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Performance Improvement of OFDM System Using Self Cancellation Windowing Technique

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Abstract: OFDM based wireless systems are spectrally efficient but they are vulnerable to Inter carrier interference (ICI). The rapid change in the channel can induce ICI. ICI will significantly increase the difficulty of OFDM channel estimation. ICI due to carrier frequency offset can be mitigated by accurate frequency synchronization but ICI due to fast fading channel is more difficult to handle. ICI causes power leakage among subcarriers thus degrading the system performance. In this paper the performance analysis of self-cancellation with window function for combating the impact of ICI on OFDM systems under Additive White Gaussian Noise (AWGN) channel is studied. The proposed scheme is a technique in which redundant data is transmitted onto adjacent sub-carriers such that the ICI between adjacent sub-carriers cancels out at the receiver with benefits of window function. In addition, since no channel equalization is needed for reducing ICI, the proposed scheme is therefore beneficial in implementation without increasing system complexity.

Keywords

OFDM, ICI, BER, FFT, SNR, CIR.

I. Introduction

Orthogonal Frequency Division Multiplexing (OFDM) is a promising candidate for achieving high data rate transmission in mobile environment. OFDM is a new Multi-Carrier Modulation technique in which a high rate bit-stream is split into N parallel bit-streams of lower rate and each of these are modulated using one of N orthogonal sub-carriers [4]. The Inverse Fast Fourier Transform (IFFT) algorithm is performed for each transmitted carrier to provide time domain representation of complex symbols generated by modulation schemes .The Fast Fourier Transform (FFT) algorithm is utilized at receiver to reverse the effect of IFFT and convert data into frequency domain. As OFDM in many applications is very sensitive to frequency offset and carrier losses it orthoganility.The sensitivity against carrier frequency offset causes attenuation and rotation of sub carriers and that leads to ICI. The demodulation of a signal with an offset in the carrier frequency can cause large bit error rate and may degrade the performance of a symbol synchronizer. Due to ICI at the demodulator we cannot get the same replica of carriers what we have sent at the transmitter, so problems in making the decision comes. This additional interference leads to an increase in the Bit Error Rate (BER) of the system. The ICI reduction techniques broadly fall into one of the four techniques: (a) Frequency domain equalization (b) Time domain windowing (c) ICI self cancellation (d) Pulse shaping. The first two methods are not so efficient because they do not address to the major cause of ICI which is due to the frequency mismatch between the transmitter and receiver, and the Doppler shift. The drawback of the ICI self cancellation method is that the same data is modulated into two or more carriers, thus reducing the spectral efficiency. In Pulse shaping method there is no loss of spectral efficiency but selection of suitable pulse is a very complex process.

In this paper the performance analysis of self-cancellation with window function for combating the impact of ICI on OFDM systems is studied .The main idea is one data symbol is modulated onto a group of adjacent subcarriers with a group of weighting coefficients. By doing so, the ICI signals generated within a group can be self cancelled each other. Window function can mitigate the joint effect of additive noise and ICI among subcarriers caused by the carrier frequency offset.

II. OFDM System Model

The Fig. 1 describes the Basic OFDM system model suitable for a time-invariant AWGN channel. In an OFDM system, at the transmitter part, a high data-rate input bit stream is converted into N parallel bit streams each with symbol period Ts through a serial-to parallel buffer. When the parallel symbol streams are generated, each stream would be modulated and carried over at different center frequencies.The sub-carriers

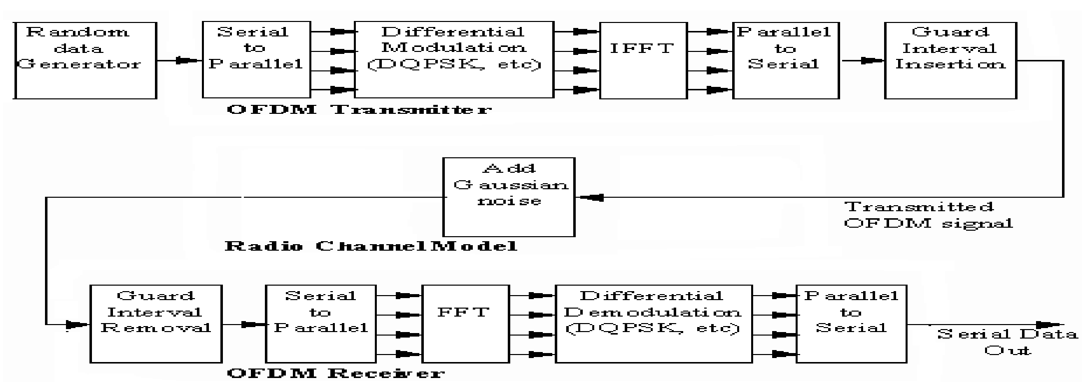


Fig. 1 Basic OFDM system model

are spaced by 1/NTs in frequency, thus they are orthogonal over the interval (0, Ts). Then, the N symbols are mapped to bins of an IFFT. These IFFT [2] bins correspond to the orthogonal sub-carriers in the OFDM symbol. This discrete signal is demodulated using an N-point FFT operation at the receiver. AWGN introduced in the channel. Then, the signal is down converted. The following step is to pass the remaining Time Domain samples through a parallel to-serial converter and to compute N-point FFT. Therefore the groups of bits that have been placed on the subcarriers at the transmitter are recovered at the receiver as well as the high data-rate sequence.

III. ICI Self Cancellation Scheme

Here one data symbol is not modulated in to one sub-carrier, rather at least in to two consecutive sub-carriers. The difference between the ICI co-efficient of two consecutive sub- carriers are very small. This makes the basis of ICI self cancellation. In self cancellation scheme the main idea is to modulate the input data symbol on to a group of sub carriers with predefined self coefficients such that the generated ICI signals within the group cancel each other. ICI self-cancellation is a scheme that was introduced by Yuping Zhao and Sven-

Gustav Haggman [1] in to combat and suppress ICI in OFDM.

ICI Cancelling Modulation

In an OFDM communication system, assuming the channel frequency offset normalized by the subcarrier separation is ε, and then the received signal on subcarrier k can be written as

$$Y(k) = X(k)\,S(0) + \sum_{l=0, l\neq k}^{N-1} X(l) S(l-k) + n_k \qquad \ldots\ldots\ldots\ldots\ldots (1)$$

Where k = 0.1.2………N-1.Where N is the total number of the subcarriers, $X(k)$ denotes the transmitted symbol for the kth subcarrier and n_k is an additive noise sample. The first term in the right-hand side of (1) represents the desired signal and the second term is the ICI component. The sequence S(l-k) is defined as the ICI coefficient between lth and kth subcarriers, which can be expressed as

$$S(l-k) = \frac{Sin(\pi(1+\in -K)}{N\,Sin\left\{\frac{\pi}{N}(1+\in -K)\right\}} \exp\left\{ j\pi(1-\frac{1}{N})(1+\in -K)\right\} \qquad \ldots\ldots\ldots\ldots\ldots (2)$$

It is seen that the difference of ICI coefficient between two consecutive subcarrier {S(l-k) and S(l+1-k)} is very small. Therefore, if a data pair (a, -a) is modulated onto two adjacent subcarriers (l , l+1), where a is a complex data, then the ICI signals generated by the subcarrier l will be cancelled out significantly by the ICI generated by subcarrier l+1. Assuming the transmitted symbols are such that

X(1) = -X(0), X(3) = -X(2),…….., X(N-1) = -X(N-2), then the received signal on subcarrier k

becomes

$$Y'(K) = \sum_{\substack{l=0 \\ l=even}}^{N-2} X(l)\left[S(l-k) - S(l+1-k)\right] + n_k \qquad \ldots\ldots\ldots (3)$$

Similarly the received signal on subcarrier $k+1$ becomes

$$Y'(k+1)=\sum_{\substack{l=0\\l=even}}^{N-2} X(l)\left[S(l-k-1)-S(l-k)\right]+n_{k+1} \qquad \text{……… (4)}$$

In such a case, the ICI coefficient is denoted as $S'(l-k)=S(l-k)-S(l+1-k)$ ……. (5)

It is found that, S\` (l - k) << S (l - k) [3]

ICI Cancellation Demodulation

ICI modulation introduces redundancy in the received signal since each pair of subcarriers transmit only one data symbol. This redundancy can be exploited to improve the system power performance, while it surely decreases the bandwidth efficiency. To take advantage of this redundancy, the received signal at the (k + 1) th subcarrier, where k is even, is subtracted from the k th subcarrier. This is expressed mathematically as

$$\begin{aligned} Y''(k) &= Y'(k)-Y'(k+1) \\ &= \sum_{\substack{l=0\\l=even}}^{N-2} X(l)\left[-S(l-k-1)+2S(l-k)-S(l-k+1)\right]+n_k-n_{k+1} \end{aligned} \qquad \text{----------------- (6)}$$

Subsequently, the ICI coefficients for this received signal becomes

$$S''(l-k)=-S(l-k-1)+2S(l-k)-S(l-k+1) \qquad \text{……… (7)}$$

When compared to the two previous ICI coefficients |S(l-k)| for the standard OFDM system and |S\`($l$-k)| for the ICI canceling modulation, $|S''(l$-k)|has the smallest ICI coefficients, for the majority of $l$-k values followed by |S\`(l-k)| and |S(l-k)|.The combined modulation and demodulation method is called the ICI self- cancellation scheme. The reduction of the ICI signal levels in the ICI self-cancellation scheme leads to a higher CIR. The theoretical CIR can be derived as

$$CIR=\frac{\left|-S(-1)+2S(0)-S(1)\right|^2}{\sum_{l=2,4,6.....}^{N-1}\left|-S(l-1)+2S(l)-S(l+1)\right|^2} \qquad \text{……….. (8)}$$

Fig.2 shows the model of the proposed method.

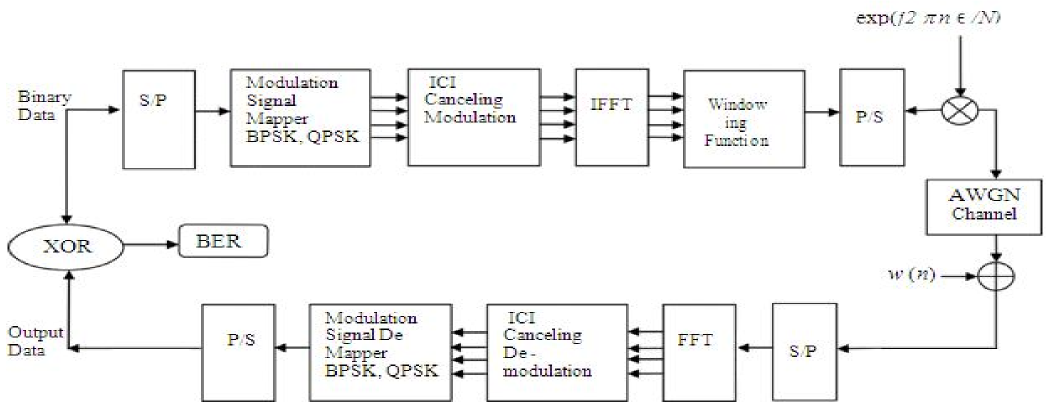


Fig. 2 Proposed OFDM System Model

The redundancy in this scheme reduces the bandwidth efficiency by half. This could be compensated by signals transmitting of larger alphabet size. Using the theoretical results for the improvement, CIR should increase the power efficiency in the system and gives better results for the BER. Hence, there is a tradeoff between bandwidth and power in the ICI self-cancellation scheme.

Windowing Function

Windowing is a well-known technique to suppress the side-lobes level of the sinc functions and thus reduce the bandwidth occupied by the signal. Windowing an OFDM symbol makes the amplitude go smoothly to zero at the symbol boundaries. A digital filter requires at least a few multiplications per sample, while windowing only requires a few multiplications per symbol, for those samples which fall into the roll off region. Due to this windowing is easier to implement. The different window function exists in Matlab. The window function used in the proposed technique is Tukey Window, Bohman Window, Triangular Window, Hamming Window, Kaiser Window and Taylor Window**.**

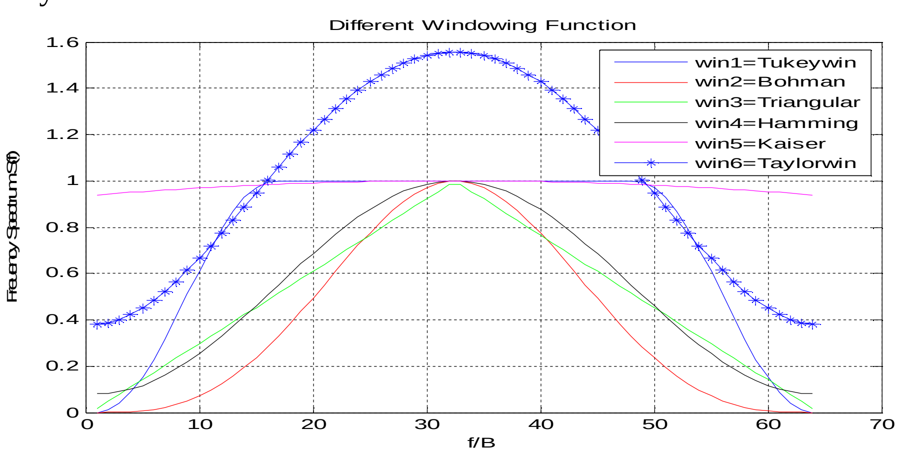
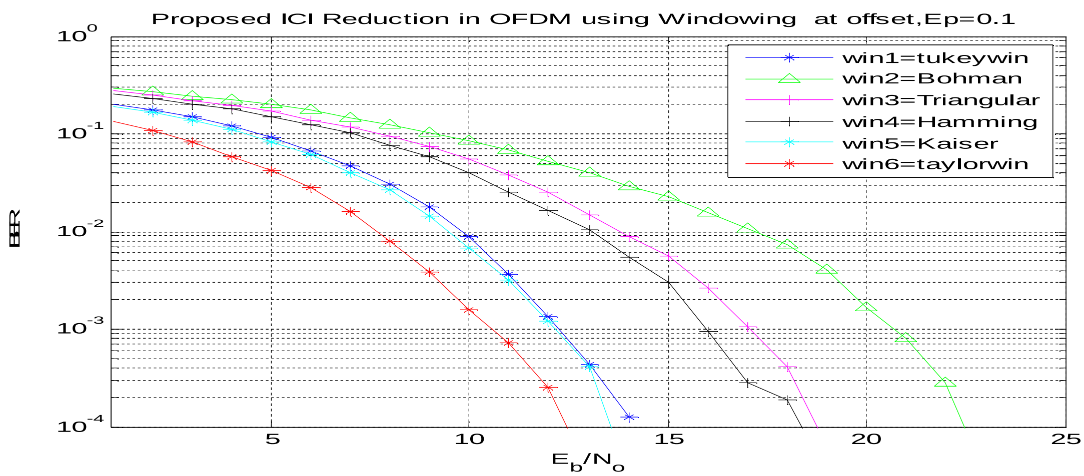


Fig. 3 Implemented window function

This work considers BPSK modulation for the performance comparisons. This is because the symbols are at equal energy levels and the effect of carrier frequency offset is easily presented in PSK modulation. Analysis is done by observing the simulation result and tabulating the analysis results to make it more convenient to be read. The simulation results are plotted in terms of BER and SNR The different window function that are implemented in the proposed scheme are plotted as above.

IV. SIMULATED RESULT ANALYSIS

BER curves are used to evaluate the performance of OFDM system each scheme. For the simulations in this



paper, MATLAB is employed with its Communications Toolbox for all data runs. The OFDM transceiver system was implemented as specified by Fig. 2. Frequency offset was introduced as the phase rotation. Modulation schemes of binary phase shift keying (BPSK) is chosen as they are used in many standards such as 802.11a.Simulations for cases of normalized frequency offsets equal to 0.1, 0.2, 0.3 and 0.5.

The simulation parameters used for the above model is as given below.

Parameter	**Specifications**
IFFT Size	64
No. of Carriers in one OFDM symbol	32
Channel	AWGN
Frequency Offset	[0.1, 0.2, 0.3 ,0.5]
Modulation	BPSK
No. of OFDM symbols for one loop	1000
Eb - No	1:25
Bits per OFDM symbols	N*log2(M)

Fig. 4 to Fig.7 provides comparisons of the
performance of proposed self cancellation scheme for different Window function and different values of the frequency offset.

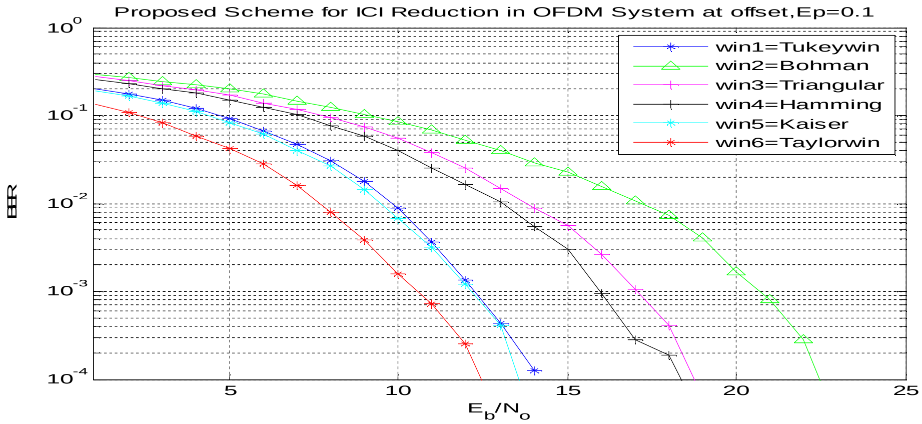


Fig. 4 BER performance of a BPSK OFDM system at Ep=0.1

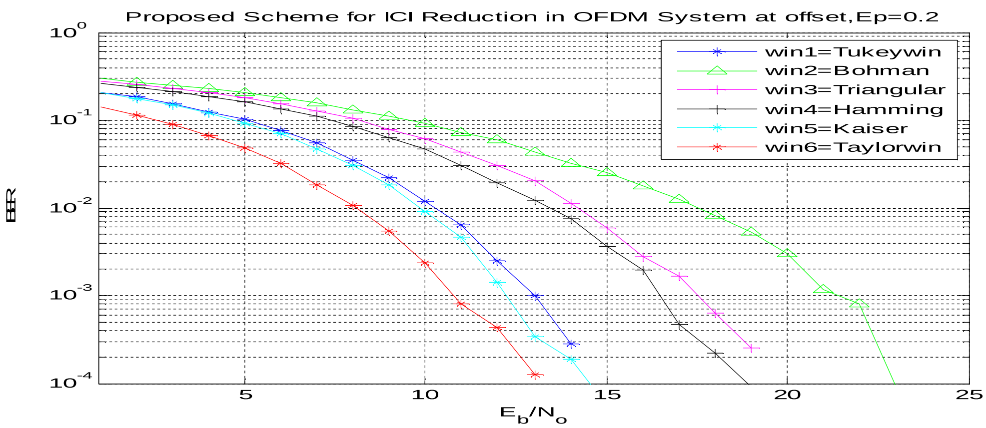


Fig. 5 BER performance of a BPSK OFDM system at Ep=0.2

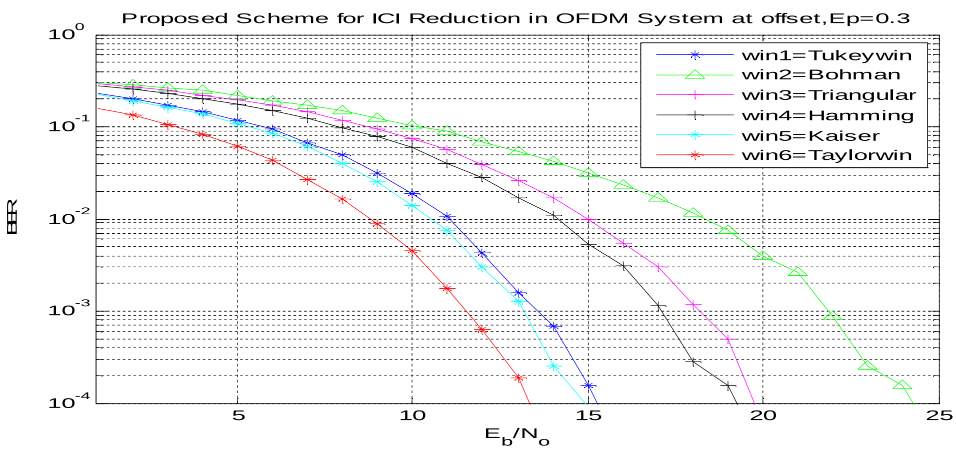


Fig. 6 BER performance of a BPSK OFDM system at Ep=0.3

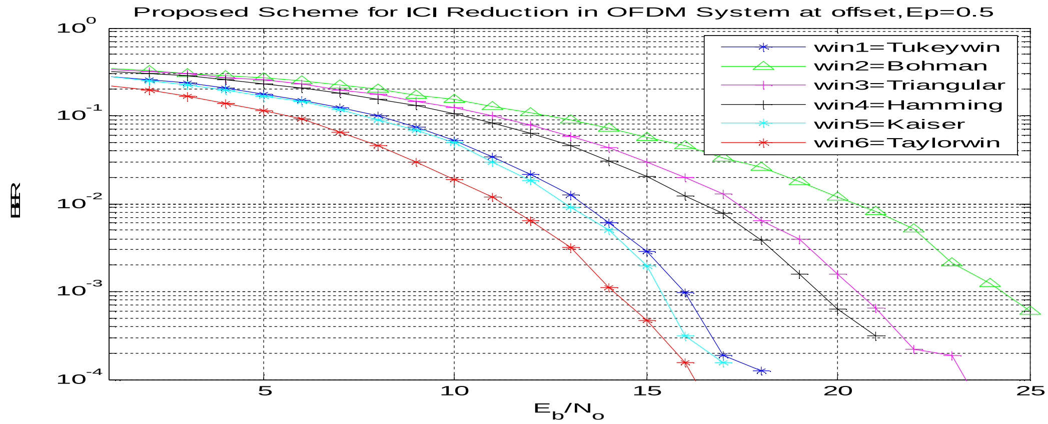


Fig. 7 BER performance of a BPSK OFDM system at Ep=0.5

Each of this result is simulated at low as well as at high frequency offset with different Window function. At high offset values Bohman window result poorest performance in comparison to other window

Tab 1: BER performance of a BPSK OFDM system at BER= 10^{-3}

Freq. Offset	Taylor Window (Win 6)	Tukey Window (Win 1)	Kaiser Window (Win 5)	Hamming Window (Win 4)	Triangular Window (Win 3)	Bohman Window (Win 2)
Ep=0.1	10.5 dB	12dB	12dB	16dB	17dB	21dB
Ep=0.2	11 dB	13dB	12.5dB	17dB	17.5dB	22dB
Ep=0.3	12 dB	13.5dB	13dB	17.5dB	18dB	22dB
Ep=0.5	14 dB	15dB	15.5dB	19.5dB	20.5dB	24dB

From the Table 1 , it is observed that Taylor window gives the better SNR improvements as comparison to other windows at low as well as at high value of carrier frequency offset .The Taylor Window gives around 10.5dB SNR at offset, Ep = 0.1 and 14 dB at offset, Ep = 0.5. As SNR increases BPSK BER curve leans downward which indicates reduction in bit error rate.The Bohman Window gives around 21dB SNR at offset, Ep = 0.1 and 24 dB at offset, Ep = 0.5. As SNR increases BPSK BER curve leans downward which indicates reduction in bit error rate.Therefore the overall BPSK-OFDM system improved SNR indicating reduction in BER.

V Conclusion

In this paper, the performance of OFDM systems with different frequency offset between the transmitter and the receiver has been studied in terms of the Carrier-to-Interference ratio (CIR) and the bit error rate performance. ICI which results from the frequency offset degrades the performance of the OFDM system.

An ICI self-cancellation with windowing function for combating the impact of ICI on OFDM systems for different frequency offset values has been considered. From the simulation result it is observed that for OFDM BPSK system Taylor window function provide better SNR improvement than other window functions. It is also suitable for multipath fading channels and is less complex. Under the condition of the same bandwidth efficiency and larger frequency offsets, the proposed scheme performs much better than standard OFDM systems. In addition, since no channel equalization is needed for reducing ICI, the proposed scheme is therefore easy to implement without increasing system complexity.

In this paper, the simulations were performed in an AWGN channel. This model can be easily adapted to a flat fading channel with perfect channel estimation. Further work can be done by performing simulations to investigate the performance of this ICI cancellation scheme in multipath fading channels without perfect channel information at the receiver side.

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