Application of Asynchronous Channels Method to the W-CDMA Systems

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Abstract— **We evaluate here an interfering suppression method that utilizes the effect of asynchronous accesses. The method called as asynchronous channels (ACL) can be applied to one of the present third generation standards, wideband code division multiple access (W-CDMA) systems. Applying together with auto-correlation controlling filters, called as Lebesgue spectrum filter (LSF), the system capacity gains up by 154% in band-unlimited situations. On the other hand, in practical band-limited situation, the asynchronous channel method can effectively halve the system chiprate. Because the next generation mobile communication system allows wider bandwidth, the mobile transmitter need to accelerate its chiprate, which induces more electricity power consumption. The asynchronous channel method can be one of solution to the electric power consumption problem of mobile communication equipment.**

I. Introduction

Wideband code division multiple access (W-CDMA), also known as universal mobile telecommunications system (UMTS), is one of third generation wireless mobile communication standards, subscribed over 2 billion today and expected 3 billion by 2010 [1]. The significant feature of W-CDMA is the tolerance of asynchronous multiple access in the uplink, the connection from user equipment (UE) transmitters to the Base Station (BS) receiver. One reason for the asynchronous uplink support is that it was easier to realize continuous system deployment, from outdoors to indoors, with no requirement of any external timing source such as global positioning system [2]. The another reason, relatively not so widely known, is that the asynchronous access suppresses interfering noise between multiple mobile stations, revealed by the pioneering analysis of direct sequence CDMA systems by Pursley in 1970's [3].

Though the estimation of interfering suppression effects in asynchronous accesses is affected by chip shapes [4], we remark that the asynchronous access is important to design highly efficient mobile communication systems. Asynchronous channels (ACL) is a method that aims to utilize such interfering suppression effect of the asynchronous access by staggering multiple channels of a user [5].

In this paper, we report simulation results of ACL applied to W-CDMA systems. ACL demonstrates highly interfering suppression effects as expected, decreasing bit error rates (BER) and increasing the system capacity. In band-unlimited situations, ACL attain the same bitrate only in half of original chiprate without loss of BER. We also demonstrate the Lebesgue spectrum filter (LSF) that controls optimal auto-correlations of scrambling sequences. ACL and LSF can work together in proper settings and situations.

The organization of the paper is as follows. In section II, we introduce the W-CDMA systems and two proposal method, ACL and LSF. In section III, we show the simulation results of ACL applied to W-CDMA systems. In section IV, we discuss the effects of ACL. Finally, in section V, we draws some conclusions and complete the paper.

II. Preliminaries

A. W-CDMA

W-CDMA is based on DS-CDMA systems where transmitted symbols are scrambled and spread by pseudo-noise codes. Fig.1 shows a simplified block diagram of the W-CDMA uplink. W-CDMA utilize two types of code spreading. The first is the channelization operation, which transforms every data symbol into a number of chips, thus increasing the bandwidth of the signal. The number of chips per data symbol is called as the spreading factor (SF). The second operation is the scrambling operation, which spread signal broadly to the

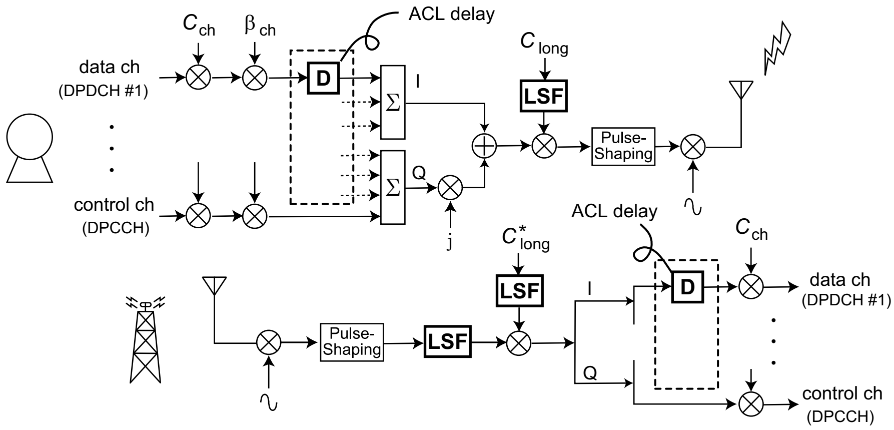

Fig. 1. A simplified block diagram of a user equipment transmitter (upper) and a base station receiver (lower) in the W-CDMA reverse link. Delay blocks and LSF filter blocks are also inserted for our proposed extension.

bandwidth by pseudo-random complex codes denoted as C_{long} in Fig.1.

The code used in channelization operation is called as Orthogonal Variable Spreading Factor (OVSF) code. The OVSF code $C_{\text{ch,SF},k}$ is defined by recursively substitutions into the Walsh function such as

$$C_{\text{ch},1,0} = 1,$$

$$\begin{bmatrix} C_{\text{ch},2,0} \\ C_{\text{ch},2,1} \end{bmatrix} = \begin{bmatrix} C_{\text{ch},1,0} & C_{\text{ch},1,0} \\ C_{\text{ch},1,0} & -C_{\text{ch},1,0} \end{bmatrix} = \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix},$$

$$\begin{bmatrix} C_{\text{ch},2^{(n+1)},0} \\ C_{\text{ch},2^{(n+1)},1} \\ \vdots \\ C_{\text{ch},2^{(n+1)},2^{(n+1)}-2} \\ C_{\text{ch},2^{(n+1)},2^{(n+1)}-1} \end{bmatrix} = \begin{bmatrix} C_{\text{ch},2^n,0} & C_{\text{ch},2^n,0} \\ C_{\text{ch},2^n,0} & -C_{\text{ch},2^n,0} \\ \vdots & \vdots \\ C_{\text{ch},2^n,2^{n-1}} & C_{\text{ch},2^n,2^{n-1}} \\ C_{\text{ch},2^n,2^{n-1}} & -C_{\text{ch},2^n,2^{n-1}} \end{bmatrix},$$

where k is the code number in $0 \leq k \leq \text{SF} - 1$ [6]. The OVSF codes preserve their orthogonality even in different lengths as far as avoiding their parents and children of recursive generations. Hence, the OVSF codes realize multiple physical channels of various bitrates [7], [8].

Among the codes of length SF, we often refer the particular number k of codes which has simple characteristics listed as follows.

- If $k = 0$ then all simbols are value $\texttt{1}$.
- If $k = \text{SF}/2$ then symbol signs alternate every chips.
- If $k = \text{SF}/4$ then symbol signs alternate every 2 chips.

In W-CDMA systems, there are two kinds of major physical channels, namely, a control channel and data channels. The dedicated physical control channel (DPCCH) is multiplied by the code $C_{\text{ch},256,0}$ that every symbol repeats sequential value $\texttt{1}$ such as $\{\texttt{1 1 1 1 1...}\}$. The dedicated physical data channels (DPDCHs) are typically used only one channel, DPDCH#1, multiplied by the code number SF/4 that symbols alternate signs every 2 chips such as $\{\texttt{1 1-1-1 1 1-1-1...}\}$.

B. Asynchronous channels

ACL is a method to stagger a control channel and data channels on purpose. As illustrated in Fig.1, we apply ACL to W-CDMA system by inserting delay blocks to DPDCHs. The delaying duration are set within a chip duration i.e. 0.26μsec at the W-CDMA default chiprate of 3.84Mcps, the W-CDMA default chiprate. Fig.2 illustrates schematic timing of spreading and scrambling of ACL applied DPDCH. The timings of multipling channelization and scrambling codes are off to the side, consequently output sequences are chopped narrower than the default chip duration. Meanwhile, the DPCCH sychronizes with the scrambling code, so it remains as is.

C. Lebesgue spectrum filter

LSF is a kind of finite impulse response filter, designed to fit ideal autocorrelation coefficient of spreading codes on generic DS-CDMA systems. As illustrated in Fig.3, LSF adds up each delayed codes multiplied by $(-r)^n$ at n-th order. In practically, it is known that the filter order is sufficient at two [9]. The coefficient $(-r)$ has minus sign because it emphasize that the average coefficient of the optimal autocorrelation tends to register minus value. The optimal value for r is analytically estimated as $2 - \sqrt{3}$ when using pseudo-random codes such as

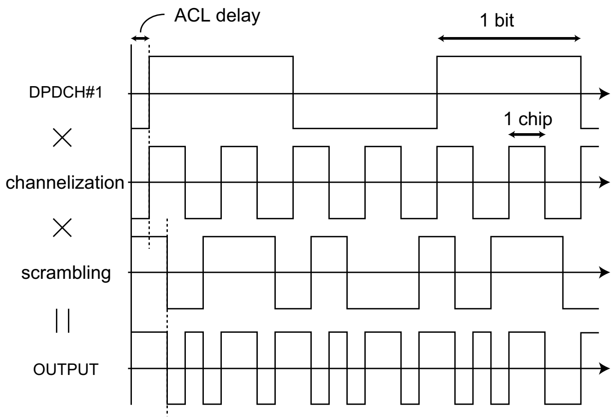

Fig. 2. Schematic chart of spreading and scrambling with ACL.

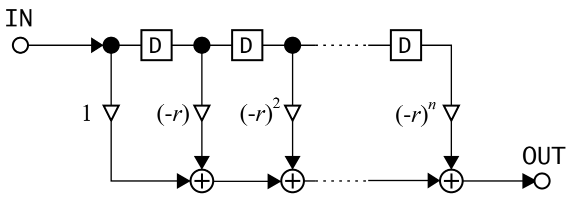

Fig. 3. Block diagram of LSF.

gold sequences or Chebychev chaotic sequences, which makes the system capacity up by 15% ideally [9].

In W-CDMA systems, LSF can be applied to scrambling or de-scrambling sequences as illustrated in Fig.1. In addition, LSF can also be applied to all the received signals. In this paper, the inserted positions of LSF are shortly denoted as ue, bs and air, respectively. Each places can be combined individually. For example, applying LSF to both scrambling and de-scrambling sequences will be denoted as ue+bs. It is reported by the authors that W-CDMA system applied LSF can gain its capacity up by 13% in band-unlimited situation with the code number zero of the channelization code and LSF applied to ue+bs [10].

III. Simulations

We evaluate effects of ACL by Monte-Carlo simulations. In the following simulations, we assume all users adopt a fixed duration for asynchronous channel delay and generic noises or fading are not concerned. First, we investigate band unlimited situation to reveal the basic capability of ACL, and then, we apply the ACL in band-unlimited situations.

A. *asynchronous channel delay and OVSF codes*

Fig.4 shows raw BER performances of ACLs against delay of DPDCH#1, where the number of user equip-

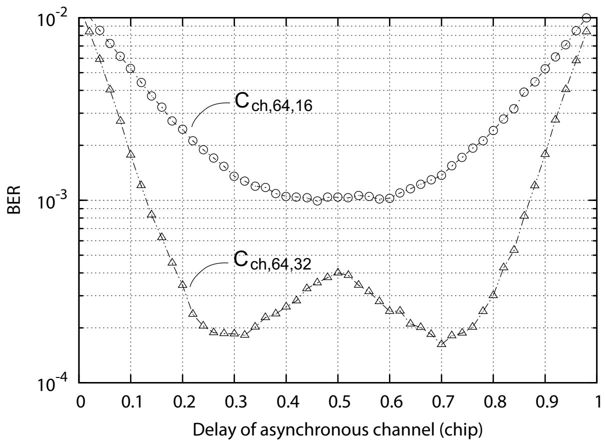

Fig. 4. BER perfomances against delay of DPDCH#1 (Ue=30, SF=64).

ments is 30 and the spreading factor is fixed to 64. When applying the W-CDMA default channelization code $C_{\mathrm{ch},64,16}$, BERs decrease along the asynchronous channel delay, reaching the minimum at the half of chip duration. This is the same result as the analysis on a simple DS-CDMA model [11]. However, when applying the code $C_{\mathrm{ch},64,32}$ that alternates signs every chips such as $\{$`1-1 1-1...`$\}$, BERs show twin valleys, reaching the minimum at both 0.3 and 0.7 chip duration.

Fig.5 show BERs against numbers of user equipments in 60Kbps. Comparing the number of Ue that achieve BER=10^{-3}, we can measure the system capacity gains. The left most plotted lines are the W-CDMA default. In Fig.5, the maximum capacity is achieved when we delay 0.3 chip duration and also apply LSF to both scrambling and de-scrambling codes, which gains up by 154% relative to the W-CDMA default plotted on the left most lines.

Fig.6 shows the system capacity gains by ACL and LSF on various bitrates from 60Kbps (SF=64) to 960Kbps (SF=4). The combination of the code $C_{\mathrm{ch,SF,SF}/2}$, 0.3 (or 0.7) chip delay and LSF applied to ue+bs always performs the highest system capacity gains.

B. *band-unlimited situation*

In practice, all radio transmitters are regulated within a given bandwidth. For the case of the present W-CDMA systems, the occupied bandwidth is limited in 5MHz. To evaluate the realizability the ACL, we have to simulate the performance in band-unlimited situations.

Fig.7 shows the BER along with bandwidths limited by ideal low-pass filters. Unfortunately, BER of both 0.3 and 0.5 chip delay at 5MHz is less than that of

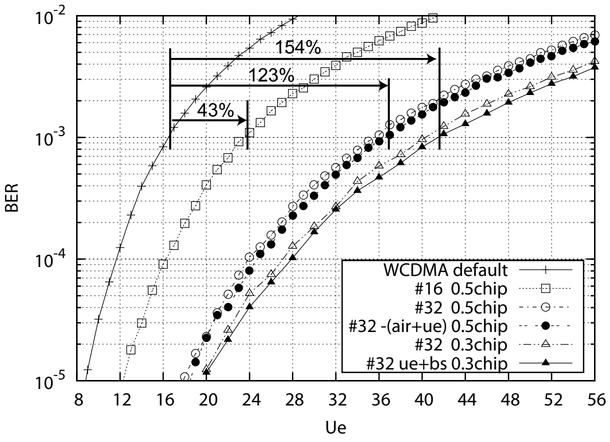

Fig. 5. Comparisons of system capacities (SF=64).

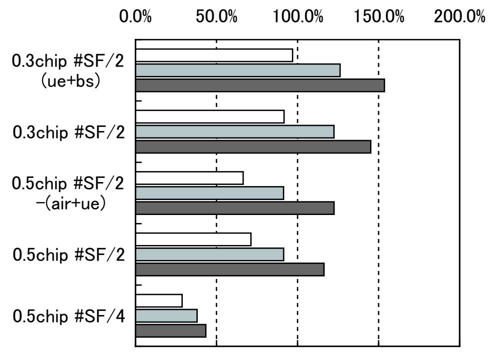

Fig. 6. System capacity gains relative to the W-CDMA default.

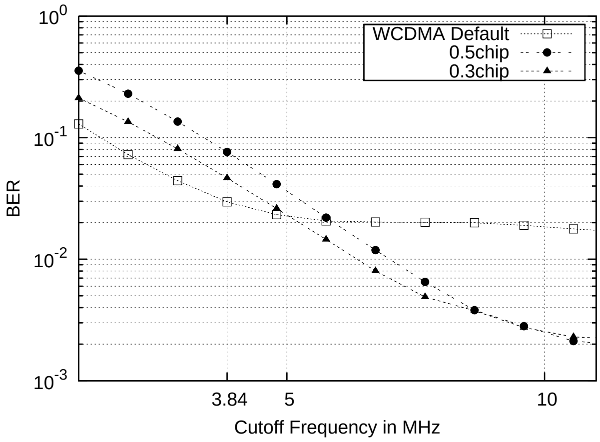

Fig. 7. Comparison of BER under band-unlimited by ideal LPF (Ue=30, R=3.84Mcps, SF=64).

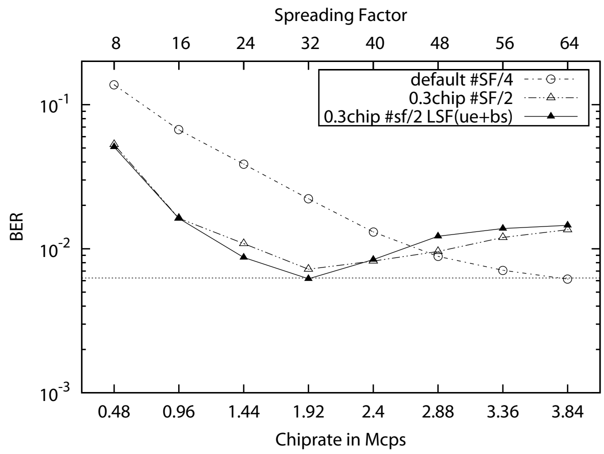

Fig. 8. Comparison of BER according to chiprates and spreading factors under the fixed bandwidth (Ue=16 and bitrate = R / SF = 60Kbps, bandwidth = 4.6848MHz). The dashed horizontal line indicate the BER of the default W-CDMA of UE=16, R=3.84Mcps and SF=64.

W-CDMA default feature. This implies that the ACL method broaden the occupied bandwidth than the original, which is the reason for getting significant system capacity gains relative to the default. Because the descending lines are not floored until 10MHz or more, the occupied bandwidth of 0.3 or 0.5 chip ACL will be widen by the double or triple compared to the default W-CDMA. However, it is possible to narrow the occupied bandwidth by decreasing the chiprate.

Fig.8 shows the another comparison of BERs where chiprates and spreading factors change under the same bandwidth limitation. The adopted low-pass filter here is the root raised cosine (RRC) filter, a well known pulse-shaping digital filter. The RRC filter has a characteristic parameter α, called as roll-off factor, which regulates the system bandwidth in $(1+\alpha)\times R$ where R is the system chiprate. In accordance with the regulation [12], the roll-off factor of the W-CDMA systems is defined as 0.22, so the bandwidth is restricted to 3.84Mcps $\times(1+0.22) = 4.6848$MHz. In the simulation, we alter the chiprate and the spreading factor but stay their ratio constant to R / SF = 60Kbps and also alter the sampling rate of the RRC filter so that the limited bandwidth is fixed to the above regulation, in other words, varying chiprate without changing the spectrum efficiency defined by bitrate per hertz. From the definition, the channelization code length is originally restricted to involution of two, but we relax the code length to arbitrary multiple of four with limiting the particular code number, SF/2 and SF/4, re-defined by the characteristics listed in section II-A. As in Fig.8, we achieve just the same bitrate and BER at the half of the default chiprate, 1.92Mcps, by delaying 0.3 chip duration and applying LSF to both scrambling and de-scrambling codes. Hence, the chiprate can be halved at the maximum application of ACL and LSF.

IV. Discussion

The ACL method can significantly increase the system capacity in band-unlimited situations. This is because the asynchronous summation of physical channels duplicates their chips, which increases seeming chiprates and widen the occupied bandwidth as shown in Fig. 7. However, the system of the half chiprate can accomplish the same BER performance without loosing bitrate and broadening bandwidth as shown in Fig. 8, this intends that the ACL method can effectively halve the system chiprates. In the next generation mobile communications, the system bandwidth broaden as to 100MHz, so the mobile transmitter need to accelerate its chiprate by twenty times in simple calculation, which induces serious electricity power consumption. In general, the electricity power consumption of radio system increases linearly by its chiprates, the problem will be critical especially for mobile transmitters. The ACL method could be one of solutions to the electric power consumption problem of mobile communication equipments.

The reason why 0.3 (or 0.7) chip delay is the optimum is still unknown. It should relate to the channelization code spreading but further analysis of the channel delay and channelization code will be our future works.

V. Conclusion

We evaluate the performance of asynchronous channels method adopted to W-CDMA systems. The ACL method employs the interfering suppression effect of asynchronous access in DS-CDMA systems. Applying together with ACL and LSF, the system capacity gains up by 154% relative to the default W-CDMA system in band-unlimited situations. In practical band-unlimited situation of the present regulation, we achieved the same bitrate and BER at the only half of the default chiprate by synergy effects of ACL and LSF. The advantage of the ACL method is that it can halve the chiprate, and it will be an another solution to the electric power consumption problem of the next generation mobile communication equipments.

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