

# Timing Synchronization and Channel Estimation of a Constant Pilot Padding OFDM System

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**Abstract**— In this paper, we propose a Constant Pilot Padding Method (CPPM) that can perform both the timing synchronization and channel estimation in the Orthogonal Frequency Division Multiplexing (OFDM) systems. The CPPM method exploits the repetitive structure of the preamble generated by inserting the constant pilots in the frequency domain to execute the timing synchronization. In addition, the CPPM method has the ability of channel estimation with these padding pilots. Compared with the conventional synchronization methods, such as the S&C method and the Park’s method, the preamble of the CPPM provides not only timing synchronization but also data transmission. Simulation results show that the proposed method is more precise and robust than the S&C method and the Park’s method.

**Index Terms**—Timing Synchronization, Channel Estimation, OFDM

## I. INTRODUCTION

ORTHOGONAL Frequency Division Multiplexing (OFDM) has been widely adopted in the current wireless communication systems, such as IEEE802.11a/g, Digital Video Broadcasting for Handheld (DVB-H), and IEEE802.16 Wireless MAN, due to its high bandwidth efficiency and the ability of overcoming frequency selective fading channel. To accomplish the frequency synchronization and the symbol detection, an OFDM system has to establish the timing synchronization [1]-[11] firstly. Two types of timing synchronization methods can be classified: one is the data-aided schemes [1]-[5] that design a preamble structure suitable for timing synchronization. For example, the S&C method [1] and the Park’s method [2] use the repetitive preamble to estimate the timing offset. These methods use the PN (pseudo-noise) sequence in the frequency domain to generate preamble with a specific repetitive form. The second type of the timing synchronization is the non-data-aided schemes [6]-[11]. [6] exploits the cyclic prefix (CP) structure of OFDM symbol and performs the Maximum Likelihood Estimation (MLE) for the timing offset. [7] uses a BPSK modulated signal to carry out a blind timing synchronization. However, the estimation performance of the non-data-aided schemes are generally poor than the data-aided methods.

In this paper, we propose a Constant Pilot Padding Method (CPPM) that has both the timing synchronization and the channel estimation abilities. Compared with the S&C method

and the Park’s method, the repetitive structure of the preamble is generated by inserting constant pilots in the frequency domain rather than the PN sequences. Besides, the generated preamble can also carry the modulated information symbols to improve the disadvantage of inefficiency bandwidth usage of the conventional data-aided methods.

This paper is organized as follows. In Section II, the proposed CPPM method and the corresponding repetitive preamble structure will be described in detail. Besides, the linear interpolated channel estimation via using the padding pilots will also be illustrated. Simulation results of the proposed CPPM method, the S&C method and the Park’s method are investigated in Section III. Some conclusions for this paper are given in Section IV.

## II. METHOD DESCRIPTION

The proposed OFDM system that exploits Constant Pilot Padding Method (CPPM) with data padding interval  $I=2$  is shown in Fig.1. Before the Inverse Fast Fourier Transform (IFFT), the padding pilots  $P$  along with the modulated data  $X_k$  are arranged as

$$X_k^P = \begin{cases} X_k, & k = 0 : I : (N - I) \\ P, & \text{otherwise} \end{cases} \quad (1)$$

where  $X_k$  are the modulated symbols inserted on the subcarriers with interval  $I$ ,  $I$  is defined as data padding interval,  $N$  is the total number of subcarriers,  $k$  is the subcarrier index and  $P$  is the pilot value.

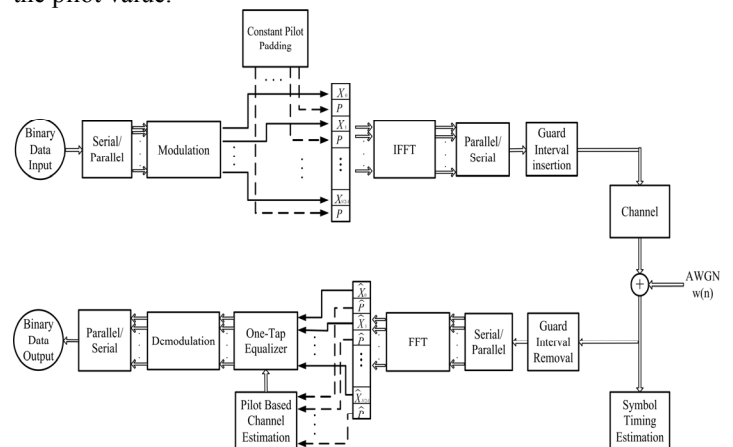


Fig.1 Block Diagram of the Proposed CPPM OFDM System

The generation of the CPPM method can be illustrated in

Fig.2. Assume there are  $N/I$  modulated symbols  $X_k$  (Fig.2(a)), Fig.2(b) illustrates the arrangement of CPPM method in the frequency domain. The modulated symbol  $X_k$  and the constant padding pilot  $P$  are inserted into the subcarriers specified in Eq.(1). After the IFFT operation, the generated preamble will have a repetitive time domain waveform in Fig.2(c). The number of repetitive waveform is determined by the padding interval  $I$ . Besides, the padding pilot  $P$  can perform the channel estimation as in Fig.2(d). Compared with the S&C's and the Park's preamble, the generated preambles of the CPPM method for timing synchronization can transmit the modulated symbols to increase the bandwidth efficiency.

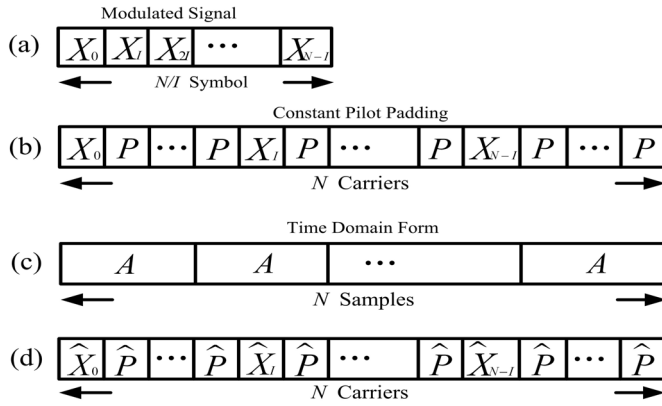


Fig.2 The CPPM Method Structure

Besides, the repetitive structure of the preamble depends on the modulation of the inserted symbols  $X_k$ . Two examples are given below:

(a). *Repetitive Waveform of Inserting BPSK Modulated Symbols*

In the proposed CPPM, if the  $X_k$  are BPSK-modulated, let the padding pilot  $P=1$ , the carrier number  $N=256$  and the padding interval  $I=1$ , after the IFFT operation, the real part and the imaginary part of the generated time domain waveform of the preamble  $X$  can be depicted in Fig.3.

An interesting property can be observed that the CPPM preamble  $X$  has the following property.

$$[x(1), x(2), \dots, x(127)] = \text{symmetry}\{[x(129), x(130), \dots, x(255)]\} \quad (2)$$

Except the two points on  $x(0)$  and  $x(128)$ , the preamble  $x = [B \ B_s^*]_{*N}$  contains two repetitive conjugate symmetric segments,  $B = [x(1), x(2), \dots, x(127)]$ ,  $B_s = [x(129), x(130), \dots, x(255)]$ ,  $(\bullet)^*$  denotes the complex conjugate.

If the padding interval  $I=2$ , except the four points on  $x(0)$ ,  $x(N/4)$ ,  $x(N/2)$ ,  $x(3N/4)$ , the preamble  $X$  contains four repetitive conjugate symmetric segments depicted in Fig.4.

Similar results can be observed if different padding interval  $I$  is adopted. Table-1 lists the time domain repetitive waveform of the preamble for different padding interval  $I$ . Generally, the preamble composes of  $2I$  segments of time domain waveform with the conjugate symmetric property. Besides, each segments contains  $(N/I)-1$  samples.

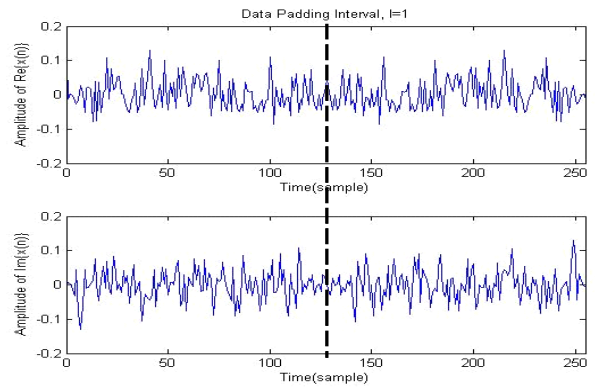


Fig.3 Time Domain Waveform of the Preamble with BPSK Modulated Symbols

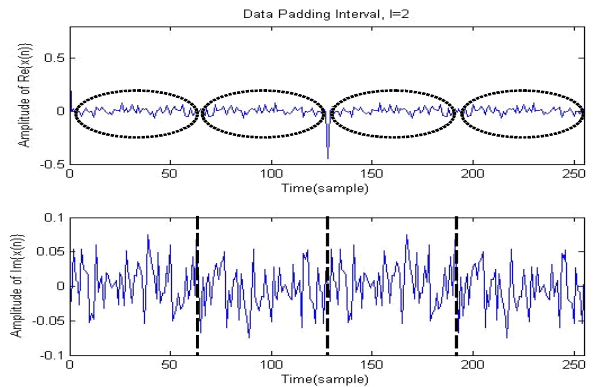


Fig. 4 Time domain waveform of BPSK with  $I=2$ ,  $P=1$

TABLE-1 TIME DOMAIN WAVEFORM OF THE PREAMBLE WITH BPSK MODULATED SYMBOLS

$I$	Time Domain Form
$I=1$	$[B \ B_s^*]$
$I=2$	$[D \ D_s^* \ D \ D_s^*]$
$I=4$	$[G \ G_s^* \ G \ G_s^* \ G \ G_s^* \ G \ G_s^*]$
$I=8$	$[T \ T_s^* \ T \ T_s^* \ T \ T_s^* \ T \ T_s^* \ T \ T_s^* \ T \ T_s^* \ T \ T_s^* \ T \ T_s^* \ T \ T_s^*]$

(b). *Repetitive Waveform of Inserting QPSK/QAM Modulated Symbols*

If the  $X_k$  are QPSK or QAM modulated symbols, let the padding pilot  $P=1$ , the carrier number  $N=256$  and the padding interval  $I=2$ . After the IFFT operation, the real part and the imaginary part of the generated time domain waveform of the preamble has the following properties. Its waveform can be depicted in Fig.5.

$$\text{Real}\{[x(1), x(2), \dots, x(127)]\} = \text{Real}\{[x(129), x(130), \dots, x(255)]\}$$

$$\text{Imag}\{[x(0), x(1), \dots, x(127)]\} = \text{Imag}\{[x(128), x(129), \dots, x(255)]\}$$

Except for the two points on  $x(0)$  and  $x(N/2)$ , the preamble  $X$





