A Novel Timing Synchronization Method for OFDM-Based UWA Systems

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Abstract

Symbol timing synchronization is of essential significance in the performance of Orthogonal Frequency Division Multiplexing (OFDM) systems. On the basis of symmetric sequences, the current study investigated a timing synchronization method intended for the OFDM system, which was applied to the underwater acoustic (UWA). As a consequence, a dramatic peak at the timing-correct location was generated by a superior pulse-like timing metric, although other components' values were marginal. Besides, the performance of the timing synchronization method was evaluated through computer simulation of the Root Mean Square Error (RMSE), whose results indicated that the proposed method was superior to the typical Park method in Gaussian white noise channel environment.

Introduction

As wireless communication technology advances accompanied by the increasing demand for marine development, the study of hydroacoustic communication has gradually attracted numerous scholars' attention..As a multi-carrier modulation technique, orthogonal frequency division multiplexing (OFDM) is applicable to achieve high-speed information transmission through the orthogonality between subcarriers, making it suitable for use in underwater channels, which is the reason why it has recently been widely applied for hydroacoustic communication. How the OFDM system performs is immediately affected by the accuracy of symbol timing offset (STO) estimation, apart from which, Inter Symbol Interference (ISI) and Inter-Channel Interference (ICI) in the system can also be brought about by timing synchronization errors .

Compared to an existing OFDM synchronization algorithm which was the benchmark algorithm, the present study proposed a new OFDM symbol pursuant to repeated symmetric sequences. According to the simulation results of Additive White Gaussian Noise (AWGN) channel, the proposed method significantly outperformed Park method in the Root Mean Square Error (RMSE).

Synchronization Method

According to this new method, a PN sequence is adopted to generate an OFDM symbol with a repeated symmetric sequence. In addition, a new timing metric is proposed with the differential absolute value as a normalization factor.

Synchronization Preamble Design. In this paper, the training sequence is modified by the Park method. The new training sequence obtained after the modification by excluding the cyclic prefix is expressed as:

$$T_{Proposed} = \boxed{C_{N/2}}\boxed{D_{N/2}}$$

Where $C_{N/2}$ represents a PN sequence of length N/2 with $D_{N/2}$ referring to a symmetric sequence of $C_{N/2}$.

Timing Synchronization. The timing metric is still expressed as

$$M_{Proposed} = \frac{\left|P_{Proposed}(d)\right|^2}{\left(R_{Proposed}(d)\right)^2}$$

Where

$$P_{Proposed}(d) = \sum_{n=0}^{N/2} r(d-n)\, r(d+n)$$

In order to reduce the size of the partials, a timing metric is proposed according to the distinction between the absolute values of the samples. The proposed normalization factor can be expressed as

$$R_{Proposed}(d) = \sum_{n=0}^{N/2} \left| r(d-n)^2 - r(d+n)^2 \right|$$

Simulation Results

With the typical Park method taken as a benchmark, the performance of the two methods in this part was evaluated and compared through simulation. Under the same conditions, the proposed method adopted the same training sequence length and the cyclic prefix length. An OFDM system with 256 subcarriers (N), N/8 samples of cyclic prefixes, and a normalized carrier frequency offset of 0.1 was simulated to assess the synchronization performance of the two methods in a Gaussian white noise channel. Besides, RMSE was applied as the performance metric to evaluate the performance.

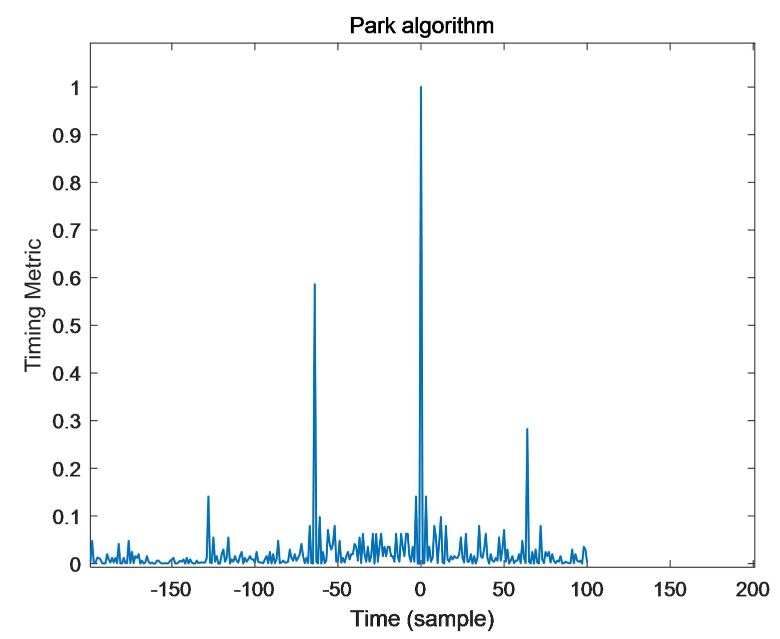

Fig. 1. Timing Metric of Park

Figures 1 and 2 showed the timing metric results obtained by the adoption of the proposed method and Park method, respectively, under the same conditions. As can be seen from Figure 1, Park method led to a peak at the correct timing metric moment along with side flaps on both sides, affecting the timing accuracy of the whole system. Moreover, the side flaps were eliminated. On the contrary, the RMSE of the proposed method was smaller and approached 10 when the signal-to-noise ratio (SNR) was 6 dB, while that of Park method reached 100. Besides, the gain of the new method was 3 dB when the RMSE was 101.

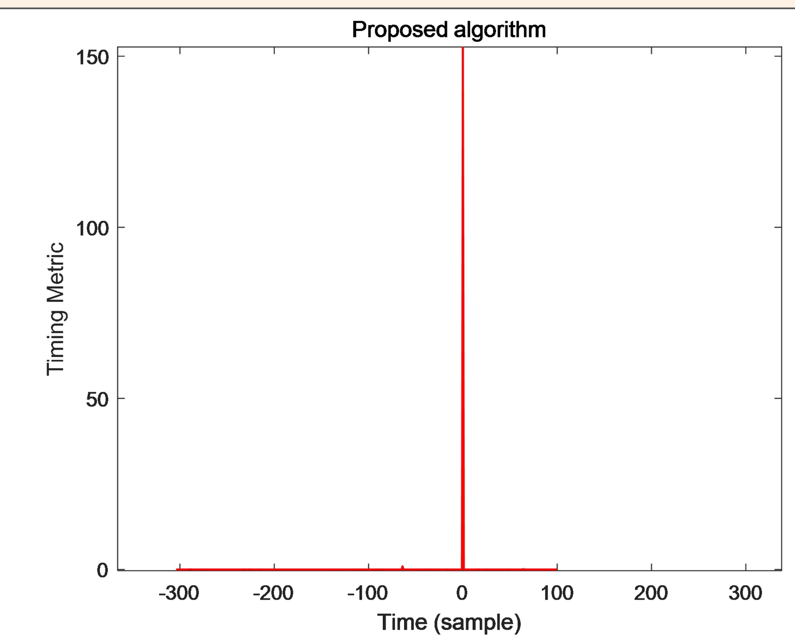

Fig. 2. Timing Metric of Propose

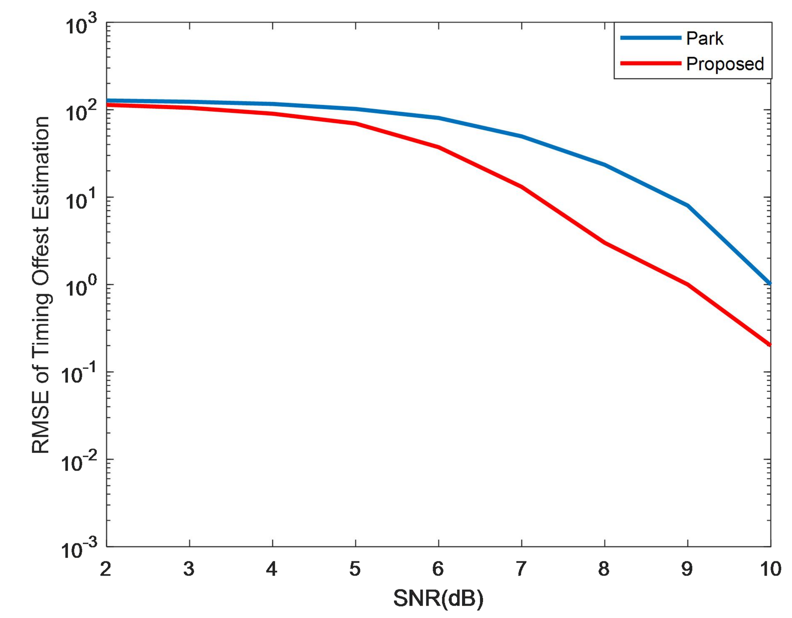

Fig. 3. MSE of timing offset.

Conclusions

In this paper, with the aim to restrict the training sequence to real values and monopoles, a new timing synchronization method was proposed and applied to hydroacoustic communication. Compared with Park method, this new method improved the training sequence structure and proposed a new timing metric algorithm with a pulse at the correct timing moment formed, as well as eliminating the side flaps. When it comes to the performance evaluated and compared in AWGN channels, the proposed synchronization method had a smaller RMSE than that of the typical Park synchronization method, which means the proposed method had a higher rate of correct timing synchronization..