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AN IMPROVED WINDOW BLOCK CORRELATION ALGORITHM FOR CODE TRACKING IN W-CDMA

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ABSTRACT

Wide-Band Code Division Multiple Access (W-CDMA) is designed to offer more flexible wide band service which cannot implement by all the current cellular systems. The performance of a W-CDMA is limited by the synchronous transmission that users are creating between them during transfer the information, and a result of losing synchronous properties it becomes more difficult for the users to maintain reliable communication.

In this paper, an algorithm is proposed in which improved the window block correlation tracking to solve this problem. That this mechanism depends on the system estimator to calculate the threshold of error in time and determine the value of the Power Delay Profile PDP at the point of synchronization by relying on guess the behavior of the PDP adaptively. Computer simulation tests are used to examine the performance of the proposed algorithm with different channel conditions, AWGN and user movement and the results show that it less complexity and faster in decision to get the synchronization as compared with the traditional algorithm.

تحسين خوارزمية تتبع كتلة النافذة لتعقب الشفرة في نظام الحزمة الواسعة بالتقسيم الشفري المتعدد الوصول

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الخلاصة:

تم تصميم نظام الحزمة الواسعة بالتقسيم الشفري المتعدد الوصول (W-CDMA) لتقديم خدمة أكثر مرونة، واسعة النطاق والتي لا يمكن تنفيذها من قبل جميع الأنظمة الخلوية الحالية. إن أداء W-CDMA يكون محدد بخاصية النقل المتزامن بين المستخدمين والتي يجرونها خلال نقل المعلومات بينهما ، ونتيجة لفقدان خاصية التزامن يصبح أكثر صعوبة بالنسبة للمستخدمين للحفاظ على اتصال حقيقي يمكن الاعتماد عليه.

في هذا البحث، تم اقتراح خوارزمية تؤدي إلى تحسين طريقة تتبع كتلة النافذة (WBC) في مواجهة هذه المشكلة. إن هذه الآلية تعتمد على نظام تخمين لحساب عتبة الخطأ الزمني وتحديد PDP عند نقطة التزامن من خلال الاعتماد على التخمين في سلوك PDP دوريا. وتم اختبار الخوارزمية المقترحة ببرنامج محاكاة بالحاسوب لبيان أدائها تحت ظروف قناة متغيرة، AWGN وحركة المستخدم والنتائج أظهرت أنها أقل تعقيد وأسرع في قرار للحصول على التزامن، مقارنة مع الخوارزمية التقليدية.

INTRODUCTION

Spread spectrum communications is considered as a leading technology for use in wideband mobile radio systems. Capitalizing on the ability of spread spectrum signals to mitigate different types of interference, such as multi-user interference and multi-path interference, spread spectrum systems enjoyed worldwide adaptation for third generation (3G) mobile radio systems (**Mohamed, 2010**). Pseudo-noise (PN) code synchronization is essential for direct-sequence spread spectrum (DSSS) systems to work effectively (**Wern, 2004**).

This is very crucial since any spread spectrum based communication system requires reliable and accurate code phase timing information to de-spread the received signal and ensure satisfactory operation (**Mohamed, 2010**). PN code synchronization has been achieved in two steps, code acquisition followed by code tracking (**Wern, 2004**). First, during acquisition, the receiver obtains the relative delay between the received and the locally generated codes to within a chip interval. Then, in the subsequent tracking phase, finer timing adjustment is performed in order to bring the residual timing error as close to zero as possible (**Mohamed, 2008**). In this paper is concentrated on the code tracking part.

In the literature, the techniques have been proposed for code tracking deals with a closed loop structure such as the delay locked loop (DLL) and the tau dither loop (TDL). Different types of DLLs and an improved the performance of DLL was efficient discussed in [(**Mohamed, 2010**), (**Wern, 2004**) & (**Wu, 2009**)]. Also, the window block correlation (WBC) is proposed by (**Asa, 2004**) for code tracking and to the best of our knowledge no previous studies are available.

W-CDMA TECHNOLOGY

Wideband wireless access based on direct sequence code division multiple access technology, the concept of W-CDMA is introduction of inter-cell asynchronous operation and the pilot channel associated with each data channel. In addition, it introduces fast transmit power control (TPC) on both reverse (mobile-to-cell-site) and forward (cell-site-to-mobile) links (**Fumiyuki, 1998**). A simplified structure of the transmission frame is depicted in **Figure 1**. The 10-ms data frame consists of 16 slots with pilot symbols at the beginning of each slot, followed by fast TPC command (**Fumiyuki, 1998**).

The configuration of W-CDMA is shown in **Figure 2**. For each user k, $k \in \{1,...,K\}$, where K is the total number of active users. The binary data stream can be divided into data blocks, each of which consists of N_c symbols. The data block for user k, is represented by a vector, denoted by $b^{(k)}$, which is given by (**Yang, 2006**).

$$b^{(k)} = \{b^{(k)}(i)\}, i \in \{1,...,N_c\} \qquad (1)$$

The data blocked is then interleaved for mapping onto the 16 slots and modulated with Quadrature Phase Shift Keying (QPSK) and is multiplexed with pilot symbols and TPC command. The spreading waveform $c^{(k)}(t)$ is of length L [(**Anhong, 2010**) & (**K. Fazel, 2003**)].

$$c^{(k)}(t) = \sum_{l=0}^{L-1} c_l^{(k)} P_{Tc}(t - lT_c) \qquad (2)$$

The rectangular pulse P_{Tc} is equal to 1 for $0 \le t < T_c$ and zero otherwise. T_c is the chip duration, l is index to the $c_l^{(k)}$ and $c_l^{(k)}$ are the chips of the user specific. After spreading, the signal $x^{(k)}(t)$ of user k is given by (**K. Fazel, 2003**).

$$x^{(k)}(t) = d^{(k)} \cdot \sum_{l=0}^{L-1} c_l^{(k)} P_{Tc}(t - lT_c), \quad 0 \le t < T_d \tag{3}$$

Where $d^{(k)}$ is the modulated data symbol of user k and for one data symbol duration $T_d = LT_c$. The multiplication of the modulated data sequence is done synchronously and the overall transmitted signal $x(t)$ of all K is synchronous users result in (**K. Fazel, 2003**).

$$x(t) = \sum_{k=0}^{K-1} x^{(k)}(t) \tag{4}$$

W-CDMA is designed to support a variety of data services from low to very high bit rates; multiple-rate transmission needs multiple spreading factors (SF) in the physical channels. Since, the cells are assigned to different scrambling codes, each cell site can use short spreading codes independent from other cell. For example, a code tree for generation of variable length orthogonal codes is shown in **Figure 3**, and the scramble code sequence whose length is the same as the data frame length (**Esmael, 1998**).

The impulse response of the multipath channel can be formulated as.

$$h(t) = A_0 \cdot \delta(t) + \sum_{n=1}^{Nn} A_n \cdot \delta(t - \tau_n) \tag{5}$$

Where A and τ are the attenuation and the delay of the nth path. The received signal from the channel can be expressed as

$$y(t) = x(t) \otimes h(t) + n(t) \tag{6}$$

Where $n(t)$ is the additive white Gaussian noise (AWGN) and $\otimes$ denotes the convolution operation [(**Wern, 2004**) & (**K. Fazel, 2003**)].

TRADITIONAL ALGORITHM OF WINDOW BLOCK CORRELATION

The Window Block Correlation (WBC) algorithm is designed by (**Asa, 2004**) for code tracking and to the best of our knowledge no previous studies are available. The WBC algorithm cross-correlates the known PN-sequence with the received signal and forming a vector with cross correlation values, as shown in **Figure 4.** This vector is the window and it gives the received information about the channel and the received signal for the synchronization (**Asa, 2004**). The traditional WBC algorithm can be done by

- The tracking algorithm starts with the received signal $y(t)$ sampled with rate R_s, then reduced by a factor $N = 2$ to reduce the amount of calculations. The output can be written.

$$y(j) = y(2jT_c) \quad j \in \{1,2,3,\ldots,N/2\} \tag{7}$$

  $N = (N_p \cdot SF + N_w) \cdot R_s$, where N_p the number of pilot bits is, N_w is the length of the window and SF is spreading factor.
- The remaining samples per chip are used for calculation of a mean value for each chip.

$$y(r)=\frac{y(j)+y(j+1)}{2} \quad r\in\{1,2,3,...,N/4\} \tag{8}$$

- The $y(r)$ sequence is correlated with the pre-defined sequence of spread and scrambled pilot bits. The resulting sequences are called Complex Delay Profile (CDP) and there are 15 CDPs per frame.

$$CDP_m(w)=\sum_{m=1}^{15}\sum_{r=1}^{Np.SF}\sum_{w=1}^{Nw}c_m(r)\cdot y(r+w) \tag{9}$$

The $c_m(r)$ is the spread and scrambled pilot bits in slot number m.

- Only 14 of the CDPs are used to calculate two Accumulated Complex Delay Profiles ($AccCDP$) according to (**Asa, 2004**).

$$AccCDP_1=\sum_{m=1}^{6}CDP_m \qquad AccCDP_2=\sum_{m=7}^{14}CDP_m \tag{10}$$

- The two $AccCDP$ are used to calculate a mean value called Power Delay Profile (PDP).

$$PDP(w)=\frac{|AccCDP_1|^2+|AccCDP_2|^2}{2} \quad w\in\{1,2,3,...,Nw\} \tag{11}$$

- After calculation the value of the PDP is reprocess after each shift in the window, so the sequence of the PDP has the same length as the window. Finally, are mated this sequence with a certain threshold T_h that depend on a number of constants and a certain amount of mean value of Signal to Interference Ratio (SIR) until that access to the point of the synchronization (**Asa, 2004**).

$$T_h=\begin{cases}\beta & \overline{SIR}\le\alpha\\ k_1\cdot\overline{SIR}+k_2 & \overline{SIR}>\alpha\end{cases} \tag{12}$$

Where T_h is threshold, β, k_1, k_2, α are constants and $\overline{SIR}$ is mean value of SIR.

THE PROPOSED ALGORITHM

At first, it has analyzed the behavior of the PDP in different environmental of channel conditions and it has been found that the distribution of the vectors of PDPs is closed in the behaviors of all these conditions with a difference in variance of distribution. It was also noted that the basic equations in the composition of the PDP has not been dependent on the other values of the PDP, and due to the central limit theorem, it is possible to estimate one behavior for the PDP with the difference of these conditions.

However, to represent mathematical operation of numerical error that arises between the true and the approximation as (**Steven, 2002**).

$$error = true \;\; value - approximation \tag{13}$$

In real world application, it will obviously not know the answer a priori. For these cases, the error is often estimated as the difference between previous and current approximation. Thus, percent relative error is determined according to (**Steven, 2002**).

$$\varepsilon = \frac{current \;\; approximation - previous \;\; approximation}{current \;\; approximation} 100\% \tag{14}$$

This algorithm depends on the instantaneous value of the PDP in order to timely update the value of the threshold and if this value satisfied the boundary of the error condition, the synchronization will achieve to happen, else the signal will be shifted by one sample and recalculation of the PDP to determine the time delay in the received signal: follow the steps

- Calculate only one value of the PDP.

$$PDP = \frac{\left|AccCDP_1\right|^2 + \left|AccCDP_2\right|^2}{2} \tag{15}$$

- Numerical analyze taken from the use of *curve fitting* to approximate mathematical equation, which represent the threshold.

$$Th = a \cdot PDP + b \tag{16}$$

Where a and b are constants according to type of channel.

- Calculate error that arises between the threshold and PDP.

$$error = \frac{T_h - PDP}{T_h} 100\% \tag{17}$$

- If $error \le v$, then the synchronization happen, else shifted by one sample and reprocess the operation, in which v is the percent of accepted error to achieve the synchronization.

SIMULATION PARAMETERS AND RESULTS

The parameters of system configuration, channel and synchronized estimator are used in the simulation can be summarized as **Table 1**.

The flowchart of the synchronized W-CDMA under noisy Rayleigh fading channel that utilizing the proposed algorithm is shown in **Figure 7**. The comparison between performance of synchronized and unsynchronized W-CDMA system under AWGN channel is as shown in **Figure 5**. It is clear that without achieving synchronization, it can not be obtained a performance of the system in measuring the BER even at decide to increasing the Eb/No. That lead, the proposed method to achieve synchronization in nosy environment only that is an effective way and led to good results, in which has been obtained the BER=10^{-4} approximately the value of Eb/No at -4db.

The BER performance of synchronized and unsynchronized W-CDMA under Rayleigh flat and selective fading with AWGN is shown in **Figure 6**. As depicted in this figure, for the proposed algorithm over Rayleigh fading channel in case of flat fading, the performance is degraded with low value of Eb/No also in case of frequency selective fading the performance is severely degraded, specially with the higher of user speed movement fd. This result is closed to the result that deals with the traditional algorithm (**Asa, 2004**).

It is important to mention here that in this paper, only the uncoded W-CDMA system has been considered, but it is clear that the performance can be further improved by introducing error correction codes.

CONCLUSION

Although the traditional method of WBC is effective and powerful way to solve the problem of the tracking phase of the synchronization, but in the environment of the channel conditions are changing slowly. As a result the process of estimation the mean value of SIR and count a threshold and conformity with the vector of PDPs needs time to estimate the point of synchronization or to determine the amount of delay in the received signal. As well as the environmental of channel conditions that are changing quickly affect to the process of estimation and therefore more Bit Error Rate (BER).

According to the analyses that mentioned previously a new mechanism has been fasted and less complexes to estimate the amount of timing error in the arrived signal. Because this mechanism depends on the instantaneous value of the PDP to calculate the threshold of error in time, therefore it is not required to calculate a vector of PDPs as compared with traditional algorithm and this need more time to determine the point of synchronization.

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Table 1 The parameters of system configuration, channel and synchronized estimator.

WCDMA system parameters	
Number of users	7
Slots per frame	16
Symbols per frame	272
Symbols per slot	17
Symbol rate	2MHz
Bit rate	4MHz
Modulation	QPSK
PN-code	Orthogonal
Number of over sample	8
Filter parameters	
Type	Nyquist filter
Number of taps	21
Roll off factor	0.5
Channel parameters	
Type	AWGN, flat, selective
Fading distribution	Rayleigh
Number of path	2 path
Attenuation level	1^{st} path=0dB, 2^{nd} path=40dB
Doppler frequency	50Hz, 120Hz
Synchronization parameters	
a, b for AWGN	0.8087, 0.2532
a, b Rayleigh & AWGN	0.9391, 0.249
v for AWGN,	7%
v for Rayleigh & AWGN	9%

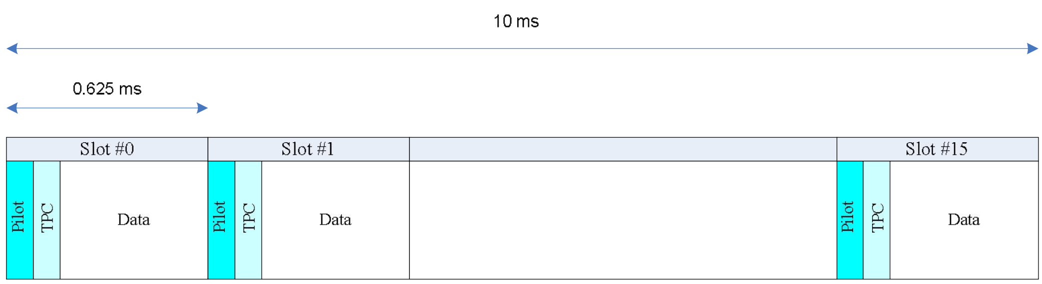

Figure 1 Frame structure (**Fumiyuki, 1998**).

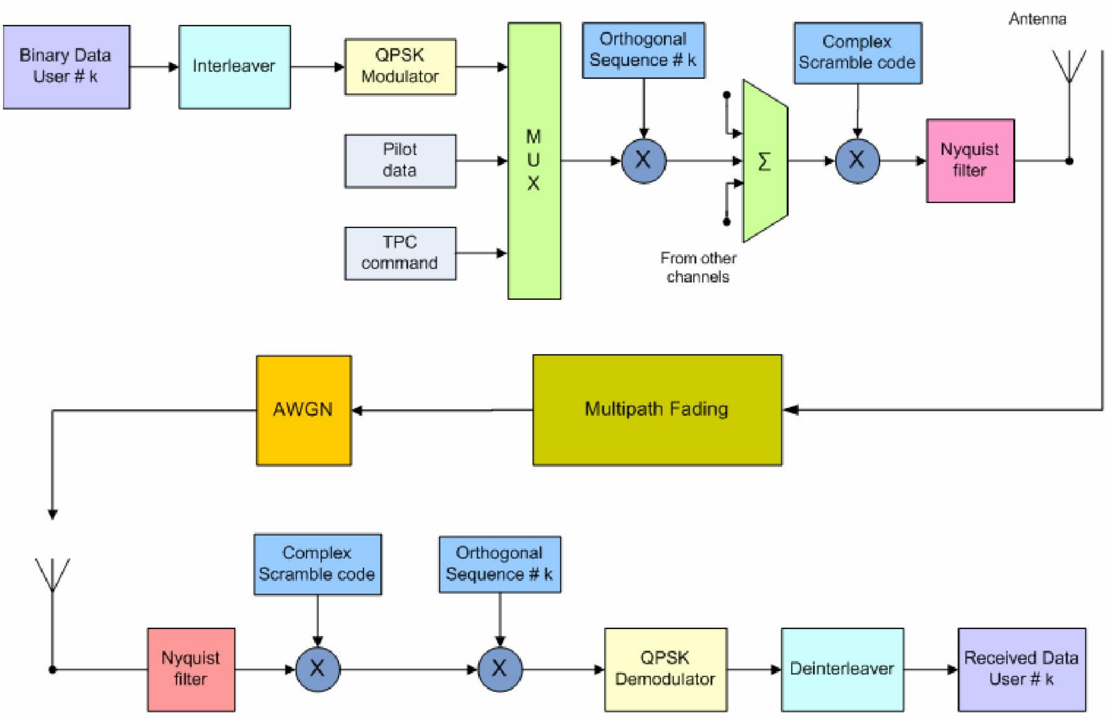

Figure 2 Simplified block diagram of base station transceiver.

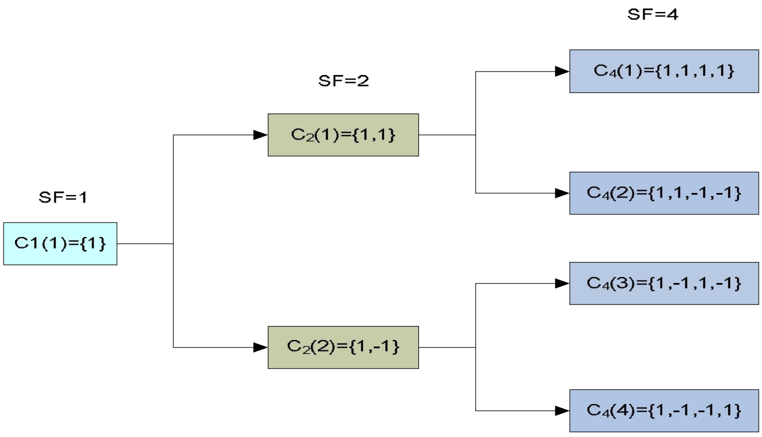

Figure 3 Orthogonal code generation (**Esmael, 1998**).

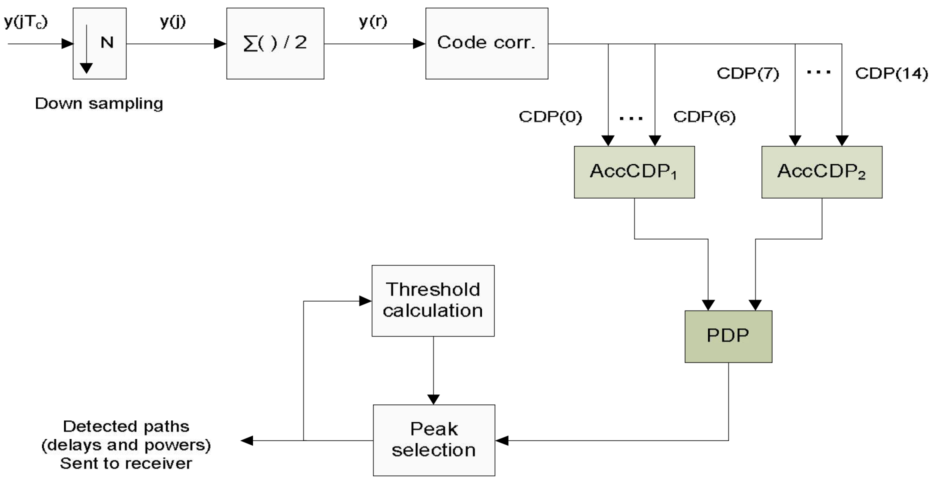

Figure 4 Window blocks correlation tracking algorithm (**Asa, 2004**).

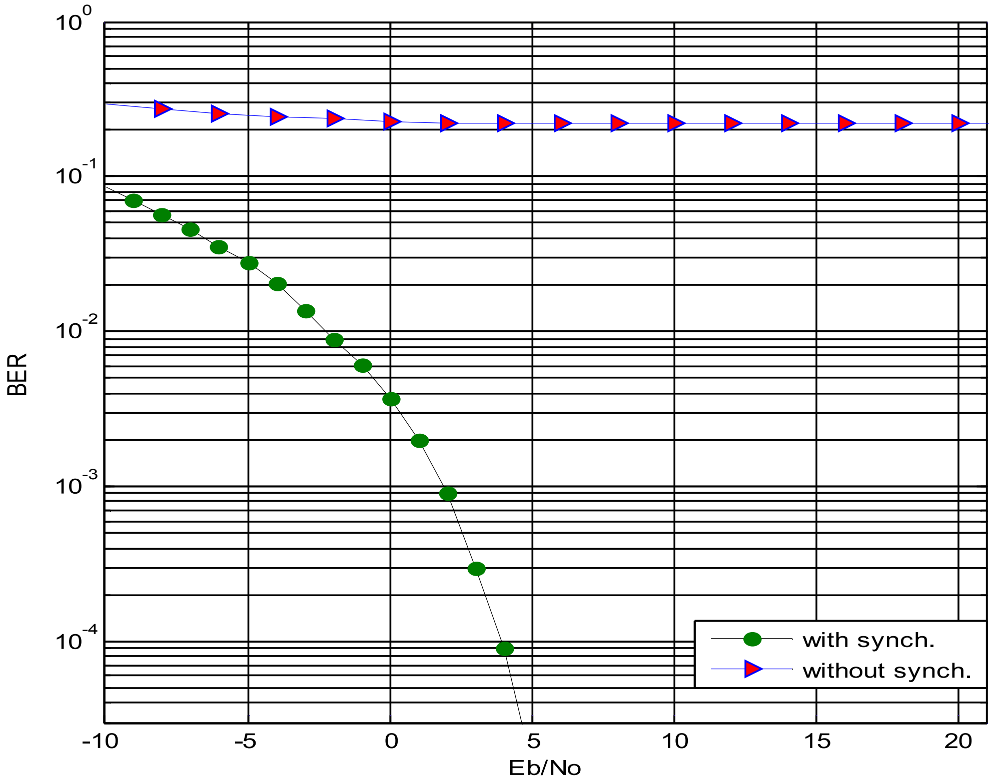

Figure 5 A comparisons between synchronized and unsynchronized WCDMA system under AWGN channel.

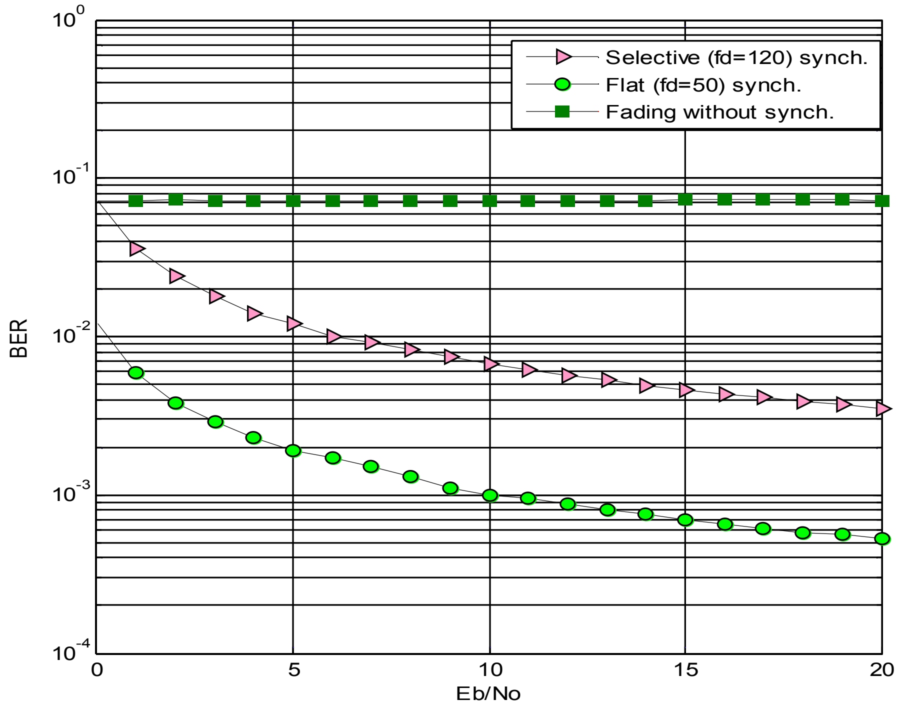

Figure 6 BER performance of synchronized and unsynchronized WCDMA system under flat and selective fading with AWGN channel.

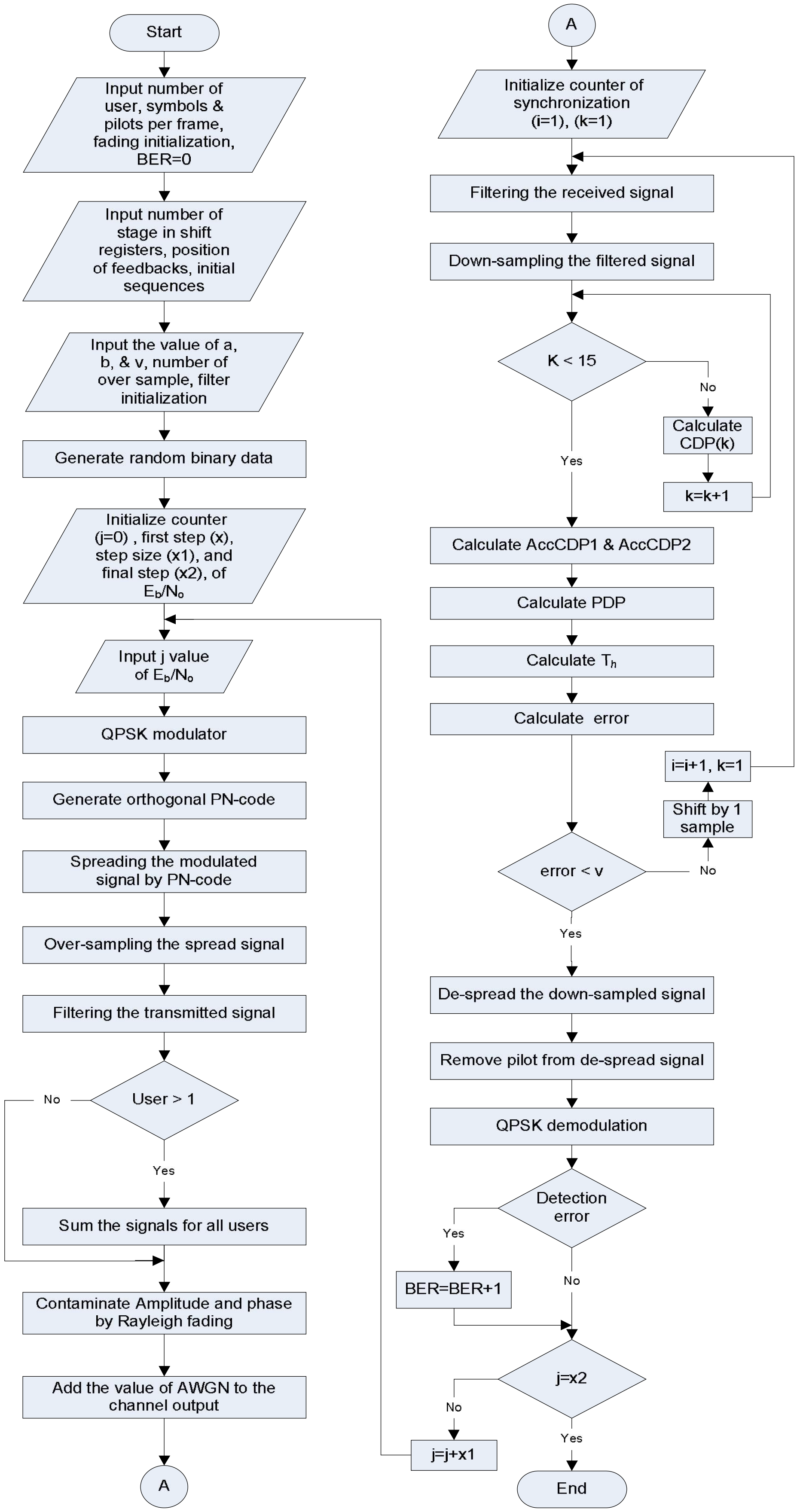

Figure 7 Flowchart of investigated W-CDMA system under noisy Rayleigh fading channel with the proposed WBC algorithm.