Performance Tradeoff of PTS & SLM Technique using Various Modulator in 802.11g

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Abstract— Orthogonal Frequency Division Multiplexing technique (OFDM) is a most widely used technology in today's wireless communication system. This technology suffer with a shortcoming known as Peak to Average Power Ratio (PAPR), due to this, the High Power Amplifiers (HPA) are worked in nonlinear region and cause inter-modulation distortion and unwanted out of band radiation. To combat the PAPR various PAPR reduction technique are developed. In this paper the most efficient signal distortion-less technique, Partial Transmit Sequence (PTS) and Selected Mapping (SLM) are used under different modulator namely Quadrature Phase Shift Key (QPSK) and Quadrature Amplitude modulator and analyzing and comparing the techniques simultaneously and varying the different parameters like Modulation factor, Sub-band, oversampling factor has been done.

Index Terms— CCDF, ODFM, PAPR, PTS, QPSK, QAM and SLM

I. INTRODUCTION

In today's wireless communication system, the orthogonal frequency division multiplexing technique is most popular and extensively used. It is widespread from wireless local area network (802.11g), worldwide interoperability for microwave access (WIMAX), to the long term evolution (LTE) system, and digital video broadcasting (DVB-T, DVB-T2) [1].The OFDM is a digital modulation technique that supports high bit rate transmission so it is used in high speed video and audio communication with elimination of inter symbol interference (ISI) and inter channel interference (ICI).It can accommodate more number of user and increased the spectral efficiency of the system. The orthogonal signals are required for favoring orthogonal frequency division multiplexing system. This concept is used to separately demodulate overlapping carriers. Orthogonality is a platform to efficiently transmit information signals via a common channel without any interference. Lack of this property may degrade the communication [1].

The OFDM modulation technique is used in 802.11g which is known as wireless local area network (WLAN). One of the IEEE standardands, 802.11 is a wireless networking transmission methods that is commonly used today in 802.11a, 802.11b, 802.11g and 802.11 versions to facilitate wireless connectivity with throughput to up to 54 Mbit/s using the same 2.4 GHz band in different places or organization such as home, office and commercial purpose.

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Fig. 1 shows the uplink communication of mobile consumer electronics in the WLAN and cellular communication system [9].

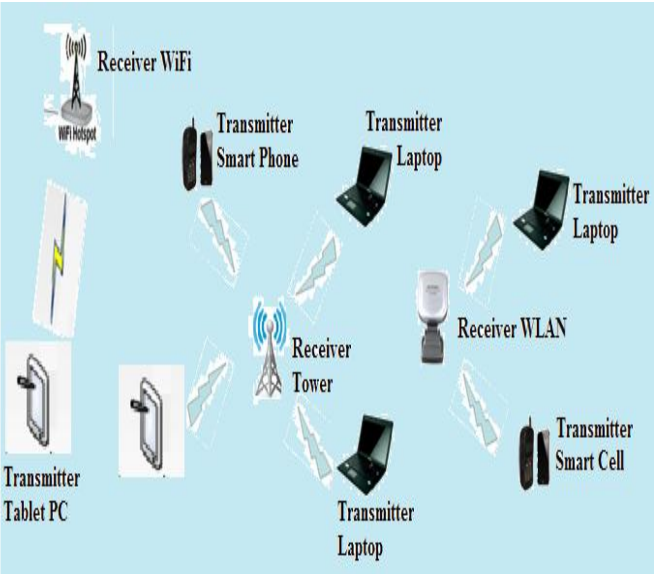

Fig.1. Wireless communication of the WLAN's and Cellular system.

With some of the advantages with OFDM system (which has many narrow band signals in the time domain) has one vital issue that is its large peak-to-average power ratio which leads to cause inter-modulation distortion and out-of-band radiation due to nonlinear function of power amplifier. This amplifier must be used in its linear region to combat distortion, out-of-band noise and bit error rate degradation. Non-linearity leads to low spectral efficiency and high amount of dissipation of power which is restricted for use in many wireless applications. This is the reason why PAPR must be reduced for application used in OFDM system.

Therefore, in order to find a solution so as to reduce high PAPR effectively, it is important to reduce the PAPR of an OFDM signal. With previous years researchers has been working on various schemes giving an attempt to reduce the PAPR in orthogonal frequency division multiplexing (OFDM) system. These can be further classified into two main types which are signal distortion and signal scrambling techniques. One of the common schemes include in Signal scrambling techniques are block coding [15], tone reservation and injection [16], Active constellation Extension(ACE) technique [15], Selected mapping (SLM) scheme[6],[5],[8], and Partial transmit sequence (PTS) schemes[2], [3], [4], [7],[8].the signal distortion technique namely Clipping and Filtering[12],[13],[14].

Among all these schemes, the SLM and PTS schemes have been considered the most attractive schemes due to its high PAPR reduction performance without incurring additional signal distortion. The rest of this paper is organized as follows. Section II, demonstrates OFDM signal and PAPR formulation. Section III illustrates complementary cumulative density function (CCDF). Section IV gives brief description of PAPR reduction techniques. Section V shows simulated experimental results. Further, section VI comes with the conclusion.

II. OFDM SIGNAL AND PAPR FORMULATION

In an OFDM system, the data block of N symbols, denoted by $X=[X_0, X_1, X_3, XN_{-1}]^T$, is modulated by a set of orthogonal sub-carrier, f_k, {k=0, 1, 2, N-1}, where T denotes the transpose. In OFDM system to maintain the orthogonality of the signals, the spacing Δf between neighboring subcarriers is set to be a multiple of 1/T. i.e., Δf=1/T, where T is the duration of an OFDM symbol and m is a positive integer we set m to be the least positive integer, in order to make full use of the bandwidth; then the transmitted OFDM symbol is given by [3].

$$x(t) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} Xk \ e^{(j2\pi f t)}, \quad 0 \le t \le T \qquad (1)$$

The OFDM signal are made up of a number of independent sub carriers, which produces the high peak to average power (PAPR) when these sub carriers are combined constructively. The different frequency signal produces a high peak power when added up in a same phase. Generally, the PAPR of the OFDM signal is known as the ratio of the maximum power to its average power of the signal.

$$PAPR = 10log10 \frac{max_{0 \le t \le T} |x(t)|^2}{P_{av}} \qquad (2)$$

Where P_{av} is the average power of the signals in time domain, and $x(t)^2$ is the maximum peak of the signal.

III. COMPLEMENTARY CUMULATIVE DENSITY FUNCTION (CCDF)

The complementary cumulative density function (CCDF) is a very effective parameter which tell us, how long a signal stay at or above the given threshold power value. With this ability of CCDF it is used to judge the efficiency of any PAPR reduction technique.CCDF is the complement of cumulative distribution function (CDF).The CCDF of the PAPR is calculates by the given below relation.

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

Where $PAPR_0$ is the given threshold value above which the signal power is exceed, Pr denotes the probability of the signal PAPR{x(n)} that exceed the given $PAPR_0$ threshold vale given in decibel [2] [8].

IV. SIGNAL SCRAMBLING TECHNIQUES

Signal scrambling techniques encodes the message signal with some random vector in such a way that it can be easily decoded at the receiver end, although signal becomes complex but it preserves the bit error rate. Many multiple signal representation technique comes under this namely Partial Transmit Sequence (PTS) and Selected Mapping (SLM) techniques. Under these techniques same signals are sent to the amplifier which has low PAPR value [6].

A. SELECTED MAPPING TECHNIQUE (SLM)

Using Selected Mapping technique (SLM), input data is partioned into sub data blocks given below of length N, and is

$$X = [X_0, X_1, X_3, \dots X_{N-1}] \qquad (4)$$

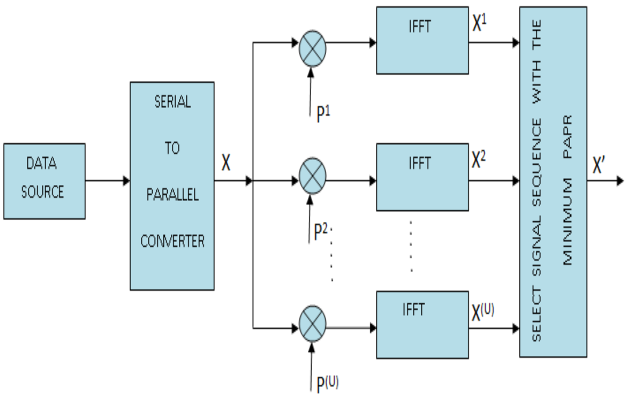

Fig.2. Block diagram of the SLM scheme

Converted into the parallel data stream using serial to parallel converter. When the data is parallel converted then OFDM data block is multiplied element by element with Phase sequence given as

$$P^u = [P^1, P^2, P^3, \dots P^U] \qquad (5)$$

Where u= [0, 1, 2….U], to make OFDM data blocks to be phase rotated. Therefore $X^{(u)}$ expressed as,

$$X^{(u)} = [X_0^{(u)}, X_1^{(u)}, \dots\dots, X_{N-1}^{(u)}]^T$$
$$= [P_0^{(u)} X_0, P_1^{(u)} X_1, \dots\dots P_{N-1}^{(u)} X_{N-1}]^T$$
$$= P^{(u)} X \qquad (6)$$

After data blocks are phase rotated, the rotated OFDM data blocks represents similar information which are unmodified OFDM data blocks, provided with known phase sequence. A block diagram of the SLM technique is shown in Fig. 2. Now frequency domain signal is converted into the time domain $X^{(u)}$, by the help of IFFT. Figure below [9], shows a butterfly of radix-2 decimation in frequency for a 16-point IFFT algorithm.

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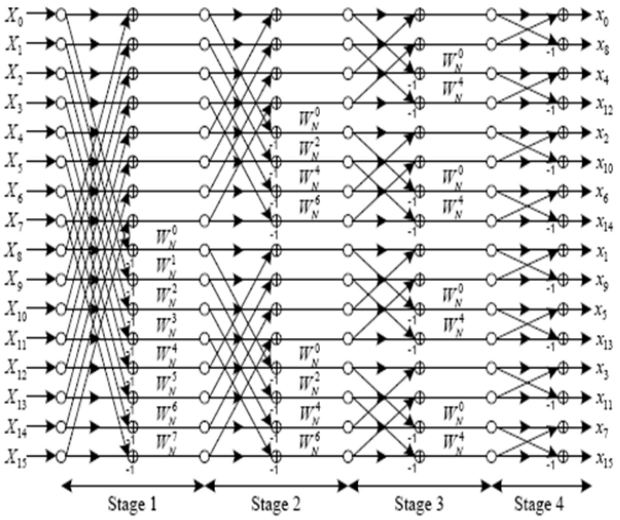

Fig.3. Illustration of butterfly diagram of Raix-2 decimation in frequency for a 16 point IFFT. [9].

In the above figure, X_k, $0 \leq k \leq 15$, denotes the frequency domain signal which given to the input of IFFT block and the output signal of the IFFT block is becomes in time domains. Stage by stage transformation is the done in this algorithm, the number of stage denoted by M is given by the relation $\log_2 N$, where N represents the total number of the input signal of the IFFT block. The output of the IFFT is in time domain and all the signal having the same information, now we have to select the OFDM signal for transmission which is having the lowest PAPR value in decibel, and to make the high power amplifier (HPA) work in the linear region. At the receiving end, the information about the phase sequence is needed to recover the actual signal which is name as side information. This side information is also transmitted with the signal, and it is occupying the spectral bandwidth so it affects the spectral efficiency.

The SLM technique have the two main drawback, first is the side information and the second is the phase sequence because to improve the PAPR performance the number of phase sequence also increased it also increase the number of IFFT block, now computational complexity and the size of the side information also increase which is not efficient for the system. To overcome these disadvantages the other technique is developed namely as Partial Transmit Sequence discussed in the next Section.[10]

B. PARTIAL TRANSMIT SEQUENCE (PTS)

According to PTS technique an N symbol input block is taken, and is divided into 'v' disjoint sub-blocks. After that the divided sub-bocks are weighted by the phase vector sequence. The selection of phase factor such that the PAPR of the resultant signal is minimum. The divided sub-block is given as.

$$X_m = [X^0, X^1, X^2, \ldots, X^{v-1}]^T \quad (7)$$

Where v = [1, 2, 3…., V], Then, the sub-blocks X are transformed into time-domain partial transmit sequence x, by using IFFT which can be represented as

$$x_m = \sum_{v=1}^{V} IFFT(X_m) \quad (8)$$

After that, these divided sequences are independently rotated by the phase factors 'P' which is given as

$$P = [P_1, P_2, \ldots, P_m] \quad (9)$$

Now the divided sub-block and phase factor are combined together to create a set of candidates.

$$X' = \sum_{m-1}^{M} P_m x_m \quad (10)$$

At the end for transmission the candidate with lowest PAPR is chosen. The principle structure of the C-PTS scheme is shown in the given below Fig.5. The objective is to optimally combine the 'V' sub-blocks to obtain the time domain OFDM signals with the lowest PAPR. Without any loss of performance, one can set P_1=1 and observe that there are 'V-1'subblocks to be optimized. Consequently, to achieve the optimal phase factor for each input data sequence (assume that there are 'W' phase factors in the phase set), combinations should be checked in order to obtain the minimum PAPR [2],[3]. Therefore, the search complexity for an optimum set of the phase factors increases exponentially with the number of sub blocks.[3],[4].

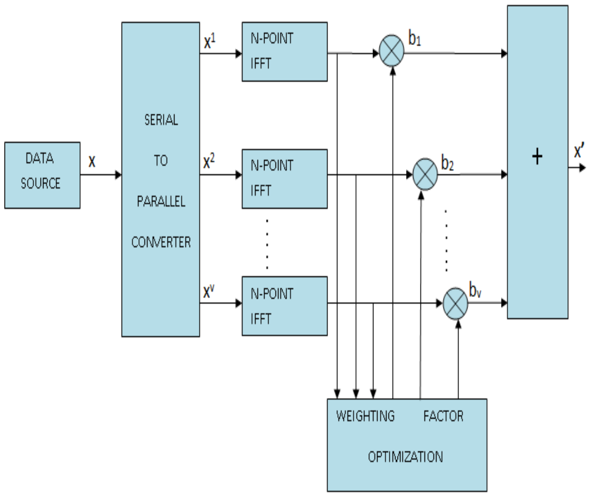

Fig. 4. Block diagram of partial transmit sequence scheme.

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V. SIMULATED EXPERIMENTAL RESULTS

Simulation Parameter	
Transmitted Data	103040
PAPR Reduction Technique	PTS & SLM
Modulator Used	QAM & QPSK
Modulation Order 'M'	2,4,8,16,32,64,128
Sub-band 'SB'	64,128,256,512
Oversampling Factor 'L'	2,4,6,8

In this section we analyze the performance of WLAN (802.11g) utilizing the PTS and SLM technique in MATLAB (version 7.140.739).The above table illustrates the parameter over which the simulation is performed. In this paper, firstly the Graphical user Interface is created (GUI), after that write the code on the shown button. The two input option are facilitate in this experiment, firstly the recorded voice signal and secondly the load option is for loading the voice file.
The performance comparison of two well known PAPR reduction techniques, PTS and SLM is shown in Fig.5. The evaluation parameter used is CCDF, the CCDF curve shows comparison between the technique while utilizing the 10340 input data sequence. For all the simulation result two modulator are used QPSK and QAM with different Modulation Order (M).

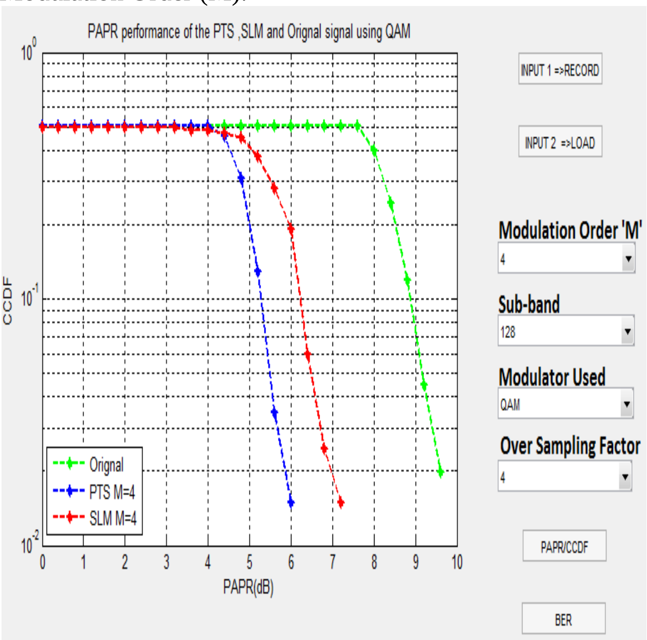

Fig. 5. CCDF curve of Original, SLM & PTS schemes, while using QAM modulator.

The table shown below gives us the PAPR value in decibel of PTS, SLM and Original OFDM signal at the parameter listed below. The PTS PAPR reduction technique shows the best result in comparison with SLM and Original OFDM signal at the listed parameter in the TABLE 1.

TABLE 1
PAPR Performance Comparison In PTS,SLM & Original Signal Using QAM

Technique Used	Modulation Order 'M'	Oversampling Factor 'L'	Sub-band "SB"	PAPR In db
PTS	4	4	128	6.0
SLM	4	4	128	7.2
Original signal	4	4	128	9.7

The same simulation experiment is performed while using different modulator QPSK. At the same parameter listed in the TABLE 2.

TABLE 2
PAPR Performance Comparison In PTS,SLM & Original Signal Using QPSK

Technique Used	Modulation Order 'M'	Oversampling Factor 'L'	Sub-band "SB"	PAPR In db
PTS	4	4	128	5.8
SLM	4	4	128	7.4
Original signal	4	4	128	12

Still the same result is observed while using the QPSK, the PTS is performed better than the SLM and the Original OFDM signal. In QPSK modulator the PAPR reduction is better as compared to QAM shown in the CCDF curve Fig.6.the lowest PAPR value in QPSK is 5.8 decibel and in QAM is 6 decibel shown in TABLE 2 & 3.

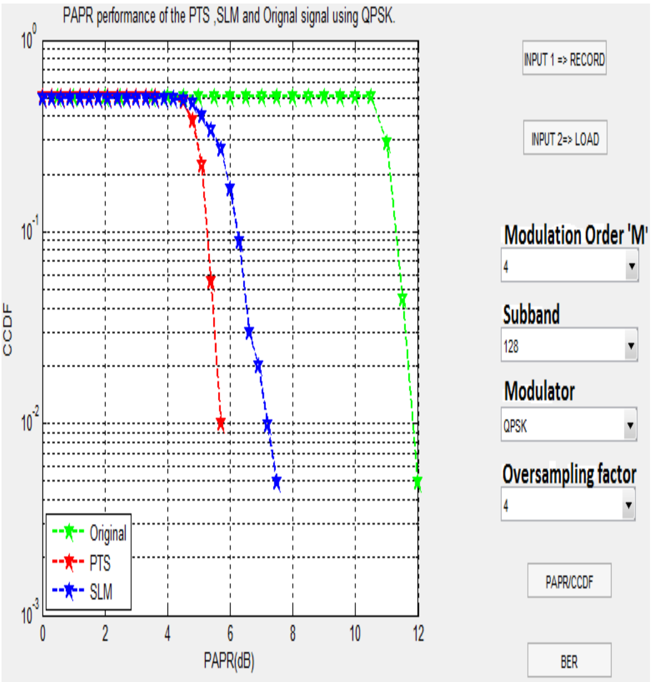

Fig. 6. CCDF curve of Original, SLM & PTS schemes, while using QPSK modulator.

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Now in the next experiment, the modulation order of QAM is varied and keeping the other parameter constant, here it is observed that as the modulation order is increased, the PAPR of the PTS signal is reduced simultaneously step by step shown in Fig.7. The difference in the PAPR value is shown in the TABLE 3 the modulation order is increased up to 128.

TABLE 3
PAPR Performance Of PTS Using QAM At Different Modulation Order 'M'

Modulation Order 'M'	PAPR In db
4	6.0
8	4.6
16	4.3
32	3.8
64	3.6
128	3.7

Now in the next step the experiment have performed on the QPSK modulator and it is observed that the PAPR is decreased as the modulation order 'M' is increased shown in Fig.8. when compare the PTS technique in different modulator it is observed that the QAM is perform better as compared to the QPSK, the lowest PAPR vale of QAM is 3.7db as compared to QPSK is 5.32 at modulation order 'M=128', the other PAPR values are listed in the TABLE 4.

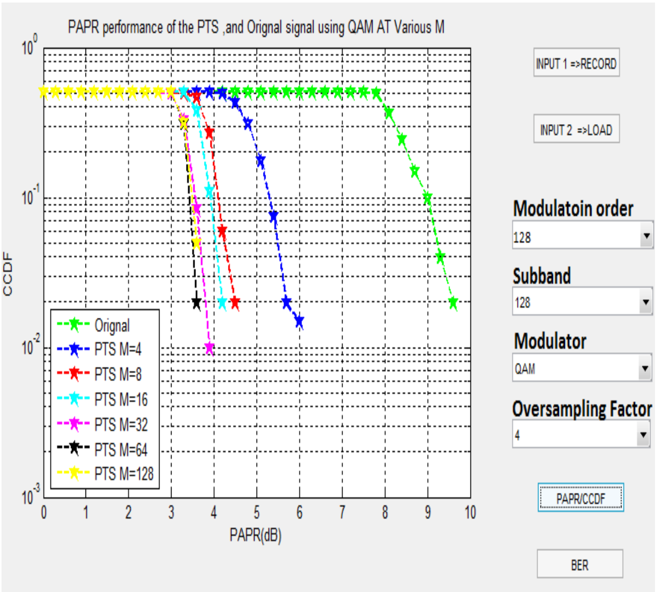

Fig. 7. CCDF curve of PTS schemes, while using QAM modulator at different Modulation Order 'M'.

TABLE 4
PAPR Performance Of PTS Using QPSK At Different Modulation Order 'M'

Modulation Order 'M'	PAPR In db
4	5.70
8	5.65
16	5.61
32	5.40
64	5.34
128	5.32

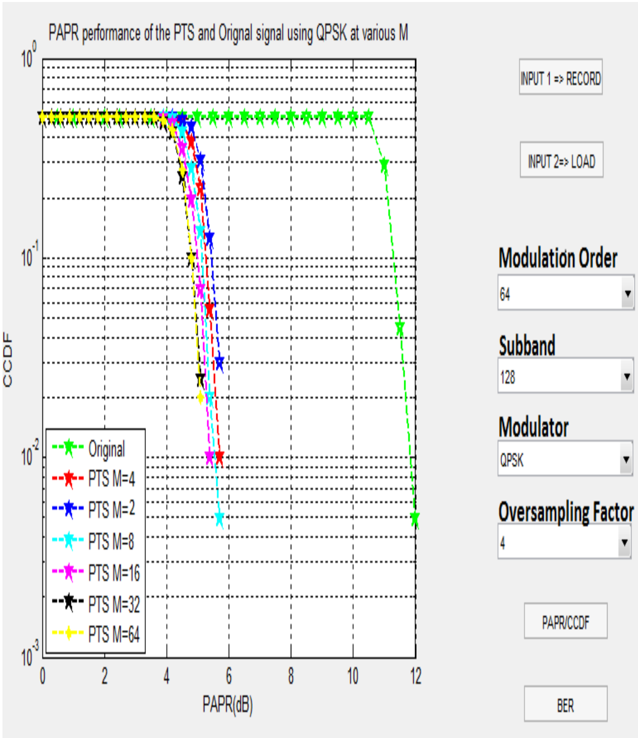

Fig. 8. CCDF curve of PTS scheme, while using QPSK modulator at different Modulation Order 'M'.

Now in the final experiment, the different parameter namely Sub-band 'SB', oversampling factor 'L', and modulation order 'M' are varied, and found that as the parameter is increased the PAPR is also increased. It is observed that if the modulation order is increased alone the PAPR value is decreased step by step but if the sub-band is increase with the modulation order the value of PAPR is increased, the values are listed in the table below. The two modulator are used in this experiment namely QAM and QPSK. The different value of PAPR using QPSK modulator is shown in the TABLE 5.

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TABLE 5

Performance Analysis of PTS vs Orignal signal Using QPSK at Various Parameter

Modulation Order 'M'	Subband	Oversampling Factor 'L'	PAPR OF PTS Signal in db	PAPR Of Orignal signal in db
4	64	2	5.0	13.6
8	128	4	5.8	-
16	256	6	7.3	-
64	512	8	8.8	-

The CCDF curve of the QPSK modulator is shown in Fig.9.in this figure it is well cleared that as we increased the different parameter listed in the TABLE 5 the curve of the PAPR is increased step by step and it gives maximum PAPR value of 8.8 decibel at modulation order 'M=64',sub-band 'SB=512'an oversampling factor 'L=8'.

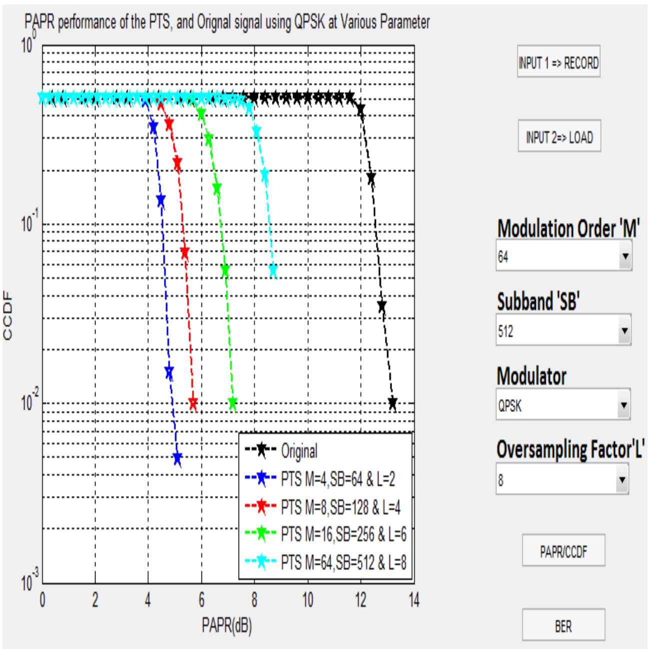

Fig. 9. CCDF curve of PTS & Original OFDM signal, while using QPSK modulator at different parameter.

Now in the next step the experiment has performed on the QAM modulator and it is observed that the QAM perform better than the QPSK if the PAPR values are compared at same parameter. The lowest PAPR value of QAM modulator is 4.5 and for QPSK is 5.0decibel. The CCDF curve of the PTS and original OFDM signal using QAM modulator is shown in Fig.10. The other PAPR values over QAM modulator are listed in the TABLE 6.

TABLE 6

Performance Analysis of PTS vs Orignal signal Using QAM at Various Parameter

Modulation Order 'M'	Subband	Oversampling Factor 'L'	PAPR OF PTS Signal in db	PAPR Of Orignal signal in db
4	64	2	4.5	10.8
8	128	4	4.8	-
16	256	6	7.0	-
64	512	8	8.4	-

We next investigate the BER performance for PTS over AWGN channel for sub-block, with QAM modulation which is presented in Fig. 11. For comparison purpose, graph clearly shows that the BER curves of the PTS scheme & original OFDM signal over original AWGN has almost equal Bit Error Rate (BER) transmission signal with probability ratio of 9.8 dB respectively. Furthermore we analyzed the BER performance for SLM over AWGN channel for sub-block, with QAM modulation which is presented in Fig. 12.

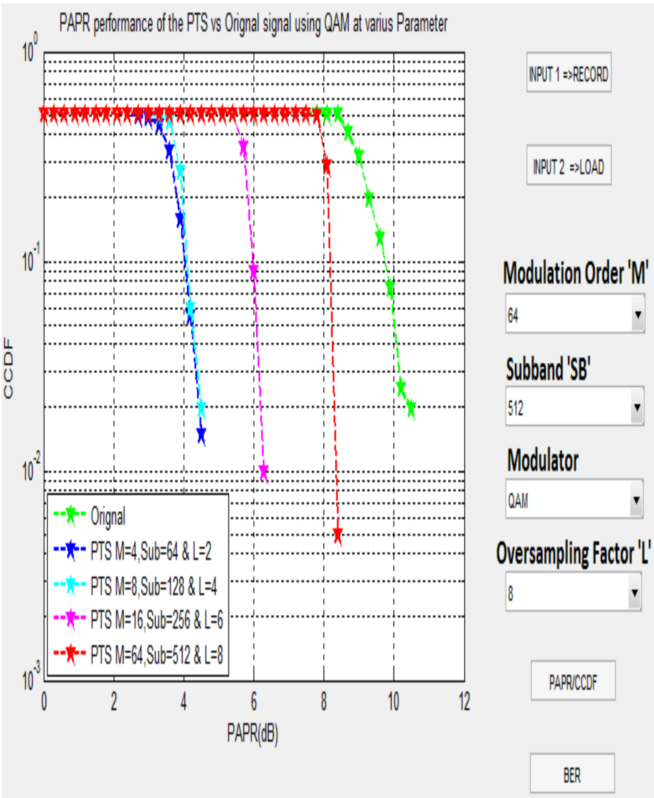

Fig. 10. CCDF curve of PTS & Original OFDM signal, while using QAM modulator at different parameter.

For comparison purpose, graph clearly shows that the BER curves of the SLM scheme & original OFDM signal over original AWGN has almost equal Bit

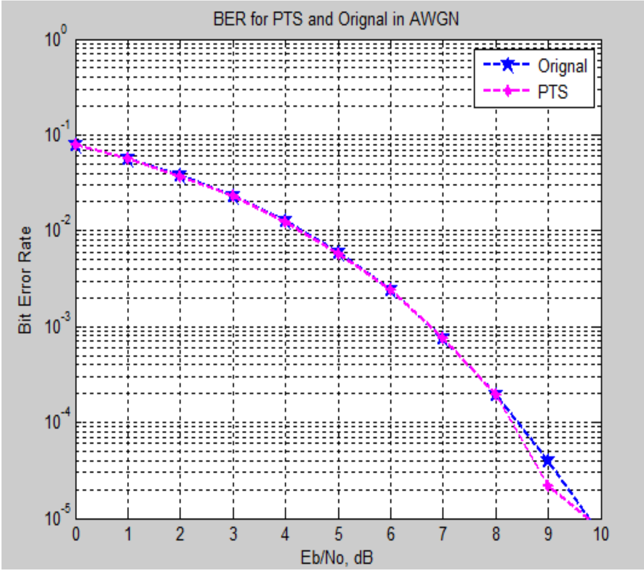

Fig. 11. BER curve of PTS & Original OFDM signal, while using QAM modulator.

Error Rate (BER) transmission signal with probability ratio of SLM is 13.9 dB and for original OFDM signal is 13.87 dB respectively.

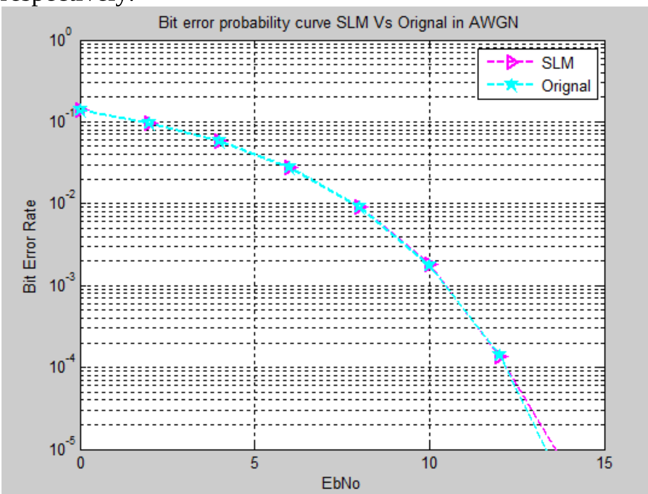

Fig. 12. BER curve of PTS & Original OFDM signal, while using QAM modulator.

VI. CONCLUSION

In this paper, two PAPR reduction techniques are analyzed and found that the PTS has shown better performance as compared to SLM in 802.11g, as we increase the modulation order of the modulator the PAPR is decreased simultaneously. The two modulator are used in the experiments and found that the QAM modulator performs the better PAPR reduction as compared to QPSK if the modulation order 'M is increased'. The sub-band also has a great impact on PAPR ,if the number of sub-band is increased the PAPR of the system is also increased and it increased the complexity of the system because the number of IFFT blocks operation is also increased.

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