2-dimensional Block Spread DS-CDMA Using MAI Cancellation

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1. Introduction

2-dimensional (2D) block spread DS-CDMA has been proposed to cancel the multi-access interference (MAI) in the uplink [1][2]. The MAI cancellation is based on the orthogonality property of OVSF codes in a slow fading channel. However, for channels with large Doppler spreads, the orthogonality property tends to be lost and the residual MAI is produced. In this paper, we present decision-feedback-assisted frequency-domain MAI cancellation to reduce the residual MAI in the case of fast fading. The transmission performance in a time- and frequency-selective fading channel is evaluated by computer simulation.

2. System Model

The uplink transmission model of DS-CDMA using 2D-OVSF block spreading [3] is illustrated in Fig.1, where only the uth user is shown.

2.1. Transmitter

The uth user's data-modulated symbol sequence $\{d_u(n); n=0\sim(N_c/SF_u^f-1)\}$ is spread using the 1st OVSF spreading code $\{c_u^f(t); t=0\sim SF_u^f-1\}$ with the spreading factor SF_u^f and further multiplied by a binary scramble sequence $\{c_u^{scr}(t); t=0\sim N_c-1\}$ to produce a chip sequence of length of N_c chips (N_c is the FFT/IFFT block size for FDE). Next, the N_c-chip sequence is spread by the 2nd OVSF spreading code $\{c_u^t(t); t=0\sim SF_u^t-1\}$ with the spreading factor SF_u^t. The 1st OVSF code is for multi-rate connection per user and the 2nd OVSF code is for orthogonal multiuser multiplexing.

As shown in Fig. 2, the overall spreading factor of 2D-OVSF codes is $SF=SF_u^t$xSF_u^f, where SF_u^f can be arbitrarily selected independent of the FFT block size N_c, but $SF_u^t\leq N_c$ and SF_u^t is chosen as $SF_u^t=U$ to allow U users access to the base station without causing the MAI. The 2D-OVSF spread DS-CDMA signal can be expressed using equivalent lowpass representation as

$$\hat{s}_u(t)=\sqrt{2E_c/T_c}\,s_u(t \bmod N_c)\,c_u^t(\lfloor t/N_c\rfloor)\,, \tag{1}$$

where $s_u(t)$ is given by

$$s_u(t)=d_u(\lfloor t/SF_f\rfloor)\,c_u^f(t \bmod SF_f)\,c_u^{scr}(t)\,, \tag{2}$$

where $\lfloor x\rfloor$ is the largest integer smaller than or equal to x, E_c is the average chip energy and T_c is the chip duration of the 2nd OVSF spreading codes. An N_g-chip GI is inserted every N_c-chip block to avoid inter-block interference (IBI).

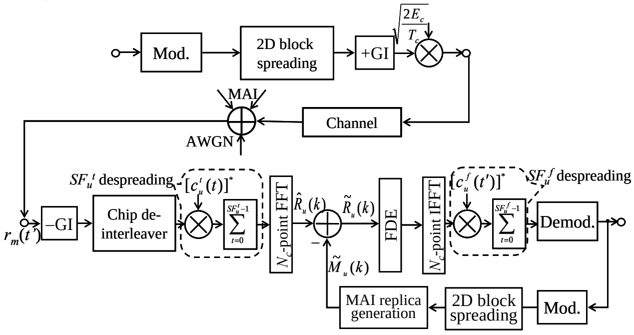

Fig. 1. Uplink transmission model for the uth user.

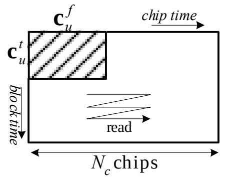

Fig. 2. 2D block spreading.

2.2. Receiver

The sum of U users' faded signals is received by a base station receiver. The received signal is sampled at the chip rate and the GI is removed. The GI-removed received signal can be written as

$$r(t)=\sum_{u=0}^{U-1}\sum_{l=0}^{L-1}h_{u,l}\hat{s}_u(t-\tau_{u,l})+n(t)\,, \tag{3}$$

where $h_{u,l}$ is the lth path gain with $\sum_{l=0}^{L-1}E[|h_{u,l}|^2]=1$, $\tau_{u,l}=\tau_u+l$ is the T_c-spaced distinct time delays with τ_u being the uth user's transmit timing offset, and $n(t)$ is the additive white Gaussian noise (AWGN) with zero-mean and variance of $2N_0/T_c$ with N_0 being the one-sided power spectrum density. Assuming block fading with the maximum Doppler frequency f_D, the path gains remain constant over one block interval $T=T_c(N_c+N_g)$ but vary block-by-block. The maximum time delay of each user's channel is shorter than GI.

$r(t)$ is deinterleaved and then the 1st despreading is performed using the 2nd OVSF code $c_u^t(t)$ as

$$\hat{s}_u(t)=\frac{1}{SF_u^t}\sum_{m=0}^{SF_u^t-1}r(t+mN_c)\left[c_u^t(m)\right]^* \tag{4}$$

for t=0~N_c-1. The MAI is cancelled due to the orthogonal property of OVSF spreading codes $\{c_u^t(t); u=0\sim U-1\}$.

However, for channels with large Doppler spreads, the orthogonal property may be lost and the residual MAI is produced.

2.3. Decision-feedback-assisted frequency-domain MAI cancellation

To reduce the residual MAI, frequency-domain MAI cancellation is applied as [4]

$$\tilde{R}_u(k)=\hat{R}_u(k)-\tilde{M}_u(k)\,. \tag{5}$$

where $\hat{R}_u(k)$ is the frequency component of $\{\hat{s}_u(t);t=0\sim(N_c-1)\}$ and $\tilde{M}_u(k)$ is the MAI replica component, given by

$$\tilde{M}_u(k)=\frac{1}{SF_u^t}\sqrt{\frac{2E_c}{T_c}}\sum_{\substack{u'=0\\u'\neq u}}^{U-1}\tilde{S}_{u'}(k)\sum_{m=0}^{SF_u^t-1}c_{u'}^t(m)[c_u^t(m)]^*H_{u',m}(k)\,, \tag{6}$$

with $H_{u',m}(k)$ being the kth subcarrier channel gain associated with the mth received chip block for the u' th user and $\tilde{S}_{u'}(k)$ being the frequency component of the decision feedback $\tilde{s}_{u'}(t)$, given by

$$\tilde{S}_{u'}(k)=1\Big/\sqrt{N_c}\sum_{t=0}^{N_c-1}\tilde{s}_{u'}(t)\exp(-j2\pi k\,t/N_c)\,. \tag{7}$$

2.4. MMSE-FDE and despreading

Then, one-tap MMSE-FDE is carried out on each frequency component as

$$Y_u(k)=w_u(k)\tilde{R}_u(k)\,, \tag{8}$$

where $w_u(k)$ is the MMSE-FDE weight given by [5]

$$w_u(k)=\left(\sum_{m=0}^{SF_u^t-1}H_{u,m}^*(k)\right)\Bigg/\left(\left|\sum_{m=0}^{SF_u^t-1}H_{u,m}(k)\right|^2+\left(\frac{SF_u^tE_c}{N_0}\right)^{-1}\right). \tag{9}$$

where $H_u(k)$ is the kth frequency channel gain of the uth user with $E[|H_u(k)|^2]=1$.

Next, N_c-point inverse FFT (IFFT) is applied to $\{Y_u(k); k=0\sim N_c-1\}$ to obtain the time-domain chip sequence$\{y_u(t); t=0\sim N_c-1\}$. The 2nd despreading using the 1st OVSF spreading code $c_u^f(t)$ is performed to get the decision variable $\hat{d}_u(n)$ for the detection of $d_u(n)$ as

$$\hat{d}_u(n)=\frac{1}{SF_u^f}\sum_{t=nSF_u^f}^{(n+1)SF_u^f-1}y_u(t)\left[c_u^f(t)c_u^{scr}(t)\right]^*\,, \tag{10}$$

based on which data symbol decision is carried out.

3. Computer Simulation

We assume QPSK data-modulation, N_c=256 and N_g=32. An L=16-path frequency-selective block Rayleigh fading channel having the uniform power delay profile is assumed. The transmit timing offsets $\{\tau_u\}$ are uniformly distributed over [–Δ/2, Δ/2] with $\Delta<(N_g-L)$ and the maximum time delay difference is less than GI. Ideal channel estimation is assumed.

Fig. 3 shows the impact of Doppler spread on the 2D-OVSF spread DS-CDMA for $SF=SF_u^t\mathrm{x}SF_u^f=16$, where $SF_u^t=U$ and $SF_u^f=16/U$, when E_b/N_0=18dB. Here, each user's signal is assumed to pass through independent fading channel but with the same f_DT. Our proposed frequency-domain MAI cancellation is very effective to improve the BER performance. For the full-loaded case (U=16), the BER performance can be almost the same until f_DT approaches 8×10^{-3} (this corresponding to a mobile moving speed of 600 km/h at 5 GHz carrier frequency for 100 Mbps transmission).

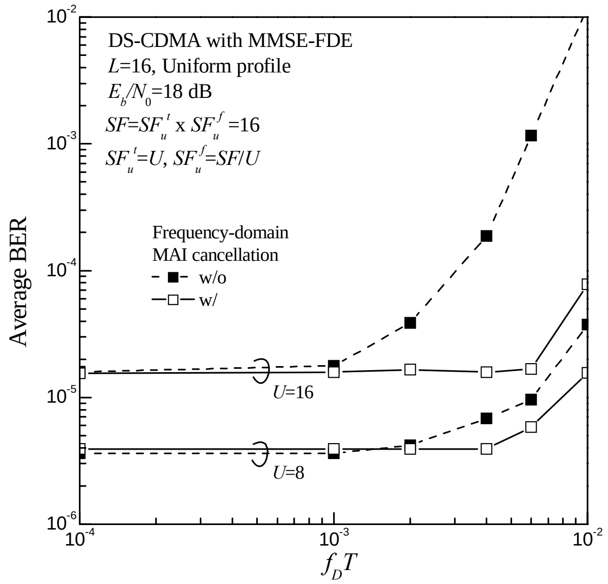

Fig. 3 Impact of f_DT.

4. Conclusion

In this paper, we presented decision-feedback-assisted frequency-domain MAI cancellation to reduce the residual MAI in the case of fast fading. Computer simulation results have shown that the use of decision feedback frequency-domain MAI-cancellation provides good BER performance in a multiuser frequency- and time-selective fading environment without using sophisticated MUD technique.

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