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INFLUENCING PARAMETERS IN PEAK TO AVERAGE POWER RATIO PERFORMANCE ON ORTHOGONAL FREQUENCY-DIVISION MULTIPLEXING SYSTEM

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ABSTRACT

Orthogonal frequency division multiplexing system is considered one of the important technologies, which used in the high-speed wireless communication system. Although, it has many advantages such as high data rate, ability to combat the multipath fading channels and more efficiency for utilization the bandwidth, the same time has some obstacles also. The peak to average power ratio considers the major drawback of OFDM system. In the OFDM system, some instantaneous power outputs increase greatly and become so far greater than the mean power of the system with the condition the phases of these carriers are same, this is defined the high PAPR, which causes running the system devices in the nonlinear region leading deterioration in performance of OFDM system. In this paper, we present the characteristics of PAPR with two cases normal and special cases (when the OFDM signal has large consistency samples). At the same time, the parameters that influence to PAPR performance have been analyzed and simulated by using MATLAB software. The simulation results show the numbers of sub-carriers, modulation schemes and oversampling rate influence to PAPR performance. It is observed that the numbers of sub-carrier have the significant influence on PAPR performance. However, oversampling rate and modulation schemes have a small effect on PAPR performance.

Keywords: orthogonal frequency division multiplexing, peak to average power ratio, number of subcarriers.

INTRODUCTION

Orthogonal frequency division multiplexing (OFDM) has been becoming the more popular modulation technique in the high-speed wireless communication system. It is used especially in Long Term Evaluation technique (LTE) which depended from fourth-generation (4G) of wireless communication system.

The demand for high-speed, efficient and reliable wireless communication system has led to the speedy development of wireless mobile communication. Orthogonal Frequency Division Multiplexing (OFDM) is one of the techniques that employed for fourth-generation (4G) systems. The cause behind that, it has many features such as the capability to combat multi-path fading, immunity to the inter-symbol interference (ISI). On the other hand, the ability for using high data rate, increasing the capacity of the system and more efficiency for utilization the bandwidth. Therefore, OFDM has been suggested in many wireless communication standards such as IEEE802.11a standard for wireless Local Area Networks (WLAN), Terrestrial Digital Video Broadcasting (DVB-T), digital sound recording/video broadcasting and the ETS1 HIPERLAN/2 standard and high-speed cellular data (Han, 2005) (Abdul hasan, 2015).
Although, OFDM technology has many advantages, at the same time have some obstacles, which confront the system in practical applications. The peak to average power ratio (PAPR) is one of the major drawbacks of OFDM system, which is running the system devices in the nonlinear region.

Many techniques have been proposed to overcome the high PAPR such as selective mapping (SLM) (Kitaek, 2003), partial transmit sequences (PTS) (Baig, 2010) (Li, 2010), clipping and filtering (Baig, 2011), clipping (Naeiny, 2011), coding (Hou, 2011), tone reservation (TR) and tone injection (TI) (Guel, 2009) (Guel, 2010). However, at the same time have a different cost for PAPR reduction. Although, there are many types of research focused on PAPR reduction performance, but it is necessary to give a comprehensive review to the parameters, which influence to PAPR.

In this paper, we analyze the combinations of parameters, which influence to PAPR with OFDM system. Numbers of sub-carriers, modulation schemes and oversampling factor can affect to PAPR. On the other hand, we will study the circumstance which leading the high PAPR of OFDM system compared with a normal case. The paper is organized as follows: Section II presents the principle of OFDM system with block diagram. Section III introduces the high PAPR of OFDM system with comparison normal case and the special case of PAPR. Section IV explains the parameters, which influence to PAPR. Section V shows the simulation results and Section VI summarizes the conclusion.

OFDM SYSTEM

Orthogonal frequency division multiplexing

OFDM is a multicarrier transmission technique, which divides the bandwidth into many carriers; each one is modulated by a low rate data stream. In terms of

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multiple access technique, OFDM is similar to FDMA in that the multiple user access is achieved by subdividing the available bandwidth into multiple channels that are then allocated to users (Ergen, 2009). However, OFDM uses the spectrum much more efficiently by spacing the channels much closer together; this is achieved by making all the carriers orthogonal to one another, preventing interference between the closely spaced carriers.

Figure-1 illustrates the typical OFDM systems. At a sender the channel encoder, constellation mapping and serial to parallel (S/P) conversion process the input binary serial data stream. A single signal is divided into N parallel routes after N-point inverse fast Fourier transform (IFFT). One of the N data routes modulates each orthogonal sub-carrier independently. In other words, the N parallel points constitute one OFDM symbol. Next, convert parallel data sequence to serial sequence and then applying cyclic prefix (CP) by copy the last samples of one symbol on the front. Finally, processing the digital to analog (D/A) conversion and radio frequency (RF) modulation, then transmit the signal (Dinanath, 2014).

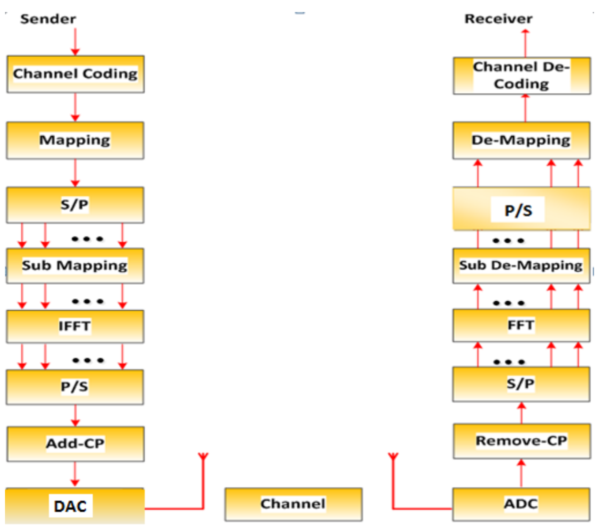

Figure-1. OFDM system block diagram (Srinivasaro, 2012).

At the receiver end, the first process is demodulated receiving signals. The demodulated signals are converted from analog to digital (A/D) converter, sample output and take time estimation to find the initial position of OFDM symbol. The CP added in transmission process is removed and N-Points fast Fourier transforms (FFT) transformation will be conducted on the sample points to recover the data in the frequency domain. Finally, the output of baseband demodulation is passed to the channel decoder to recover the original data (Newangan, 2014).

The high PAPR of OFDM system

In OFDM system, it is output produces a superposition of multiple sub-carriers. In this situation, some instantaneous power outputs may increase greatly and become so far greater than the mean power of the system with the condition the phases of these carriers are same. This is defined large Peak-to-Average Power Ratio (PAPR). High PAPR is one of the greatest problems in OFDM system. If the peak power is too high, it could be out of the scope of the linear region of system devices such as power amplifiers, analog to digital converters and digital to analog converters. It gives an increase to non-linear region distortion, which that affects and changes the superposition of the signal spectrum resulting degeneration in performance (Jaylath, 2003).

Theoretically, Xn is a data block of the N symbols, where n= 1, 2, 3,…, N-1 modulated with once of modulation schemes. OFDM signal x(n)which are obtained by taking IFFT operation on modulated input symbols Xk mathematically can be expressed as:

$$x(n)=\frac{1}{\sqrt{N}}\sum_{K=0}^{N-1} Xk \times e^{j2\pi nk/N} \quad ,0\le n\le N-1 \qquad (1)$$

The PAPR of OFDM signals x(n) in Equation. (1) is defined as the ratio between the maximum instantaneous power and its average power, which can be written as (Boonsrimuang, 2007).

$$PAPR = \frac{P_{peak}}{P_{average}} = 10\log_{10}\frac{\max\left[|x_n|^2\right]}{E\left[|x_n|^2\right]} \qquad (2)$$

Where E[·] denotes the expected value of x(n),in an OFDM system when the carriers are divided into N sub-carriers, the peak power at received signal equal N times of the average power with respect to the same phase value. PAPR of the received signal reached the maximum value theoretically as shown in the following:

$$PAPR= \left(\text{power peak /power average}\right) \qquad (3)$$

When the OFDM signal is modulated by same phases, the PAPR can be written as:

$$PAPR\ (dB) = 10\log 10\ (N) \qquad (4)$$

For example, if the number of sub-carriers N=256, the PAPR will reach a maximum value (24 dB), this value is considered to be a theoretical hypothesis. However, in a real application the probability of PAPR value to reach maximum is very low.

The maximum amplitude of the instantaneous power of the OFDM signal is less than the upper theoretical value when, the OFDM signal is modulated with different constellation phases. On the other hand, when the OFDM signal is modulated with same phases, the amplitude of instantaneous power of the OFDM signal will reach the upper theoretical value due to the OFDM signal has large consistency. The equation (4) is applied to the OFDM signal under this condition. For example, if the sequence has 16 '1' denoted by [1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1] after the modulation constellation and IFFT operation the instantaneous power will reach the theoretical value more than 16 dB. At the same time, the PAPR of the OFDM signal will reach the maximum value ($10\log_{10}(16)$ =12 dB) when the signal has large consistency samples (same initial phases).

Influencing parameters of PAPR performance

The parameters that effect on PAPR performance and effluent directly to reduce the PAPR can be divided into three:

1. Modulation schemes.
2. Number of sub-carriers.
3. Sampling rate factor.

The three parameters above are closely related to PAPR performance and it is important to study the effect of those parameters with the original OFDM signals.

Number of subcarriers (N)

The principle working in OFDM system depends on dividing the frequency into sub-carriers, each user can occupy one channel. Therefore, increasing sub-carriers lead to increasing the information that is transmitted, thus the numbers of users are also increasing. The numbers of sub-carriers play an important role for PAPR performance due to the varying information carriers. Different numbers of sub-carriers result in different PAPR performances. The simulation result will show the influencing number of sub-carriers on PAPR performance.

Modulation schemes

The input sequences in OFDM system should modulate by one type of the modulation scheme before converting from frequency domain to time domain through using IFFT to generate OFDM samples. There are several types of modulation schemes used for modulating the transmitted signal. Common types of modulation schemes such as Binary Phase Shift Keying (BPSK), Quadrature Phase Shift Keying (QPSK), 16-Quadrature Amplitude Modulation (16-QAM) and 16-Quadrature Amplitude Modulation (64-QAM) among several types of modulation schemes are used to evaluate the PAPR performance. Using different types of modulation schemes certainly produces different PAPR performances.

Oversampling rate factor (L)

In the real implementation, continuous-time OFDM signal cannot be described precisely due to the insufficient N points sampling. Some of the signal peaks may be missed and PAPR reduction performance is unduly accurate. To fixed this problem, oversampling is employed by inserting L*N points to IFFT of the original data with the (L-1)*N zero-padding that ensures to catch the peaks of the signal and PAPR performance be more accurate. The OFDM signal x(n) can be written as (Wang, 2011):

$$x\left(\frac{n}{L}\right)=\frac{1}{\sqrt{LN}}\sum_{k=0}^{N-1}xk\times e^{j2\pi nk/NL},0\leq n\leq N\ L\text{-}1 \quad (5)$$

Where L represents an oversampling factor, so that, using suitable oversampling factor L is an influence to PAPR performance.

SIMULATION RESULTS

In this section, MATLAB simulation program was conducted to evaluate and compare the PAPR performance of OFDM signal. In the computer simulations, the Complementary Cumulative Distribution Function (CCDF) was employed to show PAPR distribution for 1000 samples of OFDM signal.

Firstly, the OFDM signal is evaluated with two cases normal case and special case. Figure-2 illustrates the amplitude of the OFDM signal in the time domain when the sub-carriers N=16 with respect to the signal modulated with 16-QAM. It is clearly shown that the maximum amplitude of the instantaneous power of the OFDM signal is less than the upper theoretical value (16 dB).

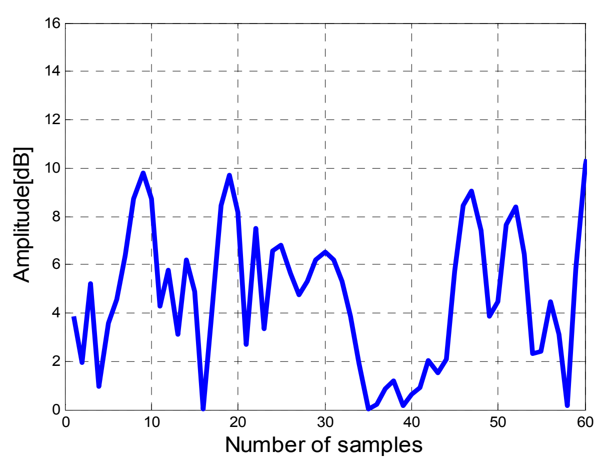

Figure-2. Normal OFDM signal power in the time domain.

Figure-3 illustrates the special case when the OFDM signal is modulated with the same phase that mean the sequence has the same samples (very large consistency

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samples). The instantaneous power of the OFDM signal reaches the maximum theoretical value (16 dB).

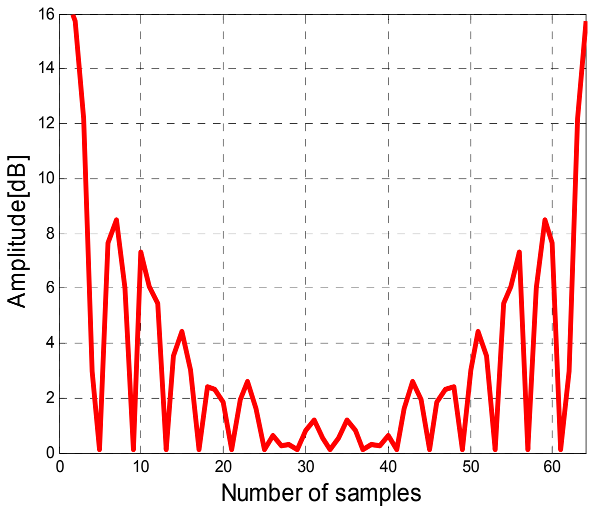

Figure-3. OFDM signal power when modulated by same phase.

Figure-4 shows the comparison between two OFDM signals when the sub-carriers are 256, 16-QAM modulation scheme. The red curve shows the PAPR value of the normal OFDM signal at value (11.33 dB) and the blue curve denoted the PAPR value of the special case when the signal of OFDM has very large consistency samples at value (24 dB) that match the theoretical maximum value. Therefore, modulation scheme samples play an important role to avoid the OFDM system of the highest PAPR problem.

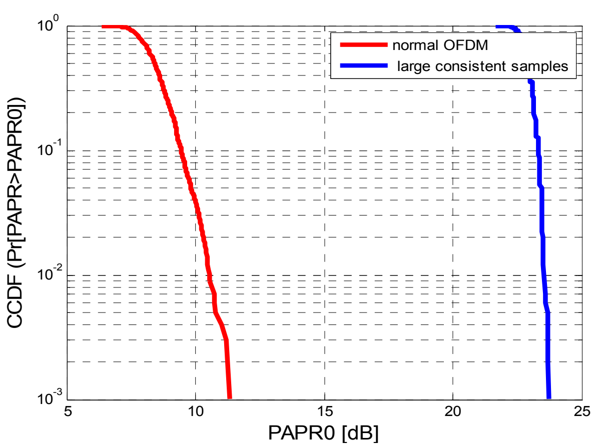

Figure-4. Comparison between PAPR of the normal OFDM signal and PAPR of OFDM signal modulated with same phases.

The simulation results in Figure-5, Figure-6, Figure-7 and Figure-8 respectively, have shown the influence of the number of sub-carriers, the oversampling factor and modulation schemes in the PAPR performance.

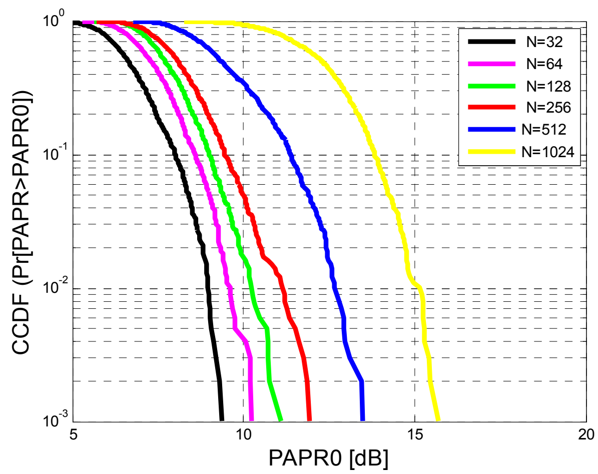

Figure-5. CCDF of the PAPR performance with different numbers of sub-carriers N.

The simulation result in Figure-5 shows the PAPR distribution with different numbers of sub-carriers (i.e. N=32, 64, 128, 256, 512 and 1024). The x-axis represents the PAPR thresholds and the y-axis acts as the probability of CCDF (probability of PAPR above PAPR threshold). The modulation scheme is 16-QAM and the sampling factor (L=8) with the samples that taken are 1000 samples. Figure-5 shows the PAPR value approximately 9.35 dB when the sub-carrier number is 32. Moreover, 10.2 dB when N=64, 11.11 dB when N=128, 11.9 dB when N=256, 13.5 dB when N=512 respectively. The yellow colour represents the PAPR of the OFDM signals at 15.7 dB when N=1024, this means increasing numbers of sub-carrier raises the PAPR value due to an increasing in sub-carriers lead to increasing of data information on those carriers, thus the PAPR value increasing also. Therefore, the number of sub-carrier is a very important influencing factor on PAPR value.

The simulation results of PAPR for different scenarios number of sub-carriers are listed in Table-1.

Table-1. Numerical simulation parameters for PAPR with different N.

No. of sub-carriers (N)	CCDF	Modulation scheme	PAPR [dB]
32	10^{-3}	16-QAM	9.35
64	10^{-3}	16-QAM	10.2
128	10^{-3}	16-QAM	11.1
256	10^{-3}	16-QAM	11.9
512	10^{-3}	16-QAM	13.5
1024	10^{-3}	16-QAM	15.7

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As shown in Figure-6, when fixing sub-carrier numbers at 256 and using the 16-QAM modulation scheme with different values of the oversampling factor (L=1, 2, 4, 6, 8, 10). The increasing of L value leads to a small increasing of PAPR due to ((L-1)*N) zero-padding is inserted through the original modulated data sequence, thus increasing the number of L does not get large influence of PAPR value. On the other hand, oversampling is effective to display the features of OFDM samples in the time domain after IFFT. In general, the oversampling factor L=4 is sufficient to catch the peak values of signals. Therefore, the oversampling factor is an important operation to ensure the accurate PAPR reduction performance.

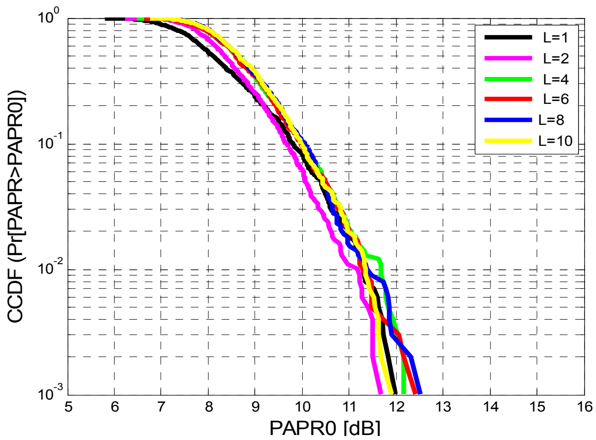

Figure-6. CCDF of the PAPR performance with different numbers of the oversampling factor L.

The simulation results of PAPR for different scenarios of the oversampling factor are summarized in Table-2.

Table-2. Numerical simulation parameters for PAPR with different L.

Oversampling factor (L)	No. of sub-carriers (N)	Modulation scheme	PAPR [dB]
1	256	16-QAM	12
2	256	16-QAM	11.67
4	256	16-QAM	12.15
6	256	16-QAM	12.4
8	256	16-QAM	12.5
10	256	16-QAM	11.9

Figure-7 and 8 illustrate the influence of the modulation schemes to the PAPR performance by several commonly used modulation schemes like BPSK, QPSK, 16QAM and 64QAM with two sets of sub-carriers (N=128, N=256) and keep the oversampling value L=8.

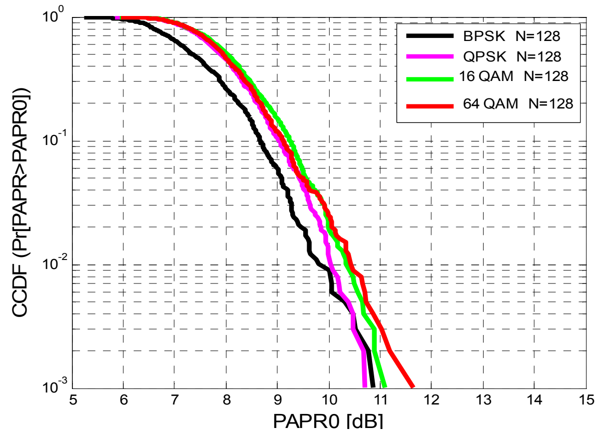

Figure-7. CCDF of the PAPR values with different modulation schemes and the number of sub-carriers N=128.

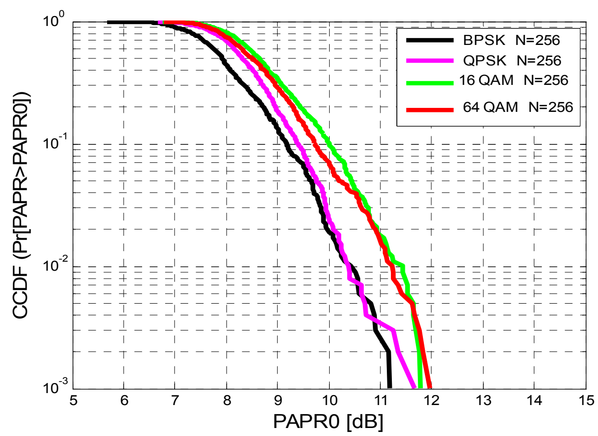

Figure-8. CCDF of the PAPR values with different modulation schemes and the number of sub-carriers N=256.

The results show that there is a small effect of modulation schemes on the PAPR performance value due to the PSK and QAM digital modulation schemes do not change the amplitude of the original data signal. Since, the PAPR produced by the fluctuation of the signal power, especially the instantaneous power of the OFDM signal, thus the PAPR value does not change greatly with the types of the modulation schemes. Therefore, different types of the modulation schemes have a small influence on the peak to average power ratio performance.

Table-3 and 4 display the simulation results of PAPR for different scenarios of modulation schemes with N=128 and 256 respectively.

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Table-3. Numerical simulation parameters for PAPR with different modulation schemes and N=128.

Modulation scheme	CCDF	No. of sub-carriers (N)	PAPR [dB]
BPSK	10^{-3}	128	10.7
QPSK	10^{-3}	128	10.85
16-QAM	10^{-3}	128	11.1
64-QAM	10^{-3}	128	11.6

Table-4. Numerical simulation parameters for PAPR with different modulation schemes and N=256.

Modulation scheme	CCDF	No. of sub-carriers (N)	PAPR [dB]
BPSK	10^{-3}	256	11
QPSK	10^{-3}	256	11.25
16-QAM	10^{-3}	256	11.95
64-QAM	10^{-3}	256	12.35

CONCLUSIONS

The peak to average power ratio one of the major drawbacks of the OFDM system in practical application because it is running the system devices in the nonlinear region so that the system encounter many restrictions in the practical application. Many research and studies are focused to reduce the PAPR values, but it is important to give a comprehensive review to the parameters that influence on PAPR value. In this paper, we present the PAPR performance with two cases normal and special cases (when the OFDM signal has large consistency sample). We calculated and made a simulation with the two cases; we proved the theoretical maximum value of PAPR also. On the other hand, we analyzed the parameters which influencing to the PAPR performance in OFDM signal. The simulation results showed PAPR influenced greatly by the number of sub-carriers because the varying of data information for each carrier, but over sampling factor had a small influence on the PAPR performance due to inserting ((L-1)*N) zero-padding points which it not effective on the original signal. Moreover, modulation schemes did not change the PAPR value due to the amplitude of the original signal does not change after modulation mapping, thus the modulation schemes had a small influence to the PAPR value with consideration all the simulations conducted under the same circumstance.

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