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# A Difference Timing Synchronization Method Based on Cyclic Prefix for OFDM Systems

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**Abstract:** Cyclic prefix is a copy of the last samples of OFDM symbol. The OFDM synchronization estimation algorithm based on cyclic prefix has low complexity and can save the bandwidth resource of the OFDM systems, so the synchronization method proposed in this study is based on cyclic prefix. Novel symbol timing metric is presented in the proposed method and the timing metric has a peak plateau. The proposed method does not need to seek for the peak value of the timing metric to realize the synchronization estimation. It just needs to find the edge of the peak plateau. In the proposed method we need to set a threshold to process symbol timing metric, after which it is easy to find the edge of the peak plateau, so the proposed method has low complexity. The simulation results show that the proposed method has low mean error and MSE.

**Key words:** OFDM, timing synchronization, difference, cyclic prefix, edge judge

## INTRODUCTION

OFDM (Orthogonal frequency division multiplexing) was proposed by Chang (1966). The transmitted serial symbol sequence is split into parallel lower rate symbol streams to modulate the orthogonal subcarriers. So the symbol duration in each subcarrier is increasing which can reduce the effect of channel time delay to OFDM systems. OFDM has better spectrum efficiency than FDM (Moose, 1994). Recently, the OFDM modulation technique has gained an increased interest due to its advantages such us high spectrum efficiency and strong anti multipath faidng ability. It has been used in digital audio broadcasting and digital video broadcasting. And it has recently become popular for wireless communication systems (Zou and Wu, 1995), for example, it has been adopted as a standard in IEEE 802.11a. Now, OFDM technology is regarded as the core technology of mobile communications beyond 3G. And people are researching on applying OFDM technology to low-voltage power line carrier communication. In recent years, the merger of MIMO and OFDM becomes the focus of study.

But OFDM systems are very sensitive to the timing synchronization errors than single carrier systems. If there are timing synchronization error in OFDM systems, it will introduce inter-symbol interference, even introduce inter carrier interference and it will destroy the orthogonality between sub-carriers, even it will deteriorate the performance of OFDM systems. So it is necessary to estimate timing synchronization error for OFDM systems. At present, there are many researches on symbol timing estimation in OFDM systems (Moose, 1994; Schmidl and Cox, 1997; Minn *et al*., 2006; Van de Beek *et al*., 1997; Jiang *et al*., 2007; Li *et al*., 2010; Yi *et al*., 2010; Chen *et al*., 2009; Wang *et al*., 2008) and these methods are classified into two kinds: data-aided and non data-aided. The synchronization estimation method based on data-aided need special training sequence or pilot which occupy the bandwidth resource of OFDM systems. One classical synchronization algorithm of this kind is S&C algorithm (Schmidl and Cox, 1997). The synchronization estimation method with non data-aided does not need neither special training sequence nor pilot, it is based on cyclic prefix which can save the bandwidth resource of OFDM systems and has lower complexity. One classical algorithm based on cyclic prefix is ML (maximum likelihood) algorithm (Van de Beek *et al*., 1997).

The timing synchronization method proposed in this study is based on cyclic prefix. The proposed method is low complexity and reduces the effect of multipath channel.

## OFDM SYSTEM MODEL

Suppose there are N subcarriers in an OFDM system, then the OFDM signal can be expressed as following:

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

where, X (k) is the baseband data modulated on the k subcarrier. The front of the resulting N block IFFT sample is augment with a Ncp block cyclic prefix to form a transmitted OFDM symbol comprised of N+Ncp samples. The Ncp length cyclic prefix sequence is a copy of the last Ncp data samples of the OFDM symbol.

The impulse response of multipath channel can be expressed as:

$$h(n) = \sum_{i=0}^{L-1} a_i(n)\delta(n-\tau_i) \tag{2}$$

where, L is the multipath number of channel, $a_l$ is fading coefficient of l path channel, $\tau_i$ is the number of delay samples of l path channel. In the ideal case, the received signal at the receiver can be modeled as:

$$y(n) = \sum_{i=0}^{L-1} a_i(n)s(n-\tau_i) \tag{3}$$

If there are time delay and frequency offset at the receiver, the signal at the receiver can be expressed as:

$$r(n) = y(n-\theta)e^{j\frac{2\pi n\varepsilon}{N}} + w(n) \tag{4}$$

Here, θ is the time delay of channel, w (n) is the additive white Gaussian noise.

## DIFFERENCE METHOD BASED ON CYCLIC PREFIX FOR OFDM SYSTEMS

**Principle block diagram:** Cyclic prefix is a copy of the last samples of OFDM symbol. If there is no multipath fading or frequency offset, cyclic prefix of and the part of the received signal which delay N should be the same. The method proposed in this study is based on the correlation between cyclic prefix and the last samples of OFDM symbol.

The principle block diagram of difference timing synchronization method based on cyclic prefix for OFDM system is shown in Fig. 1.

**Details of the proposed method:** There are three parts in principle block diagram in Fig. 1. The first part is the energy part. The energy term of the received signal is shown in Eq. 5:

$$R_1(k) = \sum_{m=1}^{M} \left| r(k+(m-1)(N+N_{cp})) \right|^2 \tag{5}$$

The energy term of the delay part of received signal is shown in Eq. 6:

$$R_2(k) = \sum_{m=1}^{M} \left| r(k+(m-1)(N+N_{cp})+N) \right|^2 \tag{6}$$

The second part is the correlation function of the received signal and the received signal which delay N:

$$\phi(k) = \sum_{m=1}^{M} r^*(k+(m-1)(N+N_{cp}))^* \times r(k+(m-1)(N+N_{cp})+N) \tag{7}$$

where, M is the symbol number in per sub-carrier.

The third part is symbol timing estimation.

Novel symbol timing metric is presented in the difference timing synchronization method based on cyclic prefix for OFDM systems. The novel timing metric is shown in Eq. 8:

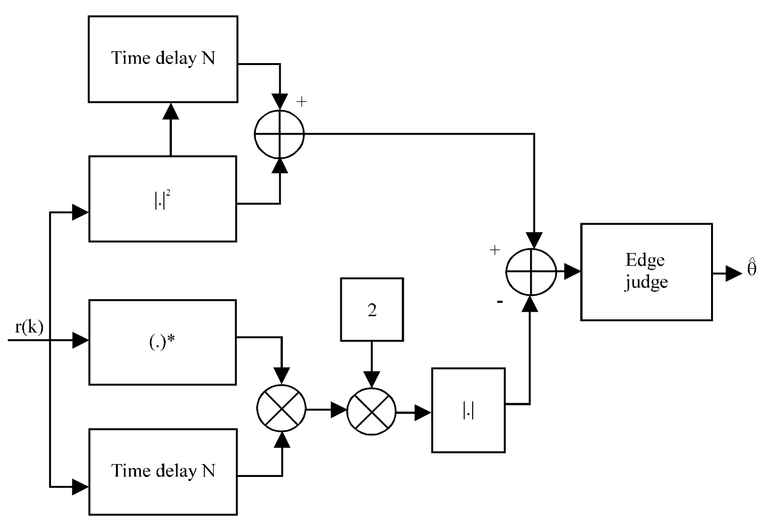


Fig. 1: Structure of the proposed estimator

$$D(k) = R_1(k) + R_2(k) - |\phi(k)| * 2 \tag{8}$$

And a threshold is set.

## SIMULATION ANALYSIS

The symbol timing metric curves of the proposed method in AWGN channel are shown in Fig. 2.

From Fig. 2, we can see that the length of the peak plateau is equal to the length of cyclic prefix. And the edge of the end of the peak plateau is the tail of cyclic prefix. And the edge can be found easily. If the edge is found, the time delay is found.

The symbol timing metric curves of the proposed method in multipath channel are shown in Fig. 3. From Fig. 3b, we can see that the length of the peak plateau is smaller than the length of the peak plateau in AWGN channel. Because there is inter symbol interference in multipath channel which affects the front-end of cyclic prefix. The part in the ring is affected by inter symbol interference as shown in Fig. 3a.

From Fig. 3, we can see that the end of the peak plateau is also the tail of cyclic prefix, so we can use the edge of the peak plateau to find the time when the OFDM symbol start.

In order to reduce the effect of the unuseful values to the synchronization estimation, a threshold is set. The timing metric curve in AWGN channel after processing by the threshold is shown in Fig. 4.

From Fig. 4, we can see that the timing metric curve in AWGN channel after processing is just a peak plateau, there are no other values. The length of the peak plateau is equal to the length of cyclic prefix. The edges of the peak plateau are very easy to be found and are vertical. So, the timing synchronization estimation can be realized very easily. The sample after the cyclic prefix is the start of the OFDM symbol.

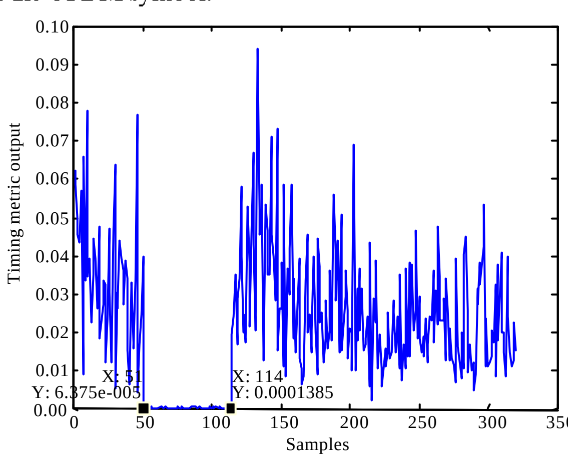


Fig. 2: Timing metric of the novel algorithm in AWGN channel (time delay = 50 samples)

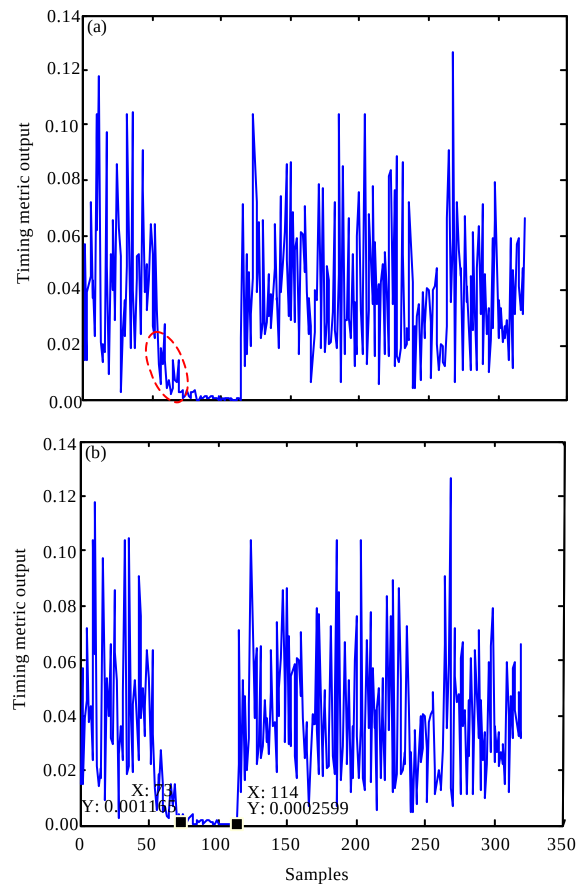


Fig. 3(a-b): Timing metric of the novel algorithm in multipath channel (time delay = 50 samples) (a) Part in the ring is affected by inter symbol interference and (b) Length of the peak plateau

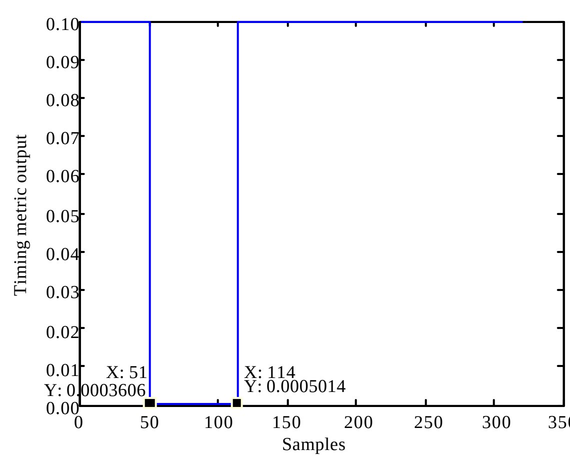


Fig. 4: Timing metric of the novel algorithm in AWGN channel after processing

The timing metric curve in multipath channel after processing by the threshold is shown in Fig. 5.

From Fig. 5, we can see that the timing metric curve in multipath channel after processing is also a peak plateau. There are no other values too. The length of the peak plateau is less than the length of cyclic prefix. But the edges of the peak plateau are very easy to be found and are vertical. So the timing synchronization estimation can be realized very easily too. The sample after the cyclic prefix is the start of the OFDM symbol.

Suppose new symbol timing metric+threshold is method 1 and new symbol timing metric+minimum is method 2. Comparing method 1 with method 2 in AWGN channel and multipath channel, respectively. The simulation parameters are shown in Table 1.

Timing mean error of method 1 and method 2 in AWGN channel is shown in Fig. 6.

Figure 6 indicates that the timing mean error of method 1 in AWGN channel is much lower than the one of method 2 when the SNR is same. And the timing mean error of method 1 reduces when the SNR increases.

Timing MSE of method 1 and method 2 in AWGN channel is shown in Fig. 7.

Figure 7 indicates that the MSE of the traditional method which seek for the peak to realize symbol timing synchronization is much larger than the one of the proposed method.

Timing mean error of method 1 and method 2 in multipath channel is shown in Fig. 8.

Table 1: Parameter list in simulation

| Parameters | Value |
|---|---|
| Numbers of sub-carriers | 256 |
| Modulation mode | Differential phase shift keying (DPSK) |
| Length of cyclic prefix | 64 |
| Time delay | 50 |
| Multipath numbers | 6 |

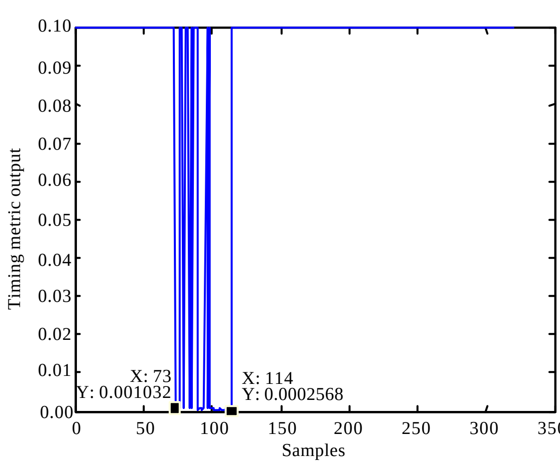


Fig. 5: Timing metric of the novel algorithm in multipath channel after processing

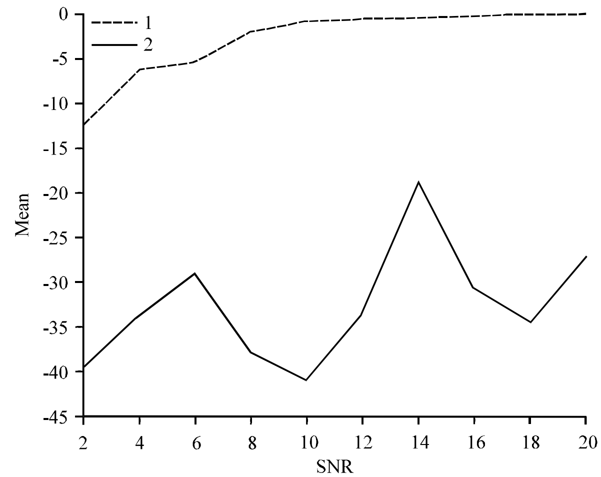


Fig. 6: Timing mean error of method 1 and method 2 in AWGN channel

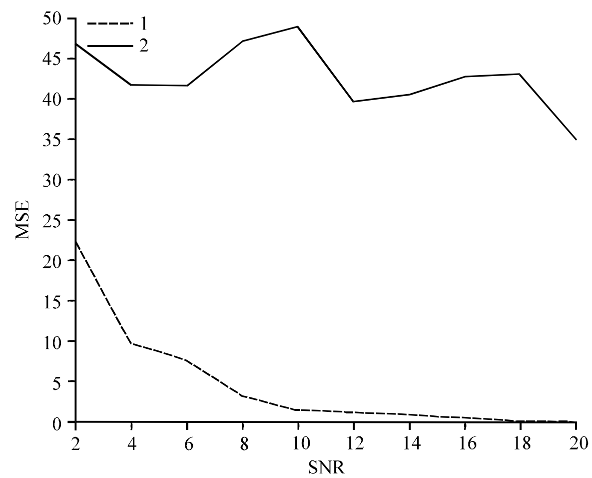


Fig. 7: Timing MSE of method 1 and method 2 in AWGN channel

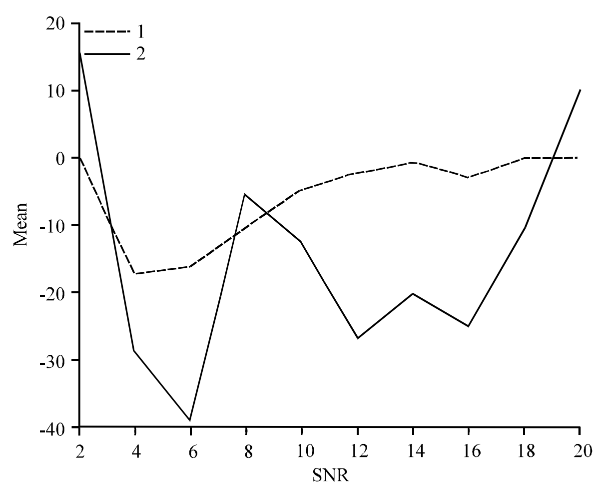


Fig. 8: Timing mean error of method 1 and method 2 in multipath channel

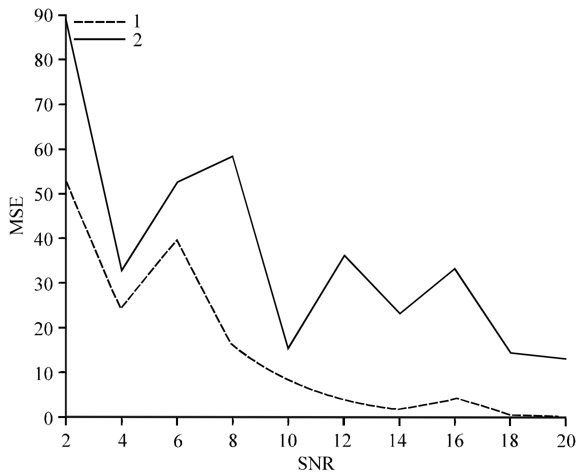


Fig. 9: Timing MSE of method 1 and method 2 in multipath channel

Timing MSE of method 1 and method 2 in multipath channel is shown in Fig. 9.

Figure 8 and 9 indicate that when SNR is same, mean error and MSE of method 1 are lower than the one of method 2.

## CONCLUSION

From the above analysis, the timing metric both in AWGN and in multipath has a peak plateau and the end of the peak plateau is the tail of cyclic prefix. After the processing by the threshold, the timing metric is just a peak plateau and the edges are vertical which can be found easily.

So, the difference timing synchronization method based on cyclic prefix for OFDM systems is low complexity and very easy. The simulation results show that the proposed method has low mean error and MSE.

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