-Point Communication is needed for connecting two points. The common example for Point-to-Point communication is telephony call, radio and TV broadcasting. A distinct type of one-to-many connections provides multiple paths from one location too many locations is called Point-to-Multipoint communication. Broadcasting communication takes message from a single sender for transmitting to all endpoints on the networks. Wireless communication is used in cell phones, GPS, IEEE 802.11, 3G, 4G, Satellites, VPN, Wi Fi, etc.

II. OFDM SYSTEMS

OFDM is an Orthogonal Frequency Division Multiplexing (FDM) scheme used as a digital multi-carrier modulation method. A large number of closely spaced orthogonal sub-carrier signals are used to carry data on several parallel data streams. The sub-carriers is modulated with a Quadrature Amplitude Modulation or phase-shift keying at a low symbol rate, maintaining total data rates similar to conventional single-carrier modulation schemes in the equal bandwidth. The major advantage of OFDM over single-carrier is its ability to cope with channel conditions for example, attenuation of high frequencies in a long copper wire, narrowband interference and frequency-selective fading due to multipath without complex equalization filters. OFDM is a digital modulation technique, it is used to transfer one bit stream over one channel using one sequence of OFDM symbols. OFDM is also a sub-carrier multiplexing method. It is for digital communication for wireless used in applications namely digital TV, wireless network, power line network, 4G mobile communication. OFDM is used in UMB, WRAN, and E-UTRA, WI Max.

The Offset Quadrature Amplitude Modulation with Orthogonal Frequency Division Multiplexing (OQAM-OFDM) system has lower side lobes, spectral efficiency is high, and ISI is low. It is used in digital broadcasting systems (DVB) [5].The major drawbacks of OFDM signals are PAPR.

III. PEAK TO AVERAGE POWER RATIO

The PAPR (Peak to Average Power Ratio) is the ratio between the maximum powers of OFDM signal and the average power of that OFDM signal. In a multi-carrier system the various sub-carriers are out of phase where the PAPR occurs. When at different phase values they are different with each other. When all points have the maximum value, it will create envelope in output side to suddenly cause a 'Peak' in the envelope output. Due to large number of sub-carriers in an OFDM system is high when comparing to the average value of the OFDM system. The ratio of the peak power within average power is known as PAPR. PAPR is referred as

$$\text{PAPR} = \frac{P_{PEAK}}{P_{AVERAGE}} = \frac{\max[|x_{1n}|^2]}{E[|x_{1n}|^2]} \quad (1)$$

Where P_{PEAK} = Peak Power of the OFDM System.

$P_{AVERAGE}$ = Average Power of the OFDM System**.**

One of the new problems arises in OFDM systems is PAPR problem. The input of IFFT should produce a uniform power spectrum, but the result of the IFFT may be non-uniform or spiky power spectrum. PAPR is mostly produced by majority subcarriers in the OFDM systems. This problem can occur in transmitting end. In linear region, the RF power amplifiers cause PAPR effect. The signal distortion produced by peak signal gets into any non-linear region of the power amplifier. Where it causes Signal distortion, such signal distortion will produce inter modulation among the subcarriers and radiations .higher peaks produces saturation in PAs, which introduces subcarriers and out- of- band energy.

The main objective is to reduce the PAPR and reduce the computational complexity of the Offset Quadrature Amplitude Modulation with Orthogonal Frequency Division Multiplexing (OQAM-OFDM) system [8]. The main work is to develop an optimal method since the required PAPR reduction with less in-band distortion and far less iteration. For reducing the Peak-to-Average Power Ratio, consider the clipping noise instead of clipping signal along with the filtering process and develop an optimization algorithm for reducing the complexity in the PAPR reduction.

The need of OQAM-OFDM system is used to improve the spectral efficiency [4] and data transmission rate. But a major drawback of OQAM-OFDM signals is their high PAPR. Since the transmitter's Power Amplifiers (PAs) are peak-power limited, the large PAPR causes to higher band distortion and radiation.

IV. PAPR REDCUTION TECHNIQUES

The PAPR reduction includes many techniques and it dependent on various factors such as Spectral Efficiency, Reduction Capacity ,Increasing of Transmit signal power, Loss in data rate, Computation Complexity, Increase in BER, Peak Reduction Carrier, Clipping and Filtering. The PAPR Techniques have been proposed in order to reduce the PAPR as more as possible. It is divided into two types namely scrambling techniques and distortion of signal techniques. Scrambling techniques are also known by block coding technique, Selective Mapping [13] and a well-known technique called as Partial Transmit Sequences (PTS). Scrambling techniques mostly acquire with side information is used to reduce the throughput since they produce redundancy. The signal distortion technique produces out-of-band interference and also reduces high peaks. To reduce PAPR, Clipping is a simple method for the OFDM signal before amplification. Clipping may cause high out-of band and in-band interference along with the Peak windowing, weighted multicarrier transmission

[6] as a common practical solution. The factors which includes for PAPR is reduction capacity, Power increase in signal, BER increases, some losses in data rate, computational complexity will increase and so on. The PAPR reduction should be chosen carefully according to the system requirements.

V. PROPOSED OICF SCHEME

In the proposed system, OICF (Optimized Iterative Clipping and Filtering) method is simplest technique to minimize the range of PAPR value of OQAM-OFDM signals [3]. In this system, change the research focus from the clipped signal to the clipping noise. The analysis shows that the optimization problem in the original OICF algorithm [10] can be transformed into an equivalent form, where a PAPR-reduction vector added to the subcarriers becomes the optimization parameter. Further analysis shows that the solution of the transformed problem can be approximately obtained by using simple algebraic operations with $\mathcal{O}(N^3)$ complexity rather than by executing special software. Based on this, a simplified OICF algorithm is proposed. Like the original OICF algorithm, the simplified algorithm itself leads to no out-of-band radiation. In the meantime, simulation results show that, for an OFDM system with N=128 subcarriers and Quadrature Phase Shift Keying (QPSK) modulation, after three iterations the original and simplified algorithms have almost the same performance: at a 10^{-4} clipping probability (i.e., the probability that a PAPR exceeds a given threshold), the PAPR gap 5×10^{-3}, while at a 10^{-7} error probability the BER performance gap is 6×10^{-3} dB. The proposed system can be implemented at transmitter side and so the complications or signal processing at the receiver side is not required and transmitter. This leads to the decrease of computation complexity [7].

The transmitter side initially includes the input OFDM signal which undergoes modulation and IFFT is applied [12]. Once IFFT is applied to the input signal and clipping is implemented. The clipping causes basic value of reduction in PAPR and so for further PAPR reduction the EVM filter is implemented and required output signal can be achieved and indulged into the Antenna, Fig. 1 and Fig. 2Shows the block diagram for the transmitter and receiver side of the Iterative clipping and filtering method. In this block diagram, the input data is given to the modulator. In the modulating process [11], the carrier signal with a modulating signal which contains information to be transmitted.

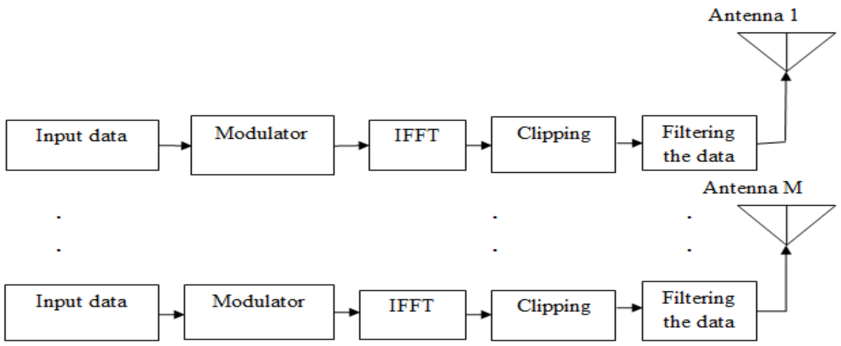

Fig. 1 Transmitter for Iterative clipping and filtering

After that, the output of the modulator is given to the IFFT block. The inverse fast Fourier transform is taken for the modulating data. Then, the iterative clipping and filtering is usually required to suppress the peak growth. Then, the filtered data is transmitted through the transmitted antennas.

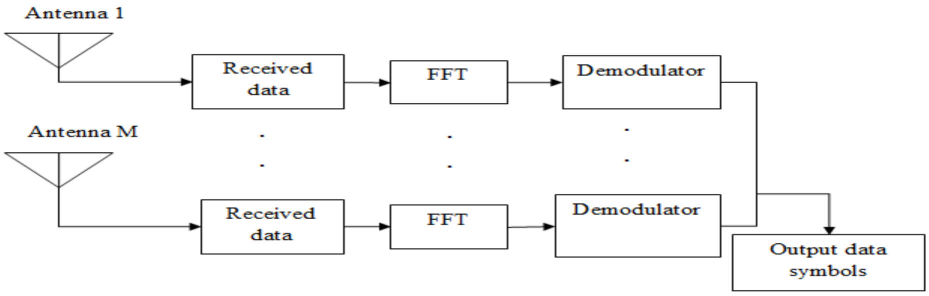

Fig. 2 Receiver for Iterative clipping and filtering

A demodulator is an electronic circuit that is used to removal of the information content from the modulated carrier wave. After that, the output symbols are recovered. The performance of the existing and the proposed system is compared. In the existing system, a Novel S-PTS scheme is proposed for the PAPR reduction. In the proposed system, Optimized Iterative Clipping and Filtering (OICF) method is used for the PAPR-reduction in the OQAM-OFDM Signals. The advantages of proposed system are High PAPR reduction, Performance is high, and BER is less.

Thus, the PAPR of OQAM/OFDM in each interval is

$$\mathrm{PAPR} = \frac{\max_{sT\le(s+1)T}|s(t)|^2}{E[|s(t)|^2]} \quad (2)$$

At the receiver side, the signal is received and fast Fourier transform is applied and the output is given to the demodulator.

The Clipped signal $\widehat{x1}(n)$ is given by

$$\widehat{x}1(n) = \begin{cases} Ae^{j\emptyset(n)}, & \text{if}|x1(n)\} > A \\ x(n), & \text{otherwise} \end{cases} \quad (3)$$

Clipping ratio L is

$$L = \frac{A}{\sqrt{P_{av}}} (4)$$

Where P_{av} is the average power of the signals.

In the existing system, a Novel S-PTS scheme is proposed for the PAPR reduction. In the proposed system, Optimized Iterative Clipping and Filtering (OICF) method is used for the PAPR-reduction in the OQAM-OFDM Signals.

Error Vector Magnitude (EVM) is defined as

$$\mathrm{EVM} = \sqrt{\frac{\frac{1}{N}\sum_{k=0}^{N-1}|X1(k)-\hat{X}1(k)|^2}{\frac{1}{N}\sum_{k=0}^{N-1}|X1(k)|^2}} = \frac{||X1-\hat{X}||_2}{||X1||_2} (5)$$

Where *X1(k)* and $\widehat{X1}(k)$ is the ideal and deviated data symbol.

The OICF technique can be formulated as

$$\min_{H^{(m)}\in C^N} \mathrm{EVM} = \frac{||X1^{(m)}-\hat{X}_1^{(m)}||_2}{||X1||_2} \quad (6)$$

Clipping and Filtering is required to suppress the peak regrowth. The convergence rate of this method to the desired PAPR becomes very slow after several iterations. ICF is this technique does not consider the in-band distortion.

VI. RESULTS AND DISCUSSION

OFDM is commonly known for multicarrier transmission. It is considered to be modulation or multiplexing techniques. OFDM signal has many numbers of closely spaced sub-carriers. By non-linearity, it causes interference between the carriers as a type of inter-modulation distortion and produces orthogonality of the transmission. It would causes unwanted signals refer as interference. This distortion causes higher level of data errors. The input signal OFDM is shown in Fig. 3.

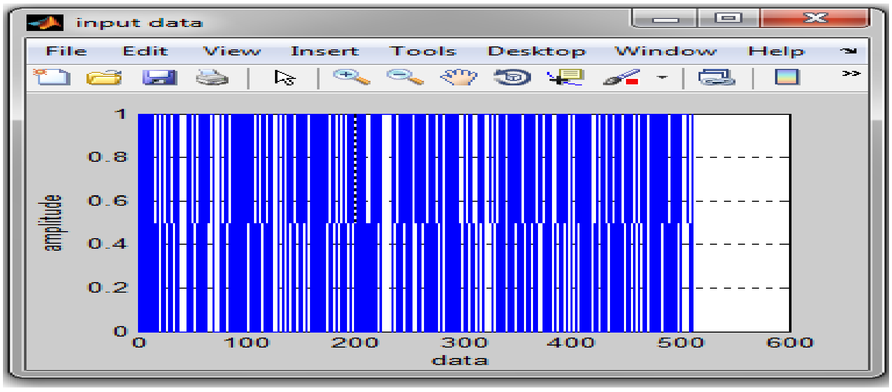

Fig. 3 Input OFDM Signal

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Clipping is the nonlinear process, which cause two undesirable effects spectral regrowth, which causes unacceptable out-of-band radiation and in-band distortion of the desired signal, which increases Bit-Error-Rate (BER). The clipping is to reduce maximum transmitted signal. The Filtering is the out-of-band radiated can and often is suppressed by filtering, which leads peak regrowth.The Clipping and Filtering of OFDM signal is given in Fig. 4.

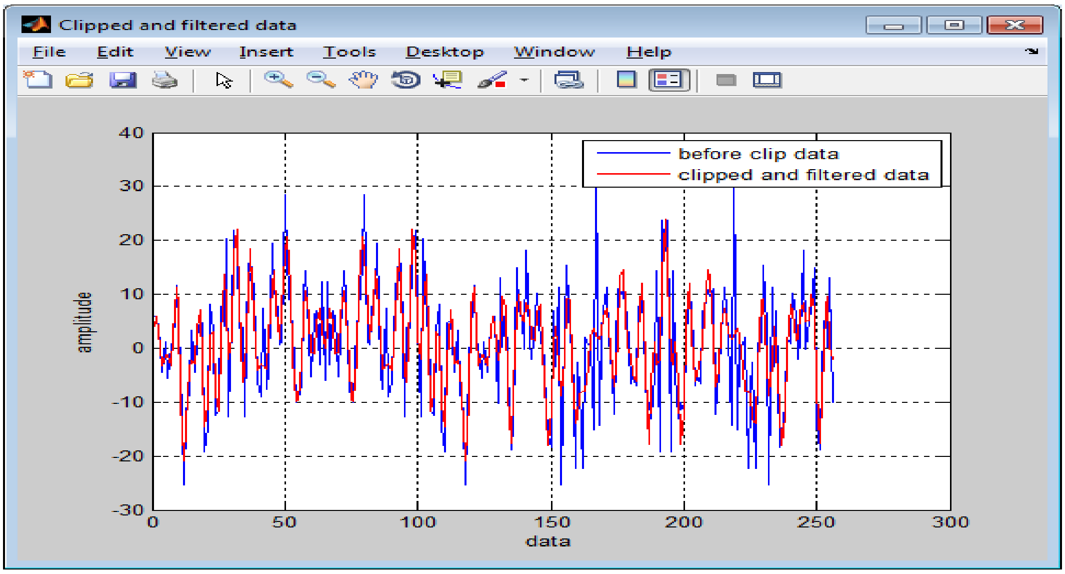

Fig. 4 Clipped and Filtered Output of OFDM Signal.

To measure the PAPR reduction in OFDM system the Complementary Cumulative Distribution Function (CCDF) 9is used successfully. The PAPR reduction performance with the OICF method in OQAM-OFDM system is given in Fig. 5. The data blocks are randomly generated with N= 256, V=4 and V=8 where V is considered to be the over sampling rate. For OICF, the Complementary Cumulative Distribution Function is 10^{-2} ,when the PAPR could be reduced from the value of 4 to 4.2 dB and 4.4 dB with L=2,4,6.At V=8 the PAPR can be reduced by 4.6 dB ,4.9 dB ,5.6 dB with L=2,4,6 ,where the length of each segment is given as L.

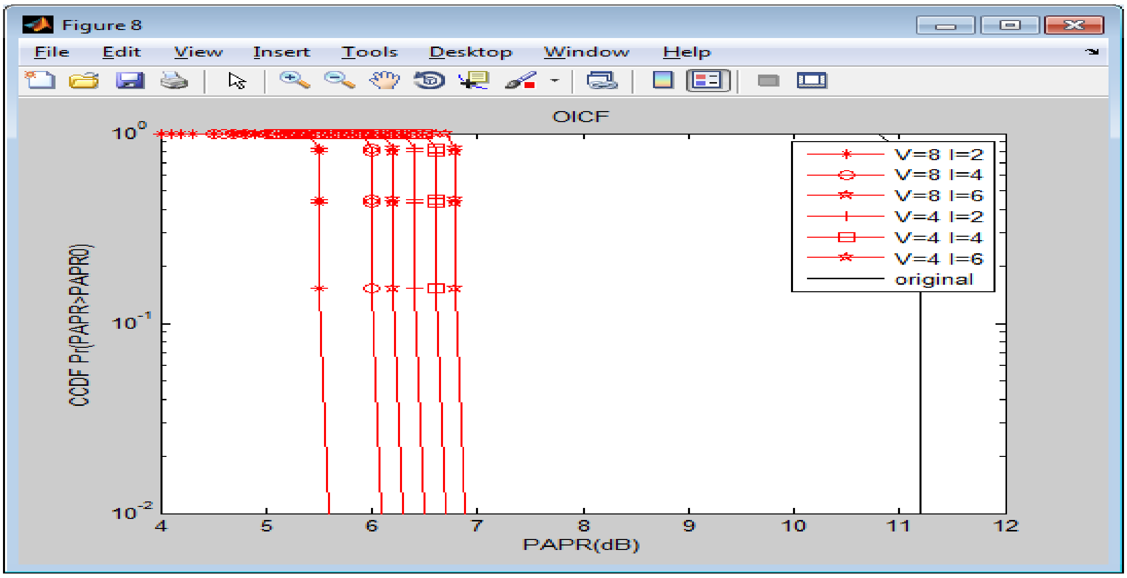

Fig. 5 PAPR reductions of the OICF method with V=4 and V=8

The BER performance are shown with the OICF scheme with V=8. Addictive White Gaussian Noise (AWGN) channel is the channel between the transmitter and the receiver antennas. The BER performance of original signals without non-linear distortion through the SSPA is known by Ideal [4]. The BER of $10^{-0.5}$, with L=2, 4, 6 .The signals operated by the OICF scheme achieve better performance than the S-PTS scheme is shown in Fig. 6.

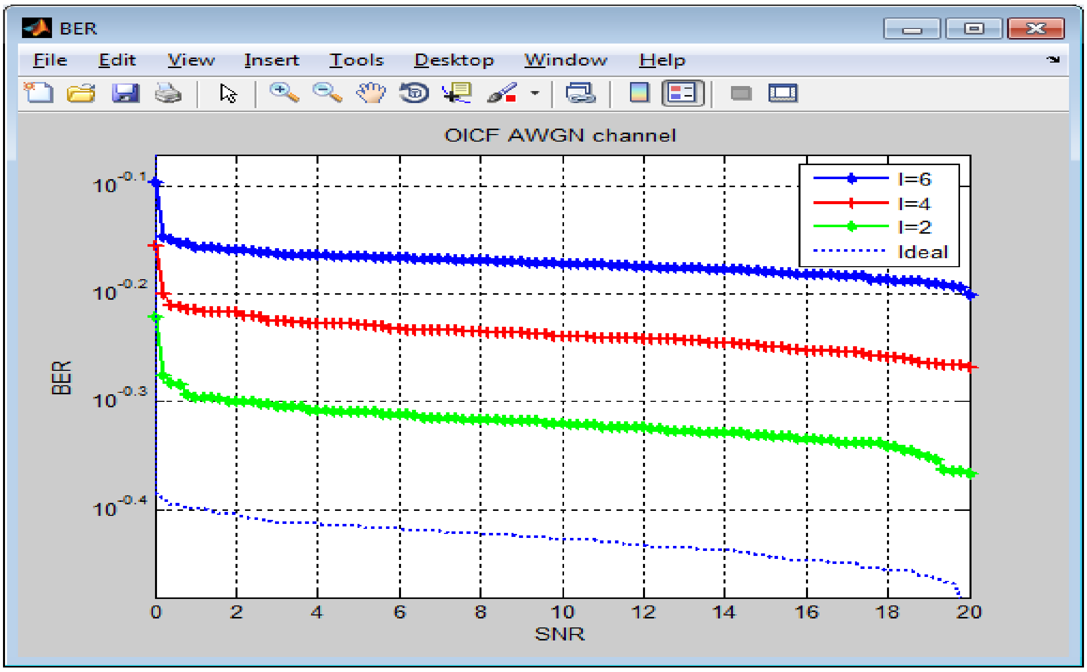

Fig. 6 BERs of the OICF method with V=8 over AWGN channel.

The comparison of PAPR reduction among the S-PTS and OICF schemes is shown. At CCDF=10^{-2} for the OICF the PAPR reduced by 4.7 dB, 5.3 dB with V=8. The sub blocks number for the S-PTS and OICF scheme is V=8, the PAPR reductions of the OICF schemes is better than that of the S-PTS scheme, since the overlapped structure of OQAM-OFDM signals are considered as a main factor in both the S-PTS and OICF schemes and it is given in Fig. 7.

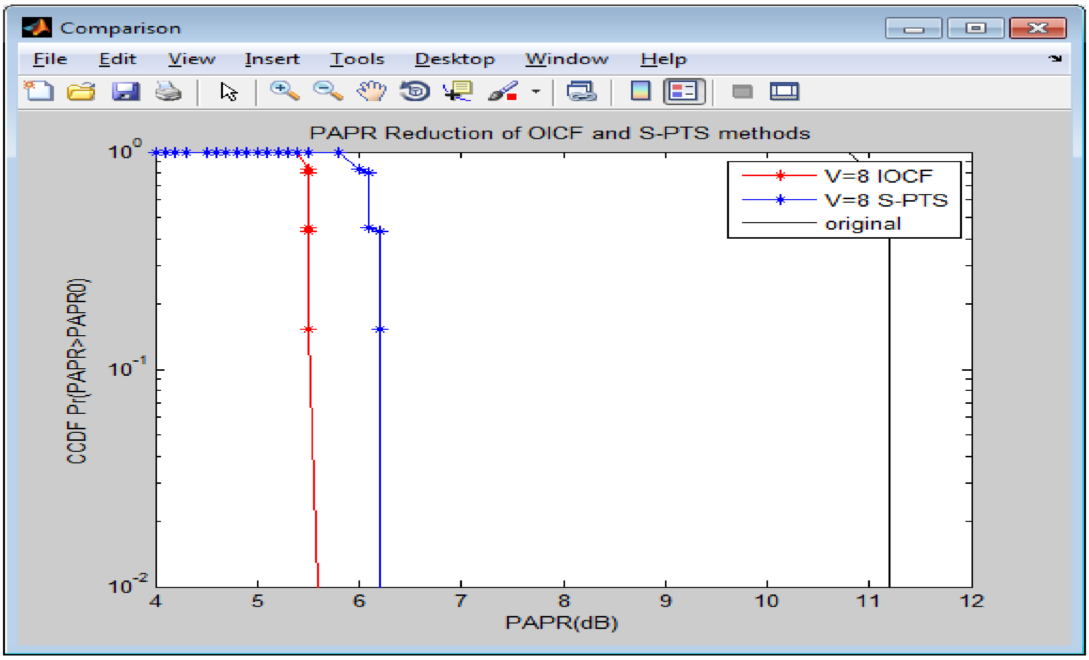

Fig. 7 PAPR Reduction of the S-PTS and OICF methods with V=8.

The statistical distribution of the received signal of flat fading channel or the envelope of multipath component is the Rayleigh distribution. The envelope of sum of two quadrature nature of Gaussian noise signals is Rayleigh distribution. The comparison of PAPR reduction is observed in the S-PTS and OICF schemes. The sub blocks number for the OICF scheme is V=8, the PAPR reductions of the OICF schemes is better than that of the S-PTS, scheme and the structure of OQAM-OFDM signals are explained in both the S-PTS and OICF schemes over Rayleigh channel is given in Fig. 8.

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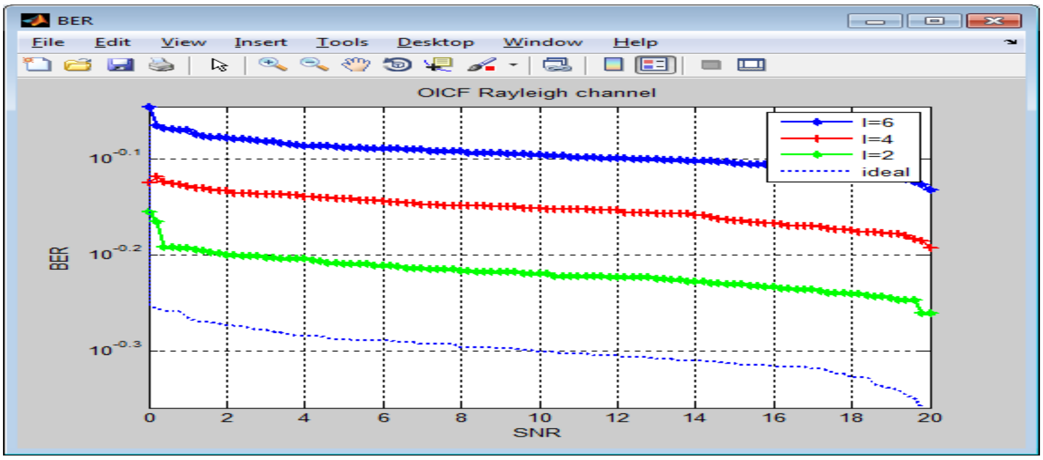

Fig. 8 BERs of the OICF method with V=8 over Rayleigh channel

The comparison of PAPR reduction among the S-PTS and OICF schemes is shown. The sub blocks number for the S-PTS and OICF scheme is V=8, the PAPR reduction of the OICF schemes is better than that of the S-PTS [4]. Since the overlapped structure of OQAM-OFDM signals are taken into account in both the S-PTS and OICF schemes is given in Fig. 9.

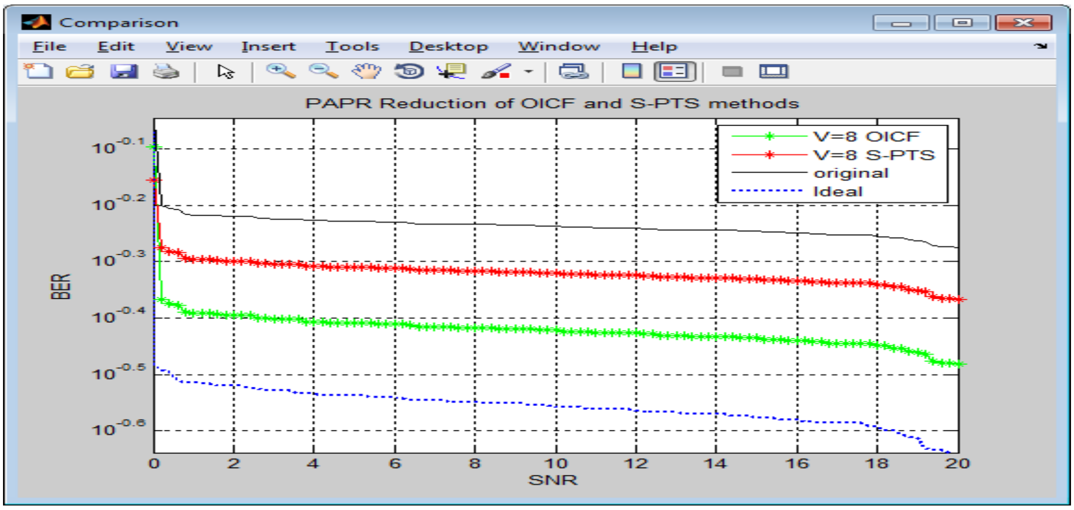

Fig. 9 BERs of the OICF, S-PTS schemes with V=8

The Average probability of symbol error is known as Bit Error Rate (BER) where the average probability of symbol error is the probability that the reconstructed symbol at the receiver output differs from the transmitted binary symbol. PAPR is nothing but randomly sinusoidal leads which causes a reduced effect during transmission of the OFDM signals, where the ratio between maximum power of pass-band signal and mean power of pass-band signal. The BER and PAPR for S-PTS and OICF are shown in Table.1.

Table. 1 Comparison table for BER and PAPR of S-PTS and OICF Method

BER(dB)		PAPR(dB)	
S-PTS	**OICF**	**S-PTS**	**OICF**
0.4277	0.5277	6.7000	6
0.4160	0.5141	6.5000	5.9000
0.4141	0.5141	6.5000	5.9000
0.4121	0.5121	6.4000	5.8000
0.4121	0.5121	6.4000	5.8000
0.4063	0.5063	6.3000	5.7000

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VII. CONCLUSION

The original OICF algorithm is a high-performance clipping and filtering technique. However, it needs to solve a convex optimization problem associated with filter, which leads to high complexity. In this work, the optimization problem has been changed equivalently to a problem with the PAPR reduction vector as the optimization parameter, which can be approximately solved by using some simple operations. Based on this analysis, a simplified OICF algorithm with much lower complexity has been proposed. The simulation results show that the original and simplified algorithms have almost the same performance in terms of PAPR reduction, BER and out-of-band radiation. Meanwhile, the simulation results also demonstrate the superiority of the algorithm when compared with the other clipping and filtering techniques. Finally, it should be noted that, although mainly investigate the case of the oversampling factor $L = 2,4,6$ in this work.

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