A Novel OFDM Timing Synchronization Algorithm
Based on Stochastic Approximation and ML Algorithm

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Abstract: ML algorithm has low computational complexity but its timing estimation is not good. In order to improve the problem, combination of stochastic approximation and ML algorithm is proposed. Using ML algorithm as tuning coarse estimation and stochastic approximation algorithm as timing fine estimation, the simulation results show that the proposed algorithm can realize more accurate symbol timing than ML algorithm.

Key words: ML algorithm, stochastic approximation, timing synchronization, OFDM, timing offset

INTRODUCTION

OFDM (orthogonal frequency division multiplexing) system which has advantages of high spectrum efficiency and good anti multipath fading performance (Latif and Ghaur, 2008) obtains more and more attention. OFDM technology is applied in wireless (Al-Kehsi, 2008), such as DVB and personal area networks (Ramesh and Vaidhe, 2006). The wireless communication system coupled with MIMO-OFDM is regarded as a good idea (Zaogah et al., 2007). OFDM is also commonly adopted in broadband wireless communications (Elahmar et al., 2007; Arioua et al., 2012; Yi et al., 2011) and in wireless underwater communication (Abdellouai et al., 2006). Recently, people try to apply OFDM system in power line carrier.

To an OFDM system, the time when OFDM symbol arrives is unknown and it is more sensitive to timing estimation error than single carrier system. So, the problem of OFDM timing synchronization needs to be solved urgently.

Now, there are many methods to solve the synchronization problem for OFDM system (Schmidl and Cox, 1997; Minn et al., 2000; Ye et al., 2007; Van de Beek et al., 1997; Chandranath and Vikram, 2002; Bolcskei, 2001; Salari et al., 2008), some based on pilot or special training sequence have good synchronization performance but they occupy system bandwidth resources (Schmidl and Cox, 1997; Minn et al., 2000; Ye et al., 2007; Yi et al., 2010); some are non data-aided which do not need neither pilot nor special training sequence and can save system bandwidth resources (Van de Beek et al., 1997; Chandranath and Vikram, 2002; Salari et al., 2008). The classical algorithm of this type is maximum likelihood estimation algorithm-ML algorithm (Van de Beek et al., 1997) which has low computational complexity, but its timing estimation error is larger. To solve the problem, a novel algorithm which combines stochastic approximation with ML algorithm is proposed.

OFDM SYSTEM MODEL

The baseband OFDM data symbol can be expressed as:

\[ s(n) = \frac{1}{N} \sum_{k=-N/2}^{N/2} x(k)e^{j2\pi kn/N} \]  

(1)

where, \( N \) is the number of subcarriers. The transmitted OFDM signal sequence \( s(n) \) is modulated by means of IFFT (inverse fast Fourier transform). There is \( L \) cyclic prefix before \( N \) IFFT samples, so, the length of the transmitted OFDM is \( N+L \).

In an OFDM system, the complex discrete time signal \( r(n) \) in the receiver can be described as:

\[ r(n) = s(n-T)e^{j2\pi fn/N} + w(n) \]  

(2)

where, \( T \) is the channel delay and \( w(n) \) is the additive white Gaussian noise.

THE TRADITION ML ALGORITHM

Cyclic prefix is the copy of the last \( L \) symbols of OFDM. The correlation between them is used for synchronization estimation in ML algorithm. The

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Actually, the synchronization problem is the stochastic optimization problem described as Eq. 8 proposed by Chandranath and Vikram (2002).

\[
\max E [ |P_u(\theta)| ]
\]  

(8)

where, \( \theta \) is an unknown parameter, \([P_u(\theta)]\) which is independent random variable sequence about \( \theta \), is defined as follows:

\[
p_u(\theta) = \frac{1}{L} \sum_{l=0}^{L-1} r(k + \theta + m(N + L)) \times r^*(k + \theta + (m+1) (N + L) - L)
\]  

(9)

where, * represents conjugate.

The steps of the proposed algorithm are as follows:

- Using ML algorithm as OFDM timing coarse synchronization and Eq. 3-7 are used here. Suppose \( \Phi = |\lambda(\theta)| - \rho \Phi(\theta) \), compare with the given threshold. When \( \Phi \) is larger than the given threshold, the OFDM timing fine synchronization namely stochastic approximation algorithm is used.

- According to the characteristic of the independent uniform distribution random variable and the current \( \hat{\theta}_m \), generate a new \( \hat{\theta}_m \). Then calculate the value of:

\[
C_u(\hat{\theta}_m, \hat{\theta}_m) = |P_u(\hat{\theta}_m)| - |P_u(\hat{\theta}_m)|
\]

If \( C_u > 0 \), then \( \hat{\theta}_{m+1} = \hat{\theta}_m \) else \( \hat{\theta}_{m+1} = \hat{\theta}_m \).

Save the updating \( \hat{\theta}_m \) every time.

- When the value of \( \Phi \) is less than the given threshold, stop to calculate \( C_u(\hat{\theta}_m, \hat{\theta}_m) \) and the last updating is the channel delay.

**SIMULATION RESULTS**

To simulate the traditional ML algorithm and the novel algorithm proposed in this article. The data symbols are modulated by means of QPSK. The number of subcarriers is 1024 and the length of the cycle prefix is 128. The simulation results are shown in Fig. 2 and 3.

We can see that the algorithm proposed in this article has good performance of timing synchronization estimation than the traditional ML algorithm from Fig. 2 and 3.
CONCLUSIONS

The novel OFDM synchronization algorithm presented in this article combines stochastic approximation with ML algorithm and it can estimate timing synchronization accurately than ML algorithm.

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REFERENCES


