International Journal of Control Theory and Applications

ISSN : 0974-5572

Volume 9 • Number 46 • 2016

Analysis and Comparison of PAPR Reduced Modified Interleaved PTS Scheme with IFFT and IDCT Block using QAM

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Abstract: In the field of wireless communication system, OFDM (Orthogonal Frequency Division Multiplexing) is a multicarrier communication system with wide bandwidth. It provides high data rate and high spectral efficiency and removes the Inter Symbol Interference (ISI). But, it also has a disadvantage of high Peak to Average Power Ratio (PAPR). The performance of High Power Amplifier (HPA) at the transmitter side, data rate and spectral efficiency is affected by the PAPR. To overcome this problem and to get optimal reduced value of PAPR and complexity, we have purposed modified Interleaved PTS scheme with IDCT transform block. We have analyzed that when we change the value of QAM, then our PAPR is affected. We have used the Fast Fourier transform block at the transmitter and Inverse Fast Fourier transform (IFFT) block at receiver side. In this paper, IDCT based modified interleaved Partial Transmit Sequence (PTS) technique is proposed to reduce the PAPR of the transmitter side and complexity is also reduced. The PAPR reduction technique's performance and complexity has been compared with Interleaved PTS scheme with IFFT and Interleaved PTS scheme with IDCT transform. The proposed technique for PAPR reduction and reduced complexity grants an improvement over the existing IFFT.

Keywords: ISI, OFDM, IFFT, Interleaved PTS, PAPR, IDCT.

1. INTRODUCTION

In the previous versions, we were using single transmission scheme in which we were transmitting a single symbol which used complete bandwidth. This was a big problem in single carrier transmission scheme because bandwidth is the most important parameter for designing a communication system. In single carrier transmission system, we have narrow bandwidth and hence only a limited data rate can be achieved. Another disadvantage of single transmission is Inter Symbol Interference due to the fact that bandwidth of signal is greater than coherence bandwidth.

The ISI is removed by OFDM. In the latest version, we are using the multicarrier transmission scheme. In this, we have large bandwidth and high data rate. It removes the ISI because in the multicarrier transmission system, we divide the spectrum into narrow bands.

$$N = \frac{W}{\Delta f}$$

where, N = bandwidth of spectrum, W = total bandwidth, Δf = change in frequency. The ISI will be removed due to greater coherence bandwidth as compared to signal bandwidth.

The characteristics of the data is converted (A/D and D/A) from one medium to another medium which affects the PAPR value. In this paper, we have used FFT and IFFT transform blocks which are further modulated with different point Quadrature Amplitude Modulation and optimum reduced PAPR value is shown in conclusion with output simulation/comparison. On replacing the IFFT block by IDCT, the complexity is reduced by the IDCT (Inverse Discrete Cosine Transform) as in this transform, we are eliminating the imaginary terms and performing the calculations only with real values.

OFDM is called orthogonal because any two bits or two symbols are orthogonal to each other. If the symbols are orthogonal, then no interference occurs and fast transmission is achieved.

FDM is defined as Frequency Division Multiplexing in which we are dividing the channel according to frequency. Because multiple users can use the same channel, multiplexing is defined as sharing of the channel. It is a multicarrier modulation technique and it has a high data rate and high spectral efficiency.

OFDM has high data rate due to the multicarrier transmission. Here, we are dividing the complete bandwidth into narrow bands. OFDM has high spectral efficiency due to removal of ISI. In OFDM, the coherence bandwidth is greater than the signal bandwidth.

OFDM has high data rate, due to which it will help in increasing the coverage area of cellular and WLANS. The area of 4G wireless communication is based on OFDM. In the 4G, the LTE (Long Term Evolution) is based on OFDM system. Thus, 4G has achieved data rate up to 100 Mbps and a high bandwidth. OFDM provides good opportunity to reduce the complexity in the equalizers and provide a system with lower multipath fading and ISI for multicarrier transmission. OFDM also is helpful in cellular system based on WIMAX. The WIMAX is a key technique which is based on OFDM. OFDM will help in improving data rate up to 200 Mbps and providing large coverage area.

2. PAPR OF OFDM SIGNAL

The PAPR of the transmitted OFDM is defined as the ratio of the maximum average power to the expected mean average power. It is denoted as:

$$\text{PAPR} = \max \frac{|x(t)|^2}{\text{E}[|x(t)|]^2}$$

where, $x(t)$ denotes an OFDM signals after IFFT, and E (.) denotes expectation. For the measurement of PAPR efficiency, we generally use the parameter known as CDF.

Cumulative Distribution Function (CDF) is defined as:

$$F(z) = 1 - e^{z}$$

The probability of occurrence of the maximum power signal decreases as N increases. To evaluate the probability of PAPR in OFDM system, CDF is generally replaced by Complementary Cumulative Distribution Function (CCDF) because the crest factor in CDF exceeds z due to increase in N.The CCDF is represented by:

$$F_z(z) = P(\text{PAPR} > z) = 1 - P(\text{PAPR} < z) = 1 - \{F(z)\}^N = 1 - \{(1 - e^{-z})\}^N$$

In 1971, Elbert and Weinstein made a system for modulation and demodulation, with IFFT and FFT, which provided orthogonally to each other. If we do not use IFFT and FFT, then we have to use a number of modulation and demodulation blocks at transmitter and receiver. But the IFFT and FFT increase the complexity of mathematical processes. The IFFT is used at the transmitter to increase the transmission rate and provide the carrier orthogonality so that both the signals are orthogonal to each other.

$$\text{OFDM SIGNAL} = \int_{-\infty}^{\infty} \cos(2\pi f_{c1} t + \varnothing 1(1) + \cos(2\pi f_{c2} t + \varnothing 2(t)$$

If two symbols are orthogonal to each other, then

$$\int_{-\infty}^{\infty} f_{c1}(t) \cdot f_{c2} = 0$$

However, it also contains some drawbacks like complexities, Inter Carrier Interference (ICI) and one of the biggest problems is high PAPR. We have two methods for reducing PAPR of OFDM signal.

1. Signal distortion e.g. clipping
2. Symbol scrambling e.g. coding

In the signal distortion method, we set a threshold value. If the information is above the threshold value then it will clip out the distortion. In second method, we are coding and selecting that signal which has minimum PAPR. In the amplitude clipping, we set the threshold value for the amplitude. If the output is greater than the threshold value, then higher portion is clipped out. There is an advantage and disadvantage of clipping of output. The upper portion being clipped may or may not have useful data in it. In the selective mapping, we are choosing the minimum PAPR value signal.

But we can't easily analyze that which signal has minimum PAPR. In the symbol scrambling, we are reducing the PAPR by a coding PTS (Partial Transmit Sequence) scheme. In PTS, we usually pass a single symbol and modulate it. The PAPR will be affected due to this scheme but it is also introducing delay.

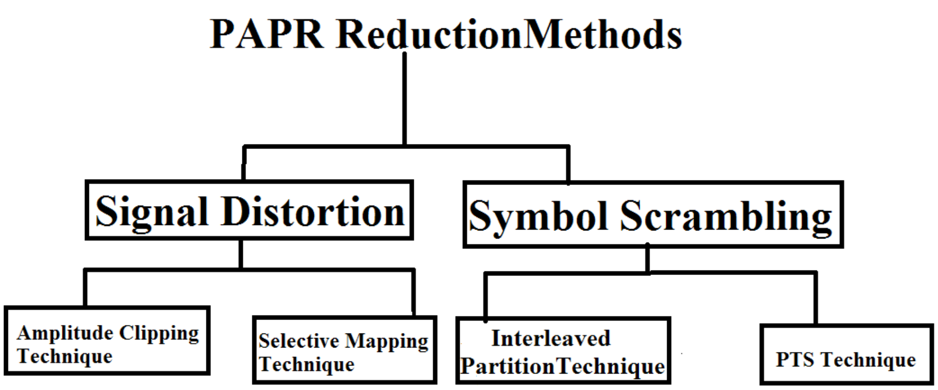

Figure 1: PAPR Reduction Techniques

2.1. Interleaved PTS Scheme

Incoming signal X from frequency domain is partitioned in to the block of N symbols and V disjoint sub-blocks which is as follows.

$$\mathbf{X}^{v} = [X_0^v, X_1^v, X_2^v, \ldots, X_{N-1}^v]^T$$

where, $v = 0, 1, 2, ..., V - 1$

Now in case of K – 1 interleaved partitioning in every sub-block, only N/V single points exist. Hence, the new signal vector will become X_k^v in place of X^v which is shown as

$$X_k^v = \begin{cases} X_{uV+v}, & k = uV + v \\ 0, & \text{otherwise} \end{cases}$$

$X(t) = X_k^v$ is our final output of interleaved PTS scheme. For selecting minimum PAPR value in interleaved PTS scheme, we are using the symbol scrambling method. In this scheme, we are using the FFT and IFFT in interleaved PTS scheme. It will maintain the orthogonality, improve the data rate, modulation or demodulation and provide us a faster transmission.

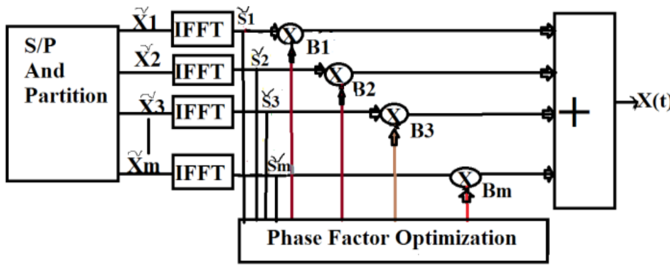

Figure 2: Standard PTS Techniques

3. DCT TRANSFORM

In this paper, we are replacing the interleaved PTS based IFFT block by IDCT block. In the IFFT, we have more complexity due to the real and imaginary terms but the complexity is removed by the IDCT. In this transform, we are eliminating the imaginary terms. So, we perform the calculation only on real values. The results confirm that DCT and IDCT implementation, we have described, gives the same type of reduction in the number of multiplications as the FFT and IFFT.

Let $y = D_n x$ be the N-point DCT of the vector x, then we have that

$$y_n = y_n = c_n \cos\left(\pi \frac{n}{2N}\right) R\left(\left(F_n x^{(1)}\right)n\right) + \sin\left(\pi \frac{n}{2N}\right) j\left(\left(F_N x^{(1)}\right)n\right),$$

where for c_0, N = 1 and for c_n, N = $\sqrt{2}$ for $n \geq 1$, and where $x^{(1)} \in R^N$ is defined by

$$(x^{(1)})_k = x_{2k} \text{ for } 0 \leq k \leq \frac{N}{2} - 1$$

$$(x^{(1)})_{N-k-1} = x_{2k+1} \text{ for } 0 \leq k \leq \frac{N}{2} - 1$$

$$A[k] = a(k) \sum_{n=0}^{N-1} a(n) \cos\left[\frac{\pi(2n+1)k}{2N}\right], \text{ where } k = 0 \text{ to } N-1$$

$$A[k] = a(k) \sum_{n=0}^{N-1} a(n) \cos\left[\frac{\pi(2n+1)k}{2N}\right], \text{ where } k = 0 \text{ to } N-1$$

3.1. IDCT with interleaved PTS Scheme

N-point IDCT of x is defined as:

$$y_n = d_{n,\mathrm{N}} \sum_{k=0}^{\mathrm{N}-1} x_k \cos\left(2\pi \frac{n}{2\mathrm{N}}\left(k+\frac{1}{2}\right)\right)$$

Now we break this equation in term of odd and even, we get,

$$y_n = d_{n,\mathrm{N}} \sum_{k=0}^{\frac{\mathrm{N}}{2}-1} x_{2k} \cos\left(2\pi \frac{n}{2\mathrm{N}}\left(2k+\frac{1}{2}\right)\right) + d_{n,\mathrm{N}} \sum_{k=0}^{\mathrm{N}/2-1} x_{2k+1} \cos\left(2\pi \frac{n}{2\mathrm{N}}(2k+1)+\frac{1}{2}\right)$$

After reversing the indices the second sun becomes,

$$d_{n,\mathrm{N}} \sum_{k=0}^{\mathrm{N}/2-1} x_{\mathrm{N}-2k-1} \cos\left(2\pi \frac{n}{2\mathrm{N}}\left(\mathrm{N}-2k-1+\frac{1}{2}\right)\right)$$

We shift the indices with N/2 then sum becomes

$$d_{n,\mathrm{N}} \sum_{k=\mathrm{N}/2}^{\mathrm{N}-1} x_{2\mathrm{N}-2k-1} \cos\left(2\pi \frac{n}{2\mathrm{N}}\left(2\mathrm{N}-2k-1+\frac{1}{2}\right)\right) = d_{n,\mathrm{N}} \sum_{k=\mathrm{N}/2}^{\mathrm{N}-1} x_{2\mathrm{N}-2k-1} \cos\left(2\pi \frac{n}{2\mathrm{N}}\left(2k+\frac{1}{2}\right)\right)$$

Wherever we have used cos, it is symmetric and periodic with period 2π. Now, we are using $x^{(1)}$ term.

$$y_n = d_{n,\mathrm{N}} \sum_{k=0}^{\mathrm{N}-1} (x^{(1)})_k \cos\left(2\pi \frac{n}{2\mathrm{N}}\left(2k+\frac{1}{2}\right)\right)$$

$$= d_{n,\mathrm{N}}\mathrm{R}\left(\sum_{k=0}^{\mathrm{N}-1} (x^{(1)})_k e^{-2\pi ni\left(2k+\frac{1}{2}\right)/(2\mathrm{N})}\right)$$

$$= \sqrt{\mathrm{N}}\, d_{n,\mathrm{N}}\mathrm{R}\left(e^{-\pi ni/(2\mathrm{N})} \frac{1}{\sqrt{\mathrm{N}}} \sum_{k=0}^{\mathrm{N}-1} (x^{(1)})_k e^{-2\pi nik/\mathrm{N}}\right)$$

$$= c_n, \mathrm{NR}(e^{-\pi ni/(2\mathrm{N})}(\mathrm{F_N} x^{(1)})n)$$

$$a[n] = c_n, \mathrm{N}\left(\cos\left(\pi \frac{n}{2\mathrm{N}}\right)\mathrm{R}((\mathrm{F_N}x^{(1)})n) + \sin\left(\pi \frac{n}{2\mathrm{N}}\right) j((\mathrm{F_N}x^{(1)})n)\right)$$

$$a[n] = \sum_{n=0}^{\mathrm{N}-1} a[k].\,\mathrm{A}[k]\cos\left[\frac{\pi(2n+1)k}{2\mathrm{N}}\right], \text{ where } n = 0 \text{ to } \mathrm{N}-1.$$

4. DISCUSSION ON MODIFIED INTERLEAVED PTS SCHEME WITH IDCT BLOCK

In this, we have discussed the symbol scrambling method as it is better than signal distortion method because in signal distortion method, probability of loss of data was maximum. We have replaced IFFT block with IDCT transform block because in IFFT, mathematical calculation are complex in nature. So, to reduce the mathematical calculations and achieve high data rate, spectral efficiency, maintain orthogonality and reduce PAPR, we are using the IDCT transform block. In IDCT, our complexity problem is resolved and modulation is also performed achieving a high data rate.

FFT

$$X(k) = \sum_{k=0}^{N-1} X(n)e^{-\frac{j2\pi kn}{N}}, \text{ where } k = N-1$$

IFFT

$$X(n) = \sum_{n=0}^{N-1} x(k)\, e^{\frac{j2\pi kn}{N}}, \text{ where } n = N-1, k = N-1$$

DCT

$$A[k] = a(k)\sum_{n=0}^{N-1} a(n)\cos\left[\frac{\pi(2n+1)k}{2N}\right], \text{ where } k = 0 \text{ to } N-1$$

IDCT

$$a[n] = \sum_{n=0}^{N-1} a[k]\,.\,A[k]\cos\left[\frac{\pi(2n+1)k}{2N}\right], \text{ where } n = 0 \text{ to } N-1.$$

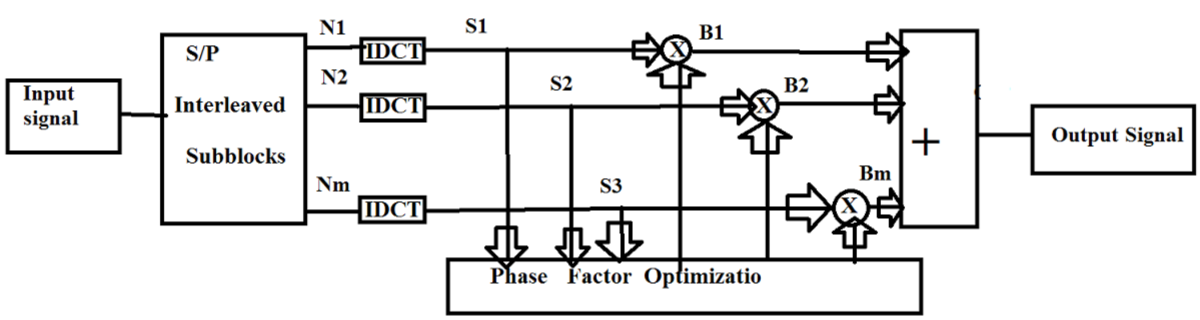

Figure 3: Modified Interleaved PTS Scheme

5. SIMULATION

Table 1
Parameters used in MATLAB simulation

Parameters	*Values*
Number of subcarriers (N)	128, 512
Number of sub-blocks (V)	4, 8
Number of sub-blocks (V)	4
Oversampling factor (K)	4
Transform blocks	IFFT, IDCT
Modulation scheme	16 QAM, 64 QAM
Phase weighting factor (b)	1, -1
OFDM iteration	3000

Figure 4 It is denoting the CCDF with 16 QAM. The arrows from the graph show the output of the graph at N = [64] at simple OFDM and then V = [4] respectively when compared with IFFT and IDCT based interleaved PTS scheme outputs.

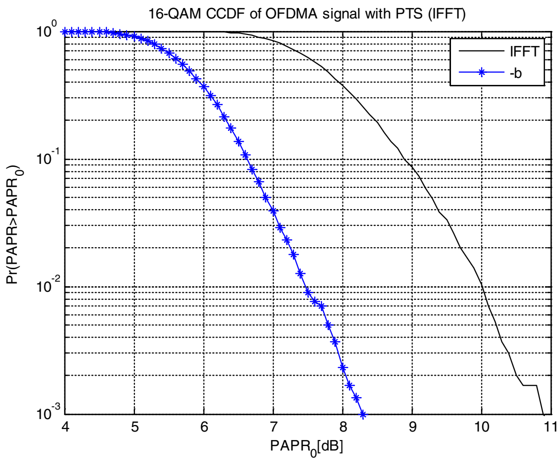

Figure 4: (a) Interleaved PTS scheme IFFT based

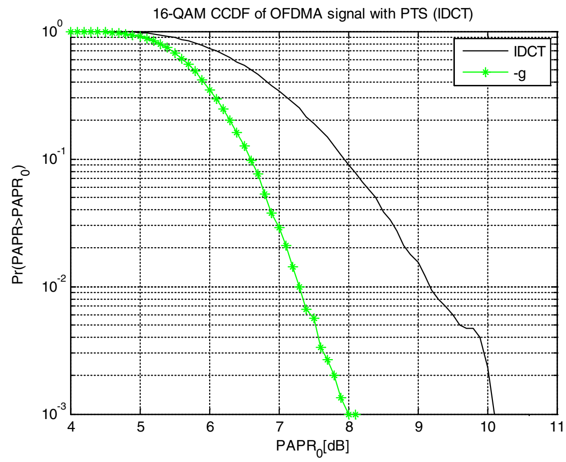

Figure 4: (b) Interleaved PTS scheme IDCT based

Figure 5 It is denoting the CCDF with 64 QAM. The arrows from the graph show the output of the graph at N = [64] at simple OFDM and then V = [6] respectively when compared with IFFT and IDCT based interleaved PTS scheme outputs.

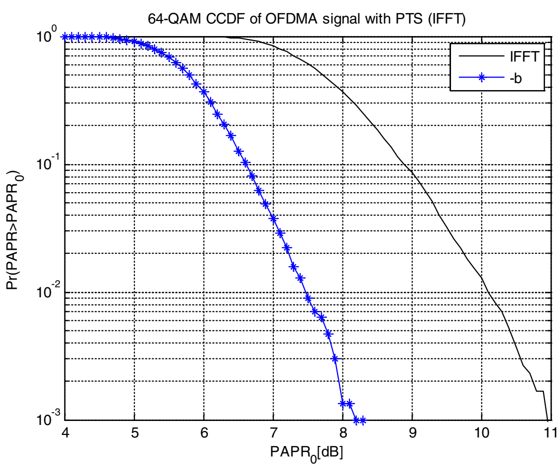

Figure 5: (a) Interleaved PTS scheme IFFT based

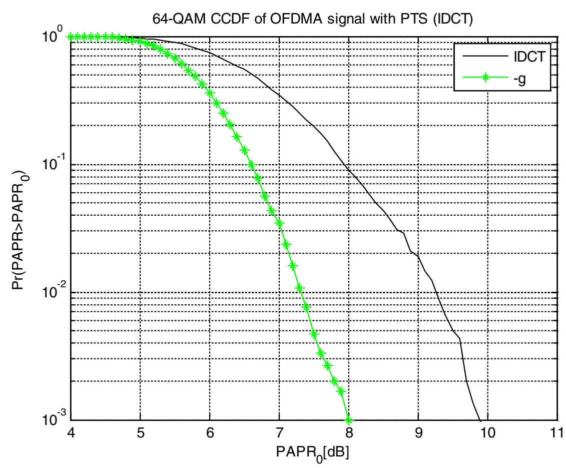

Figure 5: (b) Interleaved PTS scheme IDCT based

Figure 6 Ii is denoting the CCDF with 16 QAM. The arrows from the graph show the output of the graph at N = [64] at simple OFDM and then V = [4, 8] respectively when compared with IFFT and IDCT based interleaved PTS scheme outputs.

Figure 7 It is denoting the CCDF with 64 QAM. The arrows from the graph shows the output of the graph at N = [64] at simple OFDM and then V = [4, 8] respectively when compared with IFFT and IDCT based Interleaved PTS scheme outputs.

6. CONCLUSION

OFDM is a multicarrier communication system which has wide bandwidth and high spectral efficiency. To obtain a high data rate and to reduce the complexity and PAPR simultaneously, we have replaced the interleaved PTS scheme IFFT based block with interleaved PTS with IDCT block. We have analyzed that the process complexity is reduced along with PAPR.

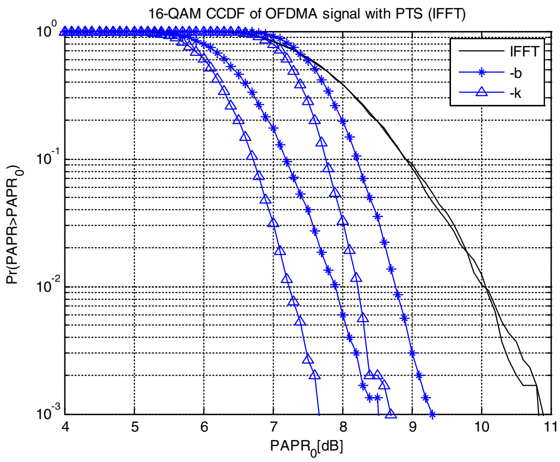

Figure 6: (a) Interleaved PTS scheme IFFT based

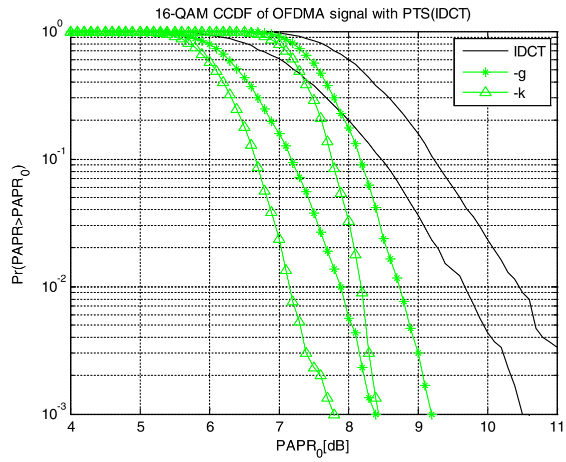

Figure 6: (b) Interleaved PTS scheme IDCT based

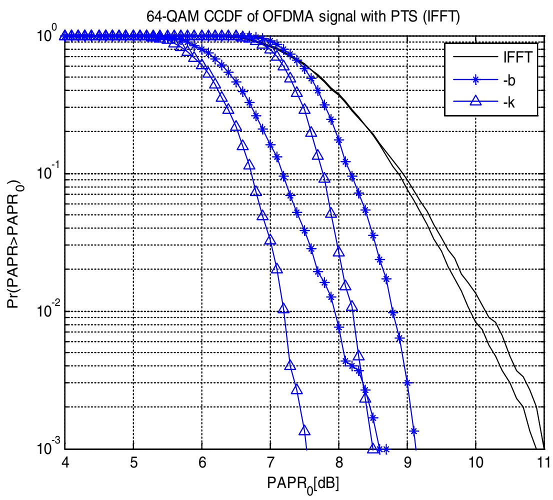

Figure 7: (a) Interleaved PTS scheme IFFT based

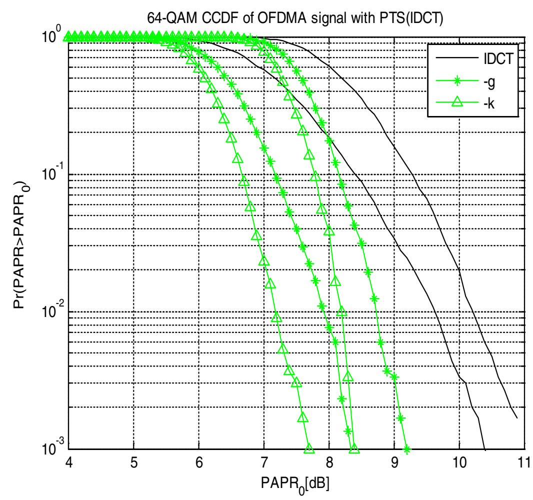

Figure 7: (b) Interleaved PTS scheme IDCT based

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