ABSTRACT

In this article, we study the performance benefits of the cell search algorithm. The purpose of the cell search algorithm in Universal Mobile Telecommunication Systems (UMTS) is to estimate the spreading code of the serving base-station and its corresponding timing offset. We study the performance benefits of estimating multiple “code-time” hypotheses in each stage of the cell search process. In addition, we also study the effect of oversampling and nonideal sampling. The improved cell search design (CSD) proposed in this article aims to achieve faster synchronization between the mobile station (MS) and the base station (BS) and thus improves system performance, also has lower hardware utilization when compared with the third generation partnership project (3GPP)-comma free cell search design scheme under the same design constraints.

Keywords: 3GPP; CSD; FHT; $P_{\text{rs}}$; PSC; SSC; UMTS; WCDMA; $V_{\text{TH}}$

INTRODUCTION

WCDMA is a wideband direct sequence code division multiple access (DS-CDMA) system, which means that the user information bits (symbols) are spread over a wide frequency bandwidth by multiplying the user data bits with a spreading code sequence of “chips.” To be able to support different bit rates as high as 2Mbp, the use of variable spreading factor and multicode connections is supported. There are two basic modes of operation in WCDMA, Frequency Division Duplex (FDD) and Time Division Duplex (TDD) (3GPP RAN TS 25.211 v4.0.0, 2001/2003). In the FDD mode, separate carrier frequencies are used for the downlink and uplink and in TDD mode only one carrier is used and it is time-shared between the downlink and uplink. TDD mode requires more synchronization between the different mobile terminals and the base stations (3GPP TS 25.104, v3.7.0, 2001). WCDMA uses a large bandwidth (5MHz) for each channel carrier (Ojanpera & Prasad, 1998). WCDMA is designed to be operational in conjunction with GSM. Therefore, handover between GSM and WCDMA systems is supported in order to be able to leverage the GSM
coverage for the introduction of WCDMA (Dahlman, Berning, Knutsson, Ovesjo, Persson, & Roobol, 1998). WCDMA permits continuous transmission from many users to the same base station on the same carrier frequency at the same time, the transmission from the base station to all the users in one cell is on another carrier frequency (3GPP RAN TS 25.214 v4.0.0, 2001; Holma & Toskala, 2000).

WCDMA is quite resistant against interference and frequency selective fading. In a “normal” wireless data transmission system the used bandwidth more or less equal to user data rate, in wireless data transmission systems based on Spread Spectrum, the used bandwidth is much higher than the data rate. The result of this is that the transmitted power is spread over a wide frequency band. Common methods to achieve spread spectrum are Direct Sequence (DS) and Frequency Hopping (FH). The radio signal propagation through the air (“channel”) is influenced by many factors; among them are reflections, diffraction, and attenuation of the signal energy. These are caused by natural obstacles, such as buildings, mountains, and so forth. The reflections of the signal results in multipath propagation. In the asynchronous WCDMA system each base station is identified by a unique scrambling code (3GPP TS 25.213, v4.0.0, 2001-2003). The mobile station has to synchronize to the scrambling code of the serving base station in order to descramble the downlink traffic channels (Wang & Ottoson, 2000). The synchronization process is commonly referred to as the cell search procedure. A three-step hierarchical cell search process has been introduced in the UMTS standard that is supported by several auxiliary synchronization channels. These include the Primary Synchronization Channel (P-SCH), the Secondary Synchronization Channel (S-SCH), and the Common Pilot Channel (CPICH) (Li, Sheen, Ho, & Chu, 2001; Wang & Ottoson, 1999).

The purpose of the cell search algorithm in UMTS is to estimate the spreading code of the serving base station and its corresponding timing offset. The search procedure consists of 3 sequential and distinct stages: (1) slot-boundary synchronization, (2) frame-boundary synchronization with code-group identification, and (3) scrambling code identification. Algorithms that have appeared for cell search have confined the “code-time” estimation in each stage to a single hypothesis (Nielsen & Korpela, 2000; Sriram & Hosur, 2000). In this article, we also study the performance benefits of estimating multiple “code-time” hypotheses in each stage of the cell search process.

In this article, we address the initial cell search procedure (as opposed to the target cell search), which is carried out when the mobile station is switched on. It is assumed that the mobile station has no preliminary information about the scrambling code of the serving cell, and a frequency offset of 20kHz at a carrier frequency of 2GHz is present (worst case scenario). An additional DFT stage following stage 3 can bring down the frequency offset to 200Hz with a high degree of reliability (Kiessling & Mujtaba, 2002; Nielsen & Korpela, 2000).

In this article, when the received signal was correlated with the primary synchronization code (PSC) sequences generated at the MS, some peak values were obtained and the maximum of those peak values was displayed as the slot value for that particular frame. In frame synchronization process, a Fast Hadamard Transformer (FHT) was used to match arbitrary secondary synchronization code (SSC) sequences with the frames and 16 values were obtained. In code synchronization process, the 16 values obtained are match with the values generated at the MS and the maximum of those values will be taken. In this article, we focus on minimizing the acquisition time while maintaining a given probability of false alarm. Prior work (Wang & Ottoson, 1999, 2000a, 2000b) has considered chip rate sampling at the receiver (i.e., an oversampling ratio of 1), and neglected the impact of nonideal sampling that may arise due to clock jitter and/or residual frequency offset. Furthermore, performance results from these studies were obtained with 1 time-code candidate passed between the various stages of the cell search process. In this article, we extend the previously published results by
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