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Partial Transmit Sequences for PAPR Reduction using Hybrid Inverse Shifting Algorithm in OFDM Systems

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Abstract: Orthogonal frequency division multiplexing (OFDM) is a widely adopted technique in many wireless communication systems as it divides the wideband channel into several narrowband signals that avoids frequency selective fading. High peak-to-average power ratio (PAPR) has always been a main issue in that leads to a severe nonlinear distortion in practical hardware implementations of high power amplifier, which can be avoided by the use of Partial Transmit Sequence (PTS) method. However, it produces computational complexity and transmission of several side information bits. In this paper, we proposed a modified hybrid technique based on the inverse shifting method that can reduce computational complexity to a great extent with very little or no loss in the PAPR reduction. Simulation results and verifications have showed that the proposed technique has performed well in managing Bit Error Rate (BER), under both Gaussian noise (GN) channel and Rician channel comparisons. It has also achieved a significant reduction in PAPR without degrading the power spectral level and promotes efficient signal transmission.

Keywords: *Bit Error Rate (BER), Gaussian noise (GN), Orthogonal frequency division multiplexing (OFDM), Partial Transmit Sequence (PTS), Peak-to-Average Power Ratio (PAPR).*

1. INTRODUCTION

Wideband wireless communications have experienced, a fast growth and promise the better performances of the system. Multicarrier (MC) modulation is a widely adopted technique in wireless communications because of its advantages. The fact that the subcarriers, which are orthogonal, allows the usage of the Fourier transform without introducing inter-carrier interference (ICI). The advancements in digital signal processing and large scale integrated circuits allow efficient and cost-effective implementation of the fast Fourier transform (FFT) operations making Orthogonal Frequency Division Multiplex (OFDM) an attractive solution for wireless channels. OFDM is a multicarrier modulation method with an orthogonality of individual subcarriers. The main drawback of OFDM systems is their high PAPR. In this paper, we focus on the issue of how to overcome the PAPR problem [1], [2]. This can be done by applying the PAPR reduction method. High PAPR degrades performance of OFDM signals by forcing the analog amplifier to work in the nonlinear region [3]. This produces distortion in the signal and make the amplifier to consume more power. The result will be increment in the cost of the system and reduction in efficiency. To overcome this impact, several techniques for reducing the PAPR have been proposed. Some of the most important techniques are Selected Mapping (SLM) [4], [5] which is in the frequency domain and Partial Transmit Sequence (PTS) [6-10] which is in the time domain.

The combination of signal distortion method and coding methods along with multiple signalling and probabilistic techniques failed to achieve better PAPR and crust factor. Thus, it is needed to improve the Signal Scrambling Techniques in the time domain for producing a better OFDM signal. PTS technique is adapted to improve the efficiency, complexity and to deduce the consumption of power in transmitter amplifier in OFDM signal transmission. Modern communication systems utilize a wide range of transmission for mobile internet and broadband services, which leads to increases the number of subcarrier used in OFDM. Multiple carriers (MC) in OFDM increase the power consumption of the amplifier at the time of transmission. Here, we present a Hybrid Inverse Shifting - PTS (HIS-PTS) based PAPR reduction technique for OFDM systems. Out band frequency signals are shifted to desired phase and pass-through FFT and in-band frequency signals are passes into inverse FFT filter. Simulation results show that the HIS-PTS method is reduced PAPR significantly, which decreases as the number of sub carrier and filtering level is increased.

2. RELATED WORK

P. Varahram et al. [11] proposed a novel PAPR scheme called Dummy Signal Insertion with Enhanced Partial Transmit Sequence (DSI-EPTS). By applying the DSI-EPTS scheme, PAPR performance was improved compared to the traditional PTS method even though the hardware complexity is even better. By reducing the complexity, the cost of the system was reduced and reducing the PAPR results in power efficiency increment. The drawback of the DS-EPTS scheme is the degradation in spectral efficiency due to the insertion of dummy sequence.

Z. Chen et al. [12] proposed a new genetic algorithm based partial transmit sequence (NGA-PTS) to cut down the PAPR of OFDM. As, the search complexity of the optimum PTS (OPTS) method was huge for the typical number of sub-blocks. So, some artificial intelligence methods, for example, genetic algorithm technique, and particle swarm optimization, were introduced to reduce the complexity. To achieve an improved solution, a phase factor optimal pair technique and an abandon/introduction new chromosome technique were also proposed in GA. The simulation outcome exhibited that the proposed method obtained a noteworthy enhancement over the TGA-PTS method in PAPR. Additionally, by using the inherent diversity of constellation for every OFDM candidate, in the receiver part, the proposed method permitted data recovery without any side information.

X. Qi et al. [13] proposed a method called as T-PTS to reduce the partial transmit sequence (PTS) complexity on the basis of W-way tree. With the nodes in the tree corresponding to phase weighting factors and layers corresponding to sub-blocks, all the candidates can be computed by the combination of layers and weighting factors on the paths from the root to the leaves. In every layer, they order the nodes in a 2W period, and set the last W nodes bilateral symmetry with the first W nodes, where only one weighting factor on the paths from the root to the neighbour leaves was different. In this manner, all candidate signals can be achieved by accumulating the difference signal on the last candidate that can lessen the complexity radically. The simulations result showed that the proposed T-PTS does not have any reduction in the performance on PAPR.

X. Wu et al. [14] analysed the independence of candidates in IP-PTS in detail and finds the effective phase factor vectors. So, to improve the PAPR performance of IP-PTS, a conjugate IP-PTS (C-IP-PTS) scheme was proposed by this research work. At the time of the execution of the conjugate operations on some sub-blocks, the number of candidates was increased. Due to the conjugate characteristic of the Discrete Fourier transform (DFT), the additional inverse DFT could be avoided. Complexity can be again lowered through enhancing the conjugate sequence. Simulation outcomes showed that C-IP-PTS can achieve better PAPR performance in comparison with AP-PTS. Simultaneously computational complexity of C-IP-PTS was not high.

C. Duanmu et al. [15] applied both the PTS algorithm and SLM algorithm to randomize the transmitted OFDM signal. Two blocks were firstly formed from the original OFDM data. Then the SLM algorithm was applied for the first block and the PTS algorithm is applied to the second block. After this, these two blocks were combined to make the transmission signal. Since the proposed two algorithms take the advantages of both the PTS and SLM algorithms in the randomization, it can further reduce the PAPR. Simultaneously, computational complexity and BER performance of the proposed two algorithms were about the same as that of the original PTS or SLM algorithm. The simulation results showed that the performance of the proposed algorithm performed much better in reducing the PAPR than the SLM and PTS algorithms, with comparable computational complexity, BER performance, and information overhead.

3. PROPOSED SYSTEM

In high geared wireless communication, MIMO (Multiple Input, Multiple Output) is an antenna technology is playing a vital role in wireless design and development and it transmits a various signal over multiple antennas. The antennas at each end of the communications circuit are combined to minimize errors and optimize the data rate transportation over various electronic systems. It can be used in various interfaces like TDMA (Time Division Multiple Access) and CDMA (Code Division Multiple) but the combination of OFDM with MIMO is very ease and data transmission standard is very high. OFDM is implemented in order to reconstruct the frequency selection MIMO channel into the coordinate plane MIMO channel in the multipath dying environment. The Hybrid Inverse Shifting PTS is introduced in this paper to improve the efficiency as follows.

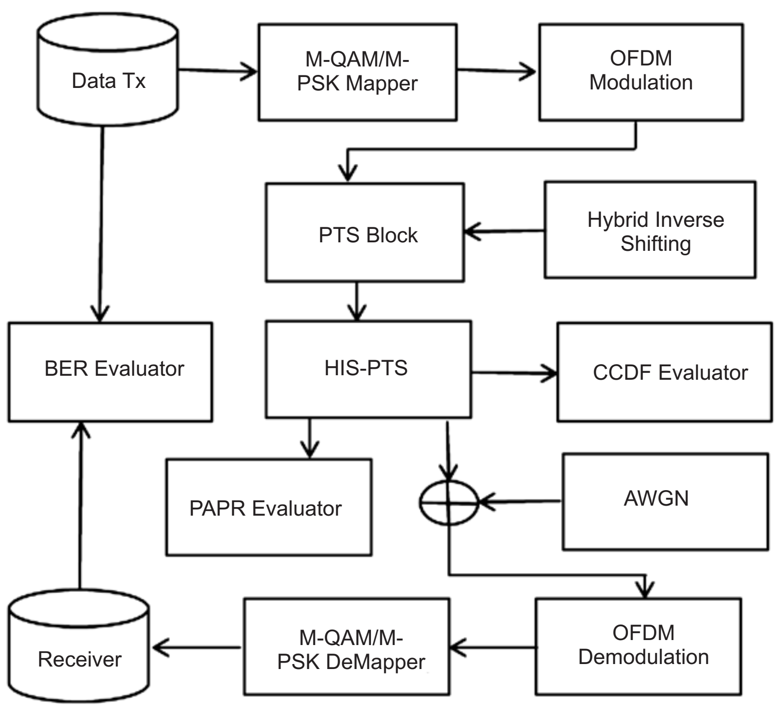

Figure 1: Block Diagram for proposed system

In OFDM system, a block $X = [X(0)\ X(1)\ X(2)...X(N-1)]^T$ with N symbols, which is formed with each symbol modulating by one set of the subcarrier. Then, an OFDM signal is attained by adding all the N modulated independent subcarriers, where N is the number of subcarriers. The subcarriers are placed orthogonally and separated by the subcarrier separation $\Delta^f = 1/T$, where T is the OFDM signal duration. The mathematical representation of the OFDM signal can be written as,

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

The subcarrier vector X is formed according to a modulation method. Thus, X is a vector of N constellation symbols from a constellation ξ. The PAPR of OFDM signal in one symbol period in Equation (1) is defined as the ratio between the maximum instantaneous power and its average power, which can be written as,

$$\text{PARR} = 10 \log 10 \frac{\max_{0 \le t \le T} |x(t)|^2}{p_{av}} \quad (2)$$

Where p_{av} is the average power of $x(t)$ and it can be computed in the frequency domain because IFFT is a (scaled) unitary transformation.

Continuous time signal $x(t)$ generates discrete time signal $x(n)$ by sampling. If sampling at critical sampling or Nyquist rate, $x(n)$ might have an overly optimistic PAPR value because it might lose some information at the peak of $x(t)$. Hence, $x(n)$ is usually oversampled by a factor Lto have a better estimation of the PAPR value of continuous time signal $x(t)$. The oversampling by the factor L can be realized by inserting (L-1)N zeros in the middle of the N-point frequency-domain signal X and passing the new LN-point data sequence through the LN-point IFFT unit. Therefore, the oversampled IFFT output can be expressed as,

$$x(n) = \frac{1}{\sqrt{LN}} \sum_{l=0}^{LN-1} \overline{X} e^{\frac{j2\pi \ln}{N}}, 0 \le n \le LN-1 \quad (3)$$

Where

$$\overline{X} = \left[X(0) \ldots\ldots X\left(\frac{N}{2}-1\right), 0, \ldots, 0, X\left(\frac{N}{2}\right), \ldots, X(N-1) \right]^T$$

It is shown L = 4 is sufficient to capture the peak information of $x(t)$.

In a typical OFDM system with PTS approach to reduce the PAPR, the input data block in X is divided by means of a certain partitioning scheme into M disjoint sub-blocks, which are represented by the vectors $\{X_m, m = 1,2,\ldots.M\}$. Therefore, we can get

$$X = \sum_{m=1}^{M} X_m \quad (4)$$

Where all the subcarrier positions which are presented in another block must be zero so that the sum of all the sub-blocks constitutes the original signal. Then, the sub-blocks X_m are transformed into M time-domain partial transmit sequence x_m, which can be represented as

$$x_m = \text{IFFT}_{L_{N*N}}\{X_m\} \quad (5)$$

Addition of disjoint sub-blocks and zeros insert sequences are represented as follows,

Table 1
PTS insertion

X:IFFT Input						
Sub-Blocks				*Insert sequence*		
1	2	……	N-1	1	…..	M

After that, these partial sequences are independently rotated by the phase factors P = $p_1 \ldots p_m$ and combined together to create a set of candidates

$$\bar{x} = \sum_{m=1}^{M} P_m X_m$$
$$= \sum_{m=1}^{M} \mathrm{IFFT}\{P_m \,\Theta\, X_m\} \tag{6}$$

Finally, the candidate with the lowest PAPR is chosen by exhaustive search of the candidates for transmission. In the PTS scheme, [$\log_2$ (O)] bits of side information to indicate the optimized phase sequence P^*(which is the phase sequence with the lowest PAPR) have to be communicated explicitly to the receiver in order to recover the original symbol X. The Optimal selection of Phase sequence will reduce computational complexity in terms of time and complexity reduction ratio (CCRR). The possible combination of phase sequence P^* as follows,

Table 2
Selection of phase sequence

+1	+1	+1	–1	+1	+1	+ *j*	– *j*
+1	+1	–1	+1	+1	+1	– *j*	+J
+1	–1	+1	+1	+1	–1	+ *j*	+J
+1	–1	–1	–1	+1	–1	– *j*	–*j*
+1	+ *j*	+1	– *j*	+1	+ *j*	+ *j*	+1
+1	+ *j*	–1	+ *j*	+1	+ *j*	– *j*	–1
+1	– *j*	+1	+ *j*	+1	– *j*	– *j*	+1
+1	– *j*	–1	– *j*	+1	– *j*	+ *j*	–1

From the above table, P^* selected and feed into equation (6). The effect of the dummy sequence insertion at the frequency domain is to rotate a phase shift for the corresponding time domain signal.

3.1. Inverse Shifting without side information

In order to avoiding the side information, the system must be able to estimate which signal had been transmitted without the help of additional information. It also means that every carrier signal in our proposed PTS scheme will have some difference from the others. The inverse shift of the phase transmitted signal get reduce the PAPR for each subcarrier. So the transmitting signal equation (6) represented as follows,

$$\bar{x} = \sum_{m=1}^{M} \mathrm{IFFT}\{P_m \,\Theta\, X_m\} \tag{7}$$

Inverse shifting takes place in terms of complex conjugate of original transmitted signal, non-zero transmit carriers are shitted this to improve the reliability against noise over transmitting medium. Inverse of data be represented as,

$$\bar{x}^* = \sum_{m=1}^{M} \mathrm{IFFT}\left\{\left(P_m \,\Theta\, X^*_m\right)\right\} \tag{8}$$

The inverse shifting equation represent in equation (9),

$$\bar{x} = \sum_{m=1}^{M} \bar{x} \,\Theta\, \bar{x}^* \tag{9}$$

X^*_m represents complex inverse of transmitted data. The computational complexity analysis as follows, when the number of subcarriers is $N = 2^n$ and oversampling factor is $L = 2^d$, Multiplication used as complex computation operator. Traditional PTS complexity depends on number of sub block used in PTS calculation. $2^{n+d-1}(n + d)M$. Where M is the number of sub blocks. The main objective of Dummy Sequence is to reduce complexity. While computing DSI in PTS half IFFT operation only required in OFDM symbols.

The CRR of proposed technique over the conventional PTS is defined as:

$$\text{CRR} = \left(1 - \frac{\text{Complexity of calculation of HIS} - \text{PTS}}{\text{Complexity of calcuklation of C} - \text{PTS}} \times 100\%\right)$$

As the length of the signal may vary according to the length, there occurs some lagging in transmission efficiency in our proposed system. Derived computational complexity for multiplication and for sub block 4 by the Hybrid Inverse shifting as follows,

Table 3
Complex Computation Table

Complex Computation	*No of Sub block*	*PTS*	*Proposed*	*CCRR*
Multiplication	4	20480	10240	50%

4. RESULTS AND DISCUSSION

The analysis of the Proposed HIS-PTS method has been carried out using MATLAB 8.6.0.267246 (R2015b). In the OFDM system under consideration, the proposed technique is applied to the sub blocks of un-coded information, which is modulated by QPSK modulation, and the phase rotation factors are transmitted directly to receiver through sub block. The performance evaluation is done in terms of complementary cumulative distribution function (CCDF). The simulation parameters considered for this analysis are summarized in Table 4.

Table 4
Simulation Parameters

Simulation Parameters	*Type / Values*
Number of random OFDM blocks	10000
Number of subcarriers	512,1024
Number of sub blocks	4
Oversampling factor(L)	4,8
Modulation scheme	QPSK
Optimal Phase weighting factor (b)	$1, -1, j, -j$

Figure 2 shows the selected period of signal form generated random signal which has 10000 samples of random numbers. We have considered 1000 samples for one symbol period, which is represented in both frequency and time domain and these samples are further processed for DSI, Block portioning, parallel to serial conversion and transmission. The proposed HIS-PTS performance is evaluated by comparing the following parameters 1. Variation in Number of sample, 2. Bit Error Rate (BER) and Signal to Noise Ratio 3.comparision of channel.

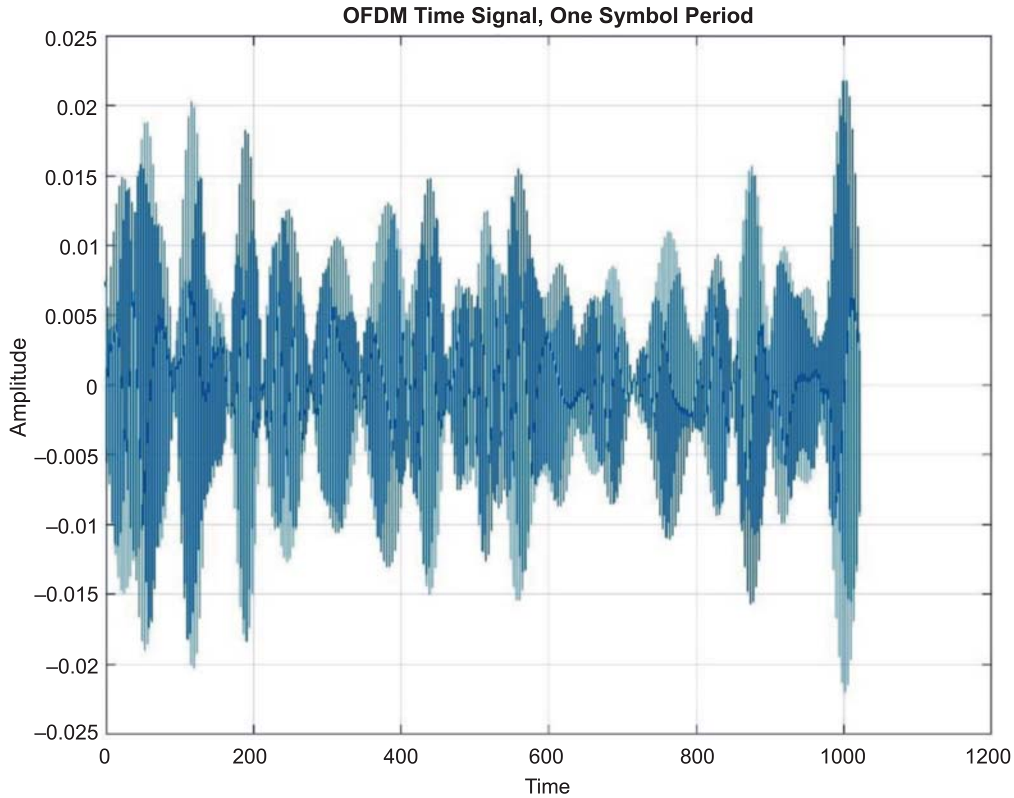

Figure 2: OFDM signal for 1 symbol period

4.1. Number of Samples Comparison

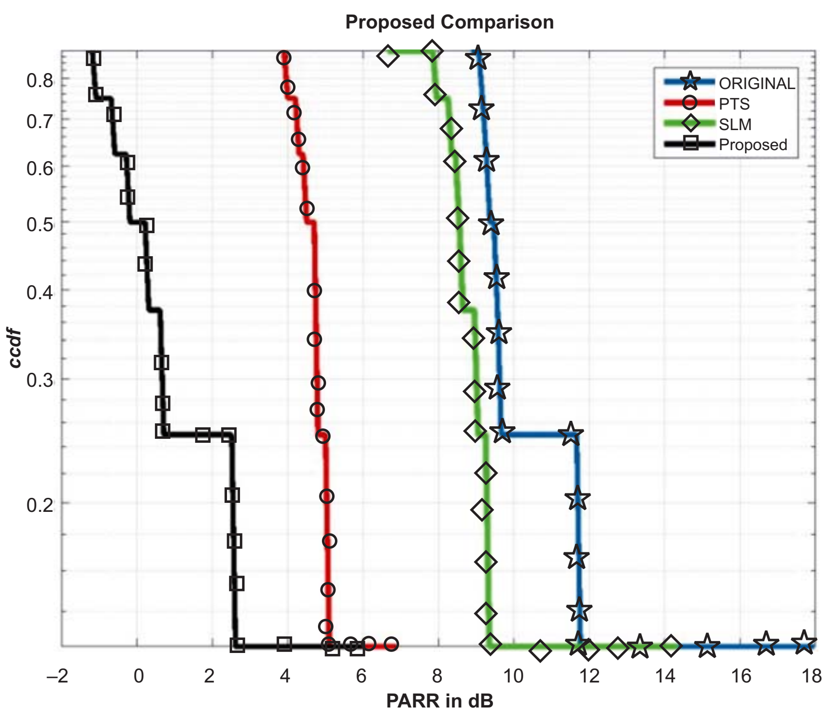

Figure 3: Comparison of existing and proposed system for FFT length 1024

Fig 4 shows the PAPR of the original OFDM is 11.78dB when CCDF hits the minimum value when compared to the PAPR value of the traditional methods such as SLM, PTS and proposed method were 9.25dB 5.15dB and 2.21dB respectively. The maximum iteration of SLM and PTS is 4 and 8. The above scenario is mentioned for the 1024 IFFT symbol. If the IFFT length is changed to different sample size such as 512 and 256 the PAPR hit value also get reduced. Our proposed method gives 0.32dB for 256 IFFT length and 0.95dB for 512 IFFT length. From the above result we can examine that the PAPR hit value gets reduced when the IFFT length is reduced.

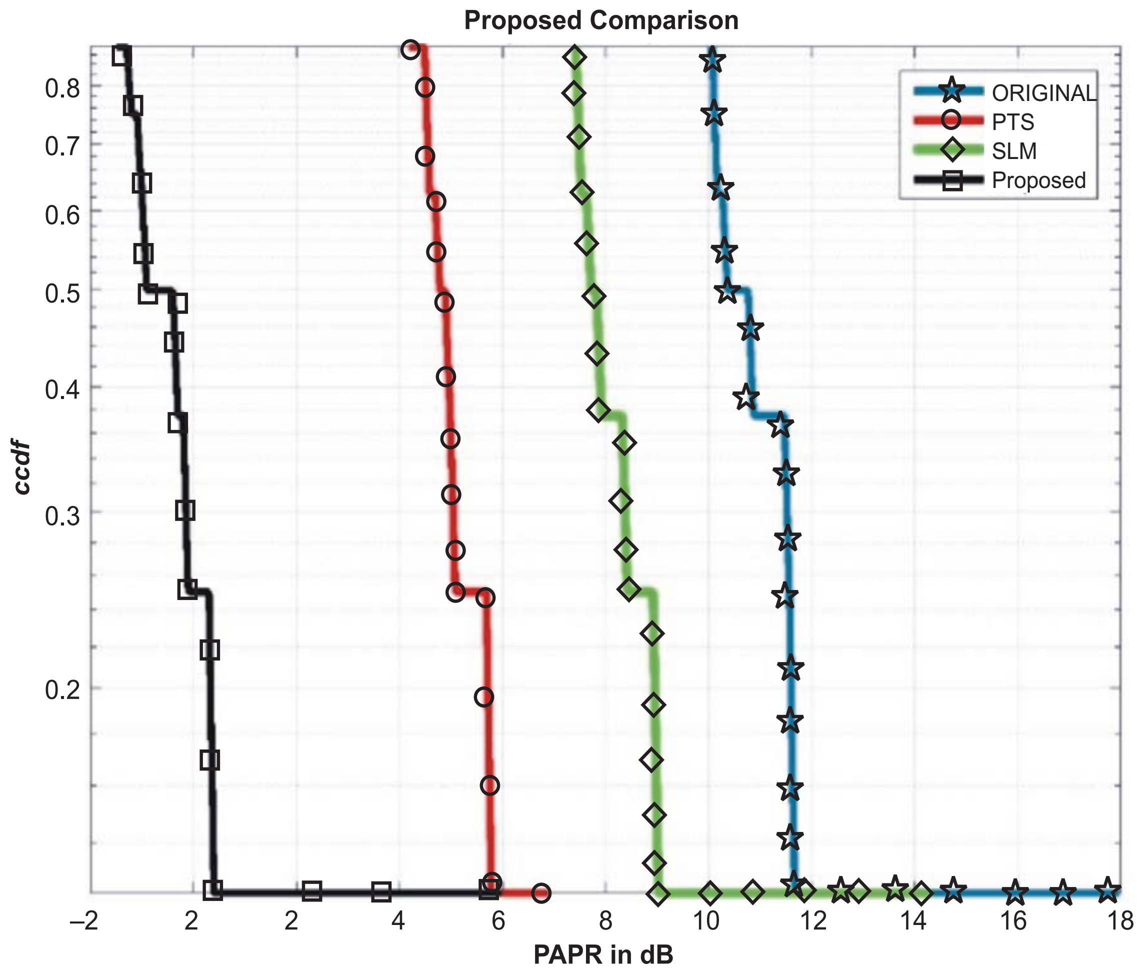

Figure 4: Comparison of existing and proposed system for FFT length 512

4.2. BER vs. SNR for Signal Length

Fig 7 shows the BER vs SNR curves for the proposed system. BER gives the end to end performance of the system during various SNR values. BER is calculated using 20 iterations and with different IFFT sizes of OFDM system. From fig7 we can observe that 1024 IFFT signal length achieves better performance when compared with various IFFT length *i.e,*. Lesser BER for the proposed system. From the result is clear that higher IFFT length produces better BER. The above mentioned scenario is mentioned for the AWGN channel.

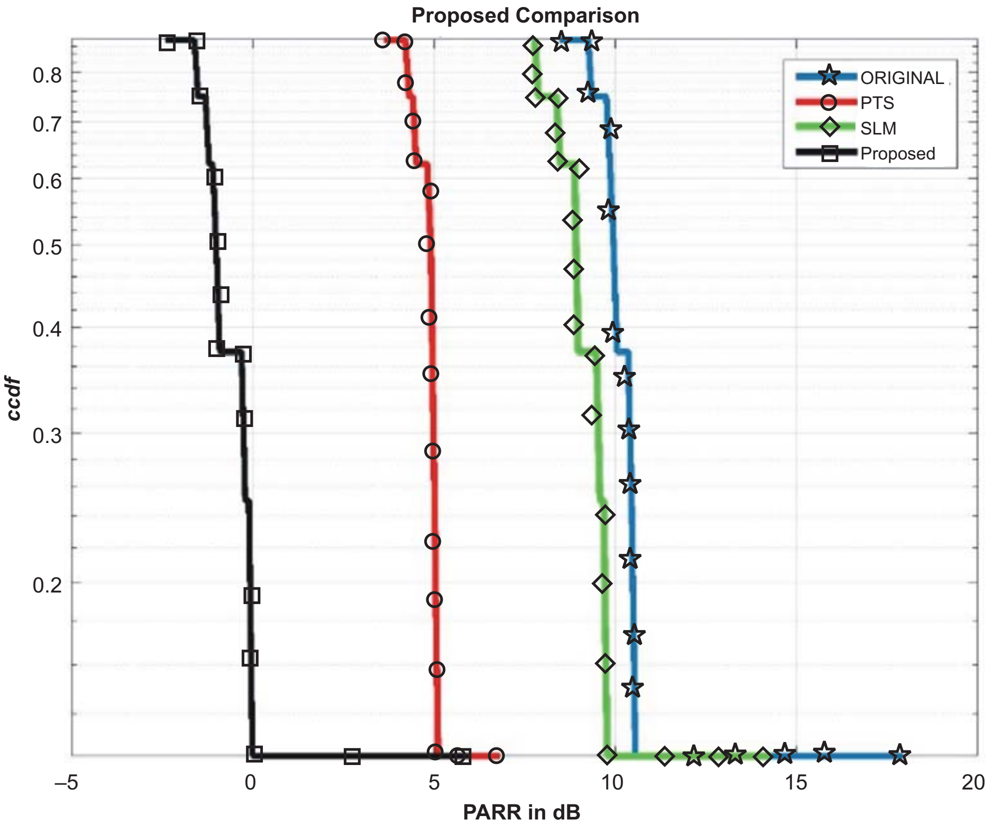

Figure 5: Comparison of existing and proposed system for FFT length 256

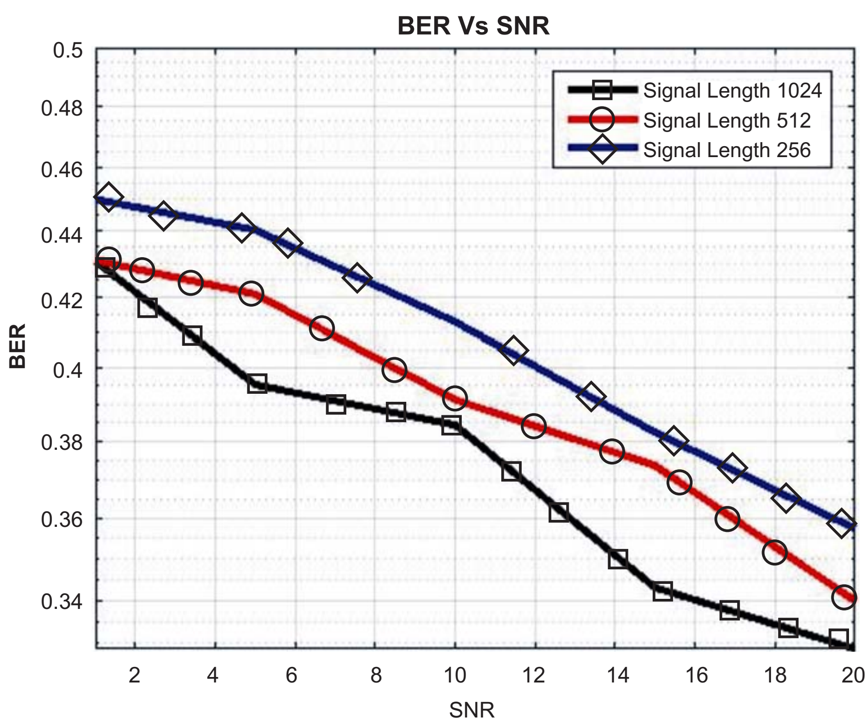

Figure 6: BER Vs SNR comparison for different FFT length 1024, 512, 256

4.3. Channel Selection Comparison

Fig 8 and 9 shows the PAPR when the SNR value is 1 for the OFDM signals. The plot evidently shows that the performance of the system is better when there is a Gaussian Channel compared to Rician channel. Rician PAPR values shows that reduction PAPR values depends on SNR and selection of channel. When fig 4 and 9 are compared for PAPR, fig 9 achieves better performance 1.56dB in the Rician channel. We can clearly observe that selection of channel plays a vital role in data transmission as it decides the data loss or data gain.

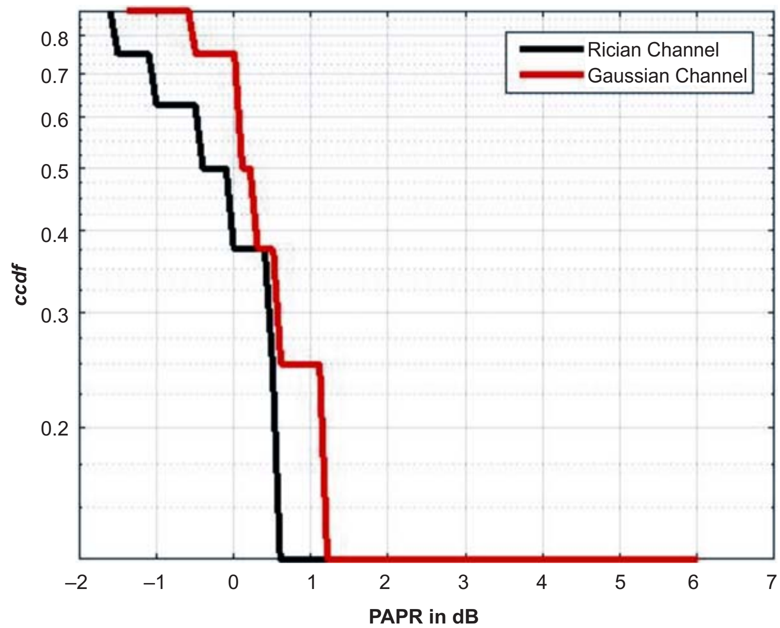

Figure 7: Proposed system comparison in AWGN and Rician channel for fixed FFT (FFT = 1024)

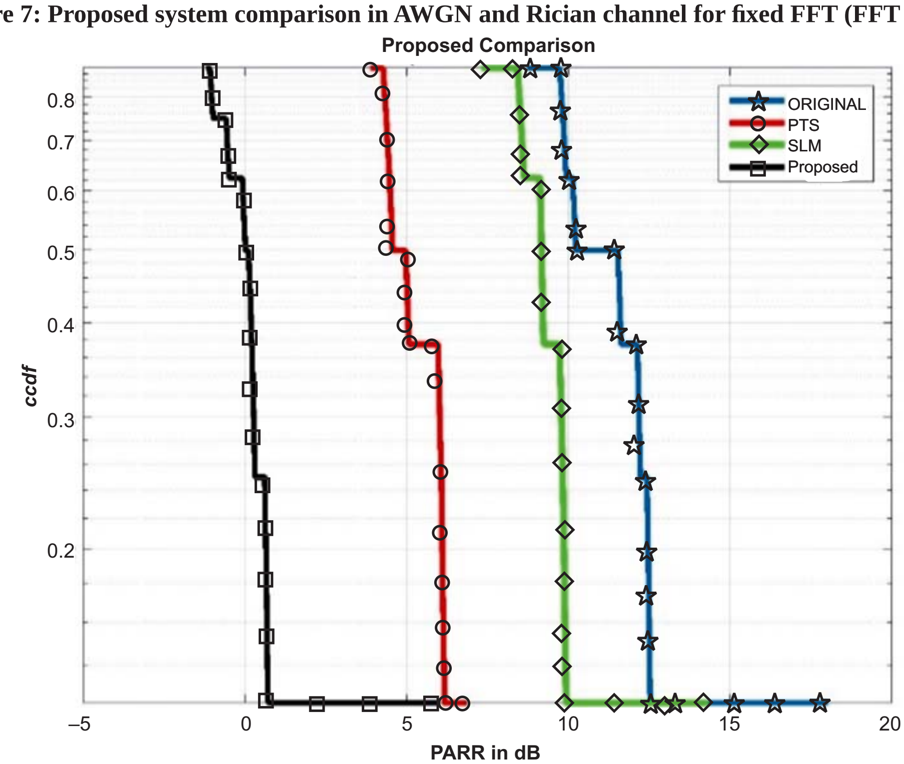

Figure 8: Comparison of existing and proposed system for FFT length 1024 in Rician channel

5. CONCLUSION

In this paper, a low complexity HIS-PTS technique is proposed which combines the channel estimation and the PAPR reduction in OFDM system. Simulation results have shown that this method is reliable to estimate the performance with 20 iterations and various IFFT sizes. The complementary cumulative distribution function is used to predict the evaluation of HIS- PTS method. As a result, it achieves almost the same BER performance like the conventional PTS scheme based on the inverse shifting process of the PTS, but without any side information in all the iterations performed in both AWGN and Rician channels. It may be useful to further study the performance of this proposed method with inverse shifting in frequency selective channels without perfect channel information in the future.

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