Development of Efficient Orthogonal Frequency Division Multiplexing System with Lower PAPR using Filtered Partial Transmit Sequence

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Abstract - Maintaining the sufficient power of a signal is the least requirement of an system. To maintain the power of signal throughout transmission over communication system and it can be achieved by keeping the average power of the signal and it is in terms of peak to average power ratio (PAPR). i.e. if PAPR is reduced the performance of the system will improve. In this work a advanced and efficient methodology is used which utilizes Filtered - PTS algorithm with difference carrier sizes to reduce the PAPR. From the simulated results performed for variable data lengths to analyze the performance of the proposed approach. Simultaneous analyzing the performance of the system in terms of PAPR.

Keywords - Orthogonal frequency division multiplexing (OFDM), peak-to-average power ratio (PAPR), selective mapping (SLM), and partial transmit sequence (PTS), high power amplifier (HPA), Filtered-PTS and CCDF etc.

I. INRODUCTION

The demand of high data rate services has been increasing very rapidly and there is no slowdown in sight. The data transmission includes both wired and wireless medium. Often, these services require very reliable data transmission over very harsh environment. Most of these transmission systems experience much degradation such as large attenuation, noise, multipath, interference, time variance, nonlinearities and must meet the finite constraints like power limitation and cost factor. One physical layer technique that has gained a lot of popularities due to its robustness in dealing with these impairments is multi-carrier modulation technique. In multi-carrier modulation, the most commonly used technique is Orthogonal Frequency Division Multiplexing (OFDM); it has recently become very popular in wireless communication.

OFDM is a special multi-carrier modulation (MCM) technique. The main idea of OFDM is to divide a high speed data stream into several low speed data streams and modulate on subcarriers that are orthogonal with each other. In this way, OFDM makes the symbol period longer than the delay spread, which avoids the small scale fading and intersymbol interference (ISI) [1]. Moreover, OFDM is spectrally very efficient since the subcarriers have significant overlap in the frequency domain [2]. OFDM is less sensitive to frequency selective fading, and transmit high-speed data with higher spectral efficiency. Thus, more and more people have been focusing on OFDM. OFDM has been widely used in wideband communication systems since the 1990s, such as digital audio broadcasting (DAB) , high-bit-rate digital subscriber line (HDSL), asymmetric digital subscriber line (ADSL. Currently, OFDM is the core technique of wireless local area networks (WLAN) , wireless local and metropolitan area networks (WMAN), and 4G-LTE networks

Unfortunately the major drawback of OFDM transmission is its large envelope fluctuation which is quantified as Peak to Average Power Ratio (PAPR). Since power amplifier is used at the transmitter, so as to operate in a perfectly linear region the operating power must lies below the available power. For reduction of this PAPR lot of algorithms have been developed. All of the techniques has some sort of advantages and disadvantages. Clipping and Filtering is one of the basic technique in which some part of transmitted signal undergoes into distortion. Also the Coding scheme reduces the data rate which is undesirable. If we consider Tone Reservation (TR) technique it also allows the data rate loss with more probable of increasing power. Again the techniques like Tone Injection (TI) and the Active Constellation Extension (ACE) having a criteria of increasing power will be undesirable in case of power constraint environment. If we go for the Partial Transmit Sequence (PTS) and Selected Mapping (SLM) technique, the PTS technique has more complexity than that of SLM technique.

This Selected Mapping is one of the promising techniques due to its simplicity for implementation which introduces no distortion in the transmitted signal. It has been described first in i.e. to be known as the classical SLM technique. This technique has one of the disadvantages of sending the extra Side Information (SI) index along with the transmitted OFDM signal. Which can be avoided using a special technique described in?

The concentration of this research work is especially upon the Selected Mapping technique. Here the three important analysis of this technique has been done. Out of them one is, how to avoid the transmission of extra information along with the OFDM signal which will be studied. Avoiding the SI index Transmission. Another one important analysis of this technique is how to reduce the computational complexity. Also one important analysis is to be done about the mutual independence between the alternative phases vectors used in this technique. The block diagram of an analog OFDM is shown in Fig. 1.1. In an OFDM system with N subcarriers, suppose that the complex symbol Xn is the signal point from the quadrature phase shift keying (QPSK) or quadrature amplitude modulation (QAM) signal constellation that is modulated on the nth subcarrier. The transmitted OFDM signal can be expressed as follows

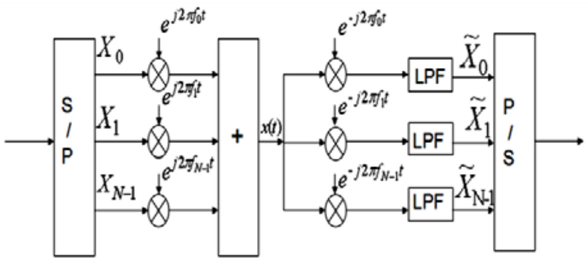

Figure 1.1 Basic block diagram of OFDM.

In practice, the subcarriers may have different phases and amplitudes because of different complex symbols; however, the subcarriers are mutually orthogonal over the Symbol interval T

II. SYSTEM MODEL

It is known that OFDM is robust to the frequency selective fading channels . However, one of the major problems with multicarrier modulation (such as OFDM) is the relatively high peak-to-average- power ratio (PAPR) that is inherent in the transmitted signal. OFDM signals with high PAPR when transmitted through a nonlinear device, such as a high power amplifier (HPA) or a digital-to-analog convertor (DAC) can suffer in-band distortion and out-of-band emission (spectral regrowth). The first effect degrades the BER performance of the system while the latter effect causes interference to other users and thus decreases the cellular capacity of the system. To avoid such undesirable nonlinear effects, in order to transmit signals with high PAPR without any nonlinear distortions, the radio frequency power amplifier must operate in a wider dynamic linear range which leads to a lower power efficiency, which is a significant burden, especially in mobile terminals. Also, the design for A/D and D/A converters is more challenging due to the high PAPR

PAPR reduction is carried out in the OFDM modulator. The following two PAPR schemes are considered multiplicative since the input symbols are multiplied by phase rotation factors in the frequency domain:

- Selected mapping (SLM)
- Partial transmit sequence (PTS)

In contrast, the following three schemes are classified as additive since PAPR is reduced by adding some peak reduction vectors to the original input symbols:

- Tone Reservation (TD)
- Clipping
- Peak cancelling

Partial Transmit Sequence

In PTS, the input symbol sequences X are partitioned into V disjoint sub blocks of clusters

$$X^{\mho} = [\boldsymbol{X_0^{\mho}}, \boldsymbol{X_1^{\mho}}, \boldsymbol{X_2^{\mho}} ,.. \boldsymbol{X_{N-1}^{\mho}}]$$

Where ℧ = 1,2,…….v(disjoint means for each k,)

where v = 1, 2,...V (disjoint means for each k, 0 < k < N — 1, Av,k = 0 expect for a single v). The block diagram of PTS is shown in Fig.2.1 below

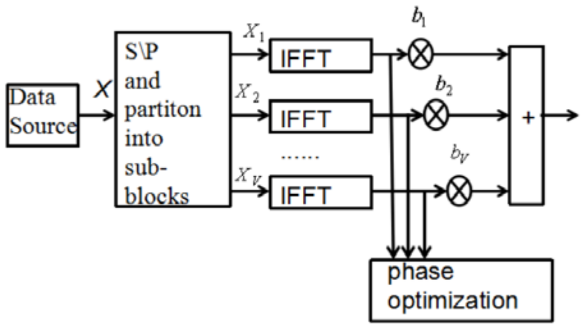

Figure 2.1 the block diagram of PTS

The sub blocks can be represented as

$$X = \sum_{v=1}^{V} X_v.$$

After a set of IFFT operations, the time domain sub-vectors $X\mho = [X_0^{\mho}, X_1^{\mho}, X_2^{\mho}, .. X_{N-1}^{\mho}]$

Where ℧ =1,2, ...V are multiplied by a set of phase rotation factors b_v^m, whereb_v^m =$e^{j\theta v}$ In general cases b_v^m is taken from a phase rotation factors alphabet W, which is [1,-1] or [1,-1,i,-i] for simplicity. Then the sub-vectors are added and a PTS OFDM signal is generated, the PTS OFDM signal

X^m = [X_v^m, X_v^m, ... X_{N-1}^m] can be expressed as follows:

$$x^m = \sum_{v=1}^{V} b_v^m x_v,$$

Where $b^m = [,b_1^m,\ b_2^m,\ b_3^m,, \ldots\ b_v^m,]$, 1 A m < M,M = |W|V-1 are called phase rotation factors. Then, M different candidate PTS OFDM signals are compared, and the system selects one that has the minimum PAPR for transmission, as

$$\tilde{m} = \arg \min_{1 \le m \le M} \mathrm{PAPR}\{x^{(m)}\}$$

In order to recover the input data, the receivers needs to know the index of rain general cases, the system needs to do exhaustive search to find the best phase rotation factors combination, for example, if there are 4 sub blocks, the system has to find the best phase rotation factors from 2(4-1) = 8 candidate sequences (if W = 2 and the first element of the phase rotation factors is fixed to 1). In other words, the performance and the computational complexity of the PTS scheme is dominated by the number of subblocks and candidate sequences. Hence, the conventional PTS scheme has to suffer high computational complexity in order to get an efficient PAPR reduction performance.

Selected Mapping

SLM is another PAPR reduction scheme based on probability. It is similar to PTS, which uses phase rotation factors to change the distribution of the signal. SLM generates enough number of candidate sequences, and then selects one that has the minimum PAPR for transmission. The difference between SLM and PTS is that in PTS the original data are rotated by phase rotation factors in subgroups after IFFT while in SLM the original data are rotated one by one before IFFT. This subsection presents a brief introduction about the SLM scheme in PAPR reduction for OFDM System.

The concept of the SLM was firstly presented in. The conventional SLM scheme is a distortion-less scheme for PAPR reduction. In the SLM scheme, U

Copies of data, which have equivalent information, are multiplied by U different phase rotation factors. Then the algorithm selects the sequence with minimum PAPR for transmission. The block diagram of the SLM is as follow:

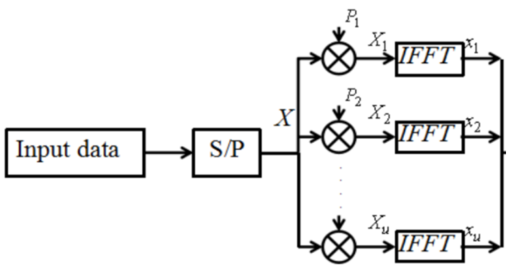

Fig. 3.4: The block diagram of the conventional SLM

The system generates U signal sequences X, which contain the same information. Then the system multiplies the U signal sequences by U different phase rotation sequences with length N,

III. PROPOSED METHODOLOGY

When in time domain all the *N* subcarriers are added up constructively, they produce a peak power that is *N* times greater than the average power of the signal. The *PAPR* is calculated by the following equation

$$PAPR = \frac{\max(x^2(t))}{\mathrm{mean}(x^2(t))}$$

Where $x(t)$ is the amplitude of the signal.

The peak power of the OFDM signal, regarding the worst case when all the subcarriers are added-up constructively, is the sum of all the *N* subcarriers: 1 ・ *N* = *N*. The mean power of the OFDM signal is the sum of all the values of the signal, which is actually *N*, divided by the total number of subcarriers, which is also *N*. Therefore the maximum *PAPR* is:

$$PAPR_m = \frac{N}{\frac{N}{N}} = N$$

This maximum *PAPR* increases whenever the number of subcarriers increases. Thus, if *N* →¥⇒*xk* becomes Gaussian distributed, for *k* = 1, ..,*N*, which means that

$$P(x_k < PAPR_m) < 1$$

When the number of subcarriers tends to ¥ this probability gives

$$\lim_{N \to \infty} \prod_{k=1}^{N} P(x_k < PAPR_m) = 0$$

If the above statement represents the probability of a signal *xk* to have a smaller *PAPR* than the given one *PAPRm*, the probability of the signal to have a *PAPR* greater than *PAPRm* is

$$\lim_{N \to \infty} (1 - \prod_{k=1}^{N} P(x_k < PAPR_m)) = 0$$

The above statement can be better understood shows the complementary cumulative distribution function (CCDF) of an OFDM signal. The CCDF denotes the probability of a signal to have a higher *PAPR* than a threshold *PAPRm*, so in the figure, horizontal and vertical axes represent the threshold values of *PAPR* and the CCDF respectively.

The PAPR of the OFDM based wireless communication system is reduced to achieve better performance of the system. The proposed methodology is shown in the figure below. The major sections (blocks) of the OFDM based wireless communication system considering AWGN channel displayed in the Fig. 3.1.

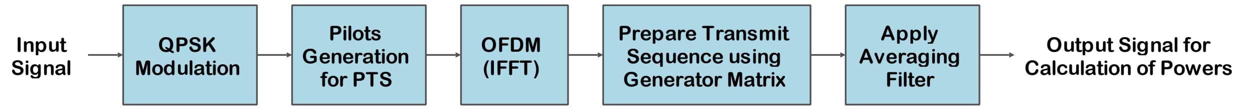

Fig. 3.1 Block Diagram of Proposed Lower PAPR OFDM System

The first block modulates the data using QPSK-modulation. The modulated signal followed by pilot generation block and pass through OFDM system in which IFFT operation is performed after that transmitting signal is generating with the help of generator matrix followed by filtering. After that all the powers are calculated to get the PAPR.

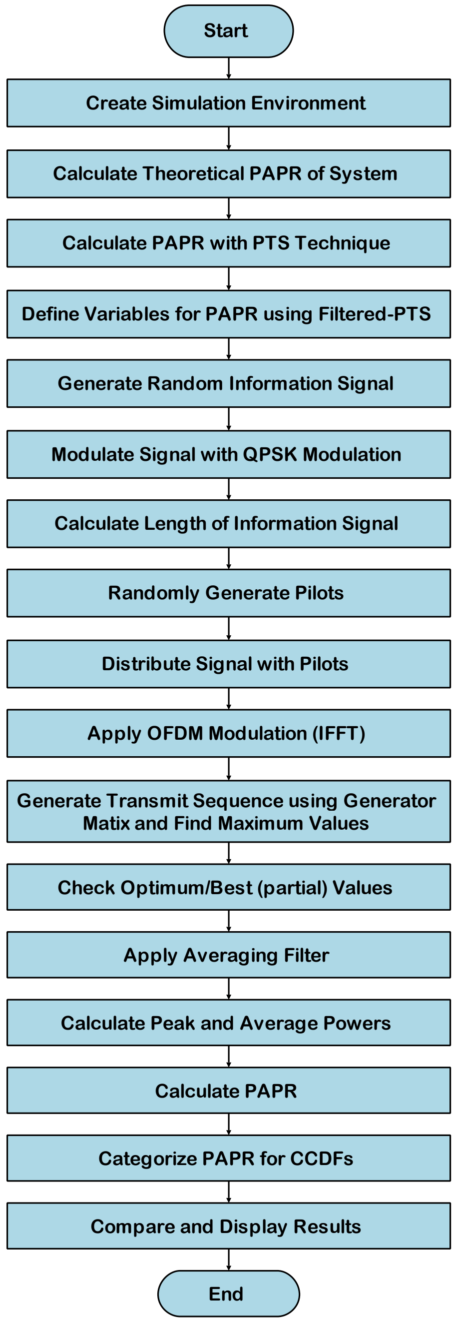

Fig. 3.2 Flow chart of proposed methodology to reduce PAPR

The flowchart of the proposed system is explained in the Fig. 3.2 where execution of the simulation model to reduce PAPR is shown. The steps are as follows:

Step 1: Variables need to be initialized to create simulation environment

Step 2: Generate random data to transmit through system

Step 3: QPSK modulation is applied on Signal

Step 4: Randomly Generate Pilots

Step 5: Distribute Signal with Pilots

Step 6: Apply IFFT operation i.e. OFDM Modulation

Step 7: Generate Transmit Sequence using Generator Matrix

Step 8: Find Optimum/Best (partial) Values

Step 9: Applying Averaging Filter

Step 10: Calculate Peak and Average Powers

Step 11: Calculate PAPR

Step 12: Categorize PAPR for CCDFs

Step 13: Compare and display results

IV. SIMULATION RESULTS

The proposed system is explained in the previous section is simulated on the simulation tool and shown performance of the system in terms of peak to average power ratio (PAPR) vs. complementary cumulative distribution function (CCDF).

The CCDF computes the power complementary cumulative distribution function (CCDF) from a time domain signal. The CCDF curve shows the amount of time a signal spends above the average power level of the measured signal, or equivalently, the probability that the signal power will be above the average power level.

$$CCDF = P(PAPR > PAPR_0) = 1 - (1 - \exp(PAPR_0))^N$$

The *PAPR* is calculated by the following equation

$$PAPR = 10\,log_{10}\left[\frac{max(x^2(t))}{mean(x^2(t))}\right]$$

Where *x(t)* is the amplitude of the signal.

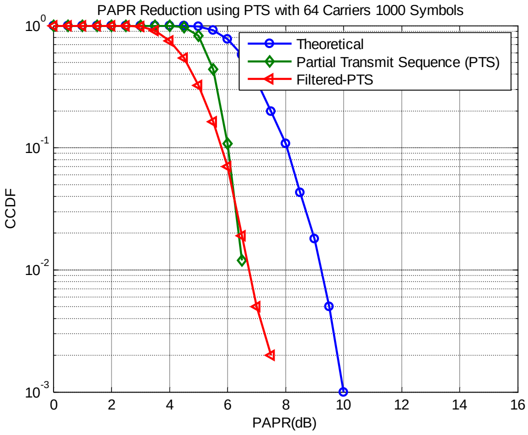

Fig. 4.1 PAPR Curve of Proposed Methodology using Partial Transmit Sequence with 64 Carriers and 1000 Symbols

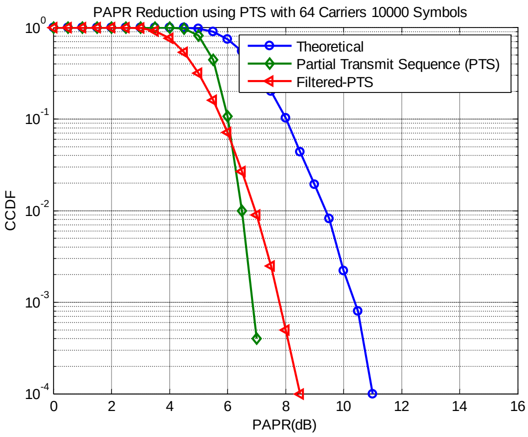

Fig. 4.2 PAPR Curve of Proposed Methodology using Partial Transmit Sequence with 64 Carriers and 10000 Symbols

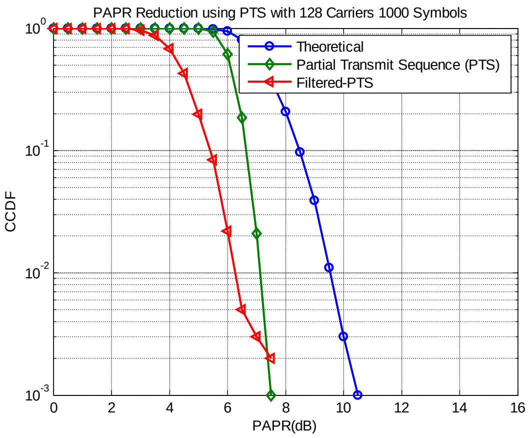

Fig. 4.3 PAPR Curve of Proposed Methodology using Partial Transmit Sequence with 128 Carriers and 1000 Symbols

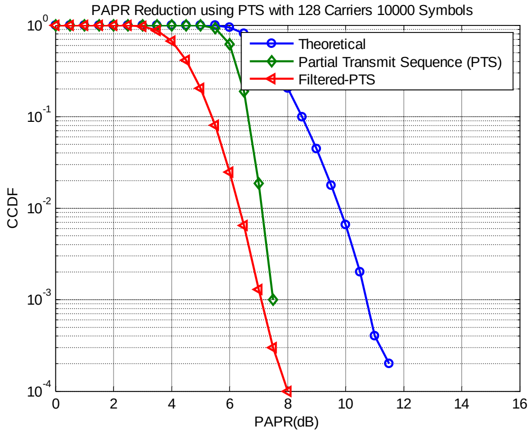

Fig. 4.4 PAPR Curve of Proposed Methodology using Partial Transmit Sequence with 128 Carriers and 10000 Symbols

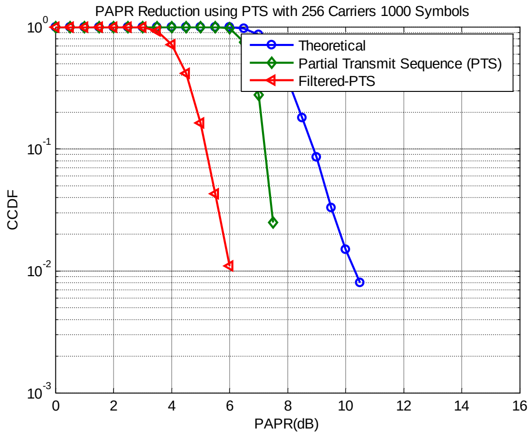

Fig. 4.5 PAPR Curve of Proposed Methodology using Partial Transmit Sequence with 256 Carriers and 1000 Symbols

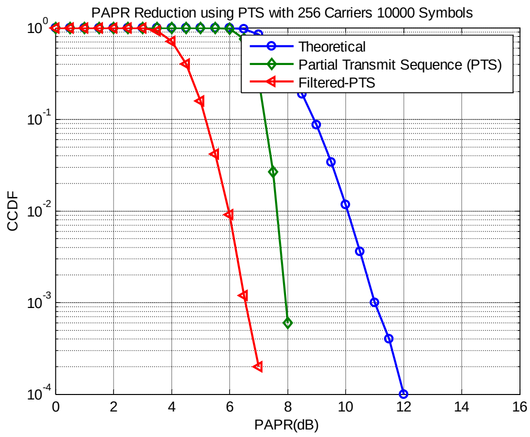

Fig. 4.6 PAPR Curve of Proposed Methodology using Partial Transmit Sequence with 256 Carriers and 10000 Symbols

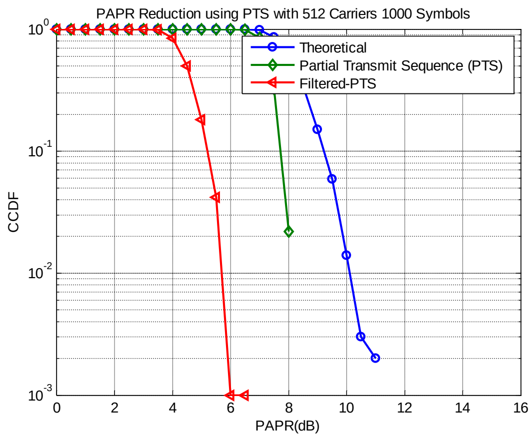

Fig. 4.7 PAPR Curve of Proposed Methodology using Partial Transmit Sequence with 512 Carriers and 1000 Symbols

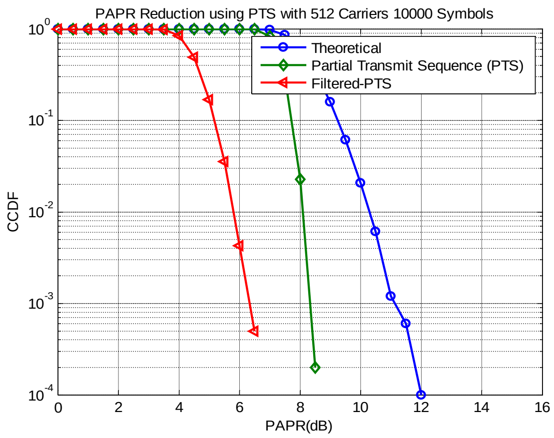

Fig. 4.8 PAPR Curve of Proposed Methodology using Partial Transmit Sequence with 512 Carriers and 10000 Symbols

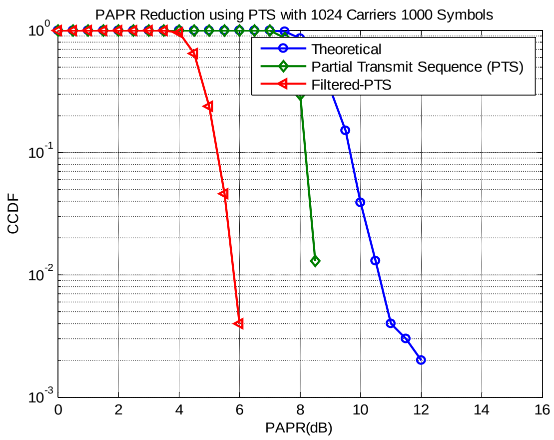

Fig. 4.9 PAPR Curve of Proposed Methodology using Partial Transmit Sequence with 1024 Carriers and 1000 Symbols

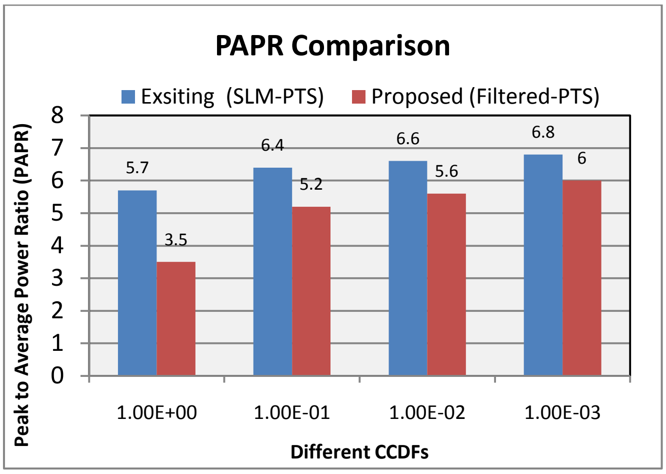

Fig. 4.10 PAPR Comparison with Existing Work

Table 1: Comparison of PAPR

CCDFs	Previous using SLM-PTS	Proposed Technique
10^0	5.7	<= 3.5
10^{-1}	6.4	5.2
10^{-2}	6.6	5.6
10^{-3}	6.8	6

V. CONCLUSION AND FUTURE SCOPE

The simulation of proposed system and its performance graphs are shown in the figures from 4.1 to 4.10. From the simulation results it can be concluded that the PAPR of the system is lower with the increase in the number of carriers not symbols. Because from the graphs when number of symbols increases PAPR decreases but performance does not drop that much. The filtered partial transmit sequence definitely the future methodology to improve PAPR further with integration with the other techniques.

REFERENCES

[1] S. Katam and P. Muthuchidambaranathan, "Low Complexity SLM-PTS Method for Reduction of PAPR in OFDM Systems," Eco-friendly Computing and Communication Systems (ICECCS), 2014 3rd International Conference on, Mangalore, 2014, pp. 233-237.

[2] Y. Rahmatallah and S. Mohan, "Peak-To-Average Power Ratio Reduction in OFDM Systems: A Survey And Taxonomy," in IEEE Communications Surveys & Tutorials, vol. 15, no. 4, pp. 1567-1592, Fourth Quarter 2013.

[3] Luqing Wang and Tellambura.C, "A simplified clipping and filtering technique for PAPR reduction in OFDM systems," IEEE signal processing let., vol.12, no.6, pp.453-456, June. 2005

[4] Muller S. H and Huber .J. B, "A comparison of peak power reduction schemes for OFDM,"IEEE Global Telecommunications Conference, vol.1, pp.1-5, 1997.

[5] Cimini L.J and Sollenberger N.R, “Peak-to-average power ratio reduction of an OFDM signal using partial transmit sequences,” IEEE International Conference on commun., vol.1, pp.511-515,1999

[6] Jones A.E , Wilkinson T.A and Barton S.K, “Block coding scheme for reduction of peak to mean envelop power ratio of multicarrier communication schemes,” Electronics let.,vol.30,pp.2098-2099, Dec. 1994

[7] Wen-Xiang Lin et al., “Modified selective mapping technique for PAPR reduction in OFDM systems,” ITS telecommunications, pp.764-768,2012.

[8] M.S. Hussain , S.Ahmed , E.Ullah and M.A.Islam, “PAPR Reduction of OFDM System Through Iterative Selection of Input Sequences,” International Journal of Electronics Communication and Computer Technology(IJECCT),vol.3(2), 2013.

[9] C. L. Wang et al., “Low-Complexity selected mapping schemes for peak-to-average power ratio reduction in OFDM systems,” IEEE Transactions on Signal Processing, vol.53,no.12, pp.4652-4660, Dec 2005.

[10] Chih-Peng Li et al., “Novel Low-Complexity SLM Schemes for PAPR Reduction in OFDM Systems,” IEEE Transactions on Signal Processing., vol.58, no.5, pp.2916-2921, May 2010.