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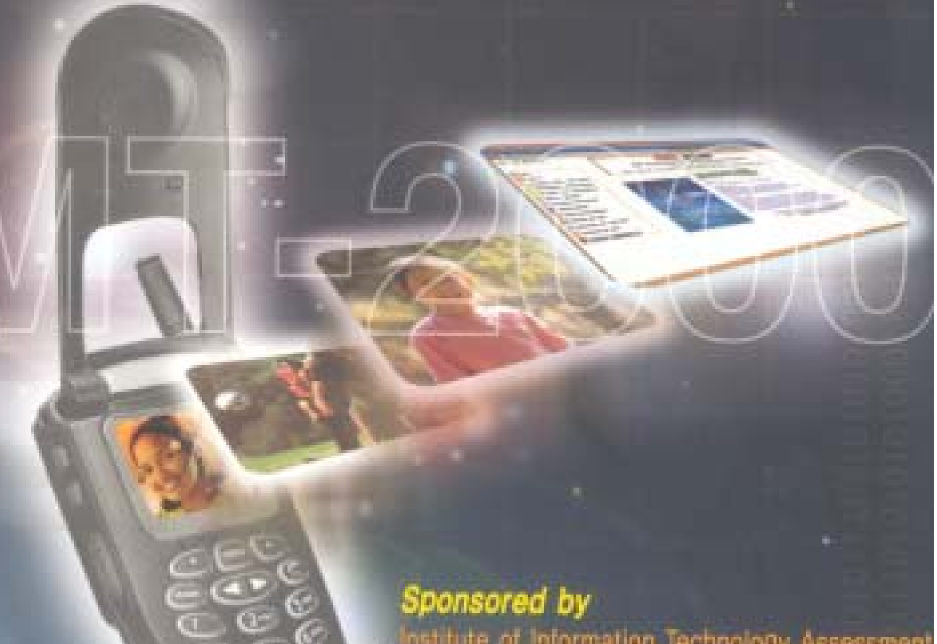

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A DATA-AIDED CHANNEL ESTIMATION TECHNIQUE FOR COHERENT DS/CDMA SYSTEMS USING MAXIMUM DOPPLER FREQUENCY ESTIMATION AND BLIND SPREADING FACTOR DETECTION

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Abstract

In this paper, we consider a data-aided channel estimation technique for coherent DS/CDMA systems, mainly focusing but not limited on the uplink of the 3GPP W-CDMA systems. A blind spreading factor (SF) detector is employed for the case where the SF is not known to the channel estimator. A maximum Doppler frequency (MDF) estimator is also employed for efficient channel estimation. It is shown that the performance of the proposed system is very close to the case with perfect channel information when the SF is small or the MDF is small.

1 Introduction

In coherent direct sequence code division multiple access (DS/CDMA) communication systems, a time-varying radio channel should be estimated. To estimate the channel, pilot tone or pilot symbols are sent with the traffic data. In the uplink of the 3rd Generation Partnership Project (3GPP) wideband-CDMA (W-CDMA) systems, a dedicated control channel, containing pilot symbols, is sent with dedicated data channels. The energy contained in pilot symbols should be considered as an overhead. To reduce the required pilot power, data-aided channel estimation schemes have been considered [1]-[3]. In these schemes, the SF of the traffic data channel is assumed to be known to receivers. However, in the uplink of the 3GPP W-CDMA systems, a SF can vary frame by frame and the SF of a frame can be obtained at the end of the frame. Thus, in order to use a traffic data in channel estimation, a blind SF detection is required.

To further optimize the performance of a coherent DS/CDMA system, the channel estimation filter should be optimized. It is well known that a Wiener filter is an optimal solution. However, it is virtually impractical to estimate the Doppler spectrum of a wireless channel accurately. Thus, a lowpass filter is widely used for channel estimation. In the 3rd generation mobile communication systems, the carrier frequency increased to 2GHz and the maximum supported mobile speed increased up to 300km/h, in which the MDF can be as high as 560Hz. Thus, it is beneficial to use a lowpass filter whose cutoff frequency varies with the MDF.

In this paper, we propose a data-aided channel estimator for DS/CDMA systems using blind SF detector and MDF

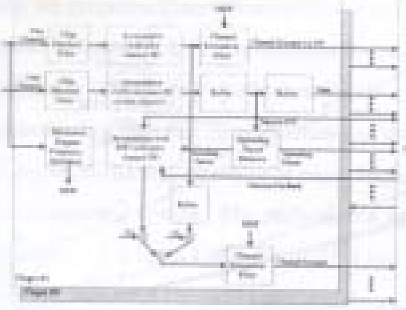

Figure 1: Schematic of the proposed channel estimator.

estimator. In Fig. 1, a schematic of the proposed channel estimator is shown. A bank of lowpass filter coefficients is stored in channel estimation filter and one of them is selected based on the estimated MDF. Then, the channel is estimated using pilot symbols first. With the estimated channel, the data symbols are estimated with the result of the SF detector. As the last step, the channel is again estimated with both the pilot and the accumulated decision feedback data symbols during a pilot symbol period. Here, G_c and G_d are weighting factors for the pilot symbols and the accumulated decision feedback data symbols, respectively.

2 Blind Spreading Factor Detection

In the 3rd generation mobile communication systems, variable SF is used for variable data rate. In order to use a data channel for channel estimation, the SF of the current symbol should be known to a receiver. However, in the uplink of the 3GPP W-CDMA systems, the SF is varying frame by frame and is not known to a receiver until the end of the current frame. Thus, a blind SF estimator is required for data-aided channel estimation. Let $SF_0 = N, \cdots, SF_n = N \times 2^n$ be the possible SFs in ascending order. Then, the output of a chip-matched filter can be integrated with the minimum SF $SF_0 = N$. Next, we assume that the pilot channel is spread with the maximum SF SF_n. Let $r_i = s_i + n_i, i = 1, \cdots, 2^n$ be integrator (with SF_0) outputs during SF_n chips interval. Here, we assume that the n_i, $i = 1, \cdots, 2^n$, is identical and independent complex Gaussian noise with mean zero and variance σ^2 and that $A = |s_i|$ is a constant. As an optimal solution, a maximum likelihood estimator is one that choose a SF of a signal vector $\hat{\mathbf{s}} = [\hat{s}_1, \cdots, \hat{s}_{2^n}]$ that maximizes the joint probability density function (pdf) of $r_1, \cdots, r_{2^n}$, conditioned on $\hat{\mathbf{s}}$. However, it is too complex. Thus, as a suboptimal solution, the following algorithm is considered.

Let $d_k = \sum_{i=1}^{2^{n-k}} \left|\sum_{j=(i-1)2^k+1}^{i2^k} r_i\right|^2$, $k = 0, \cdots, n$, and SF_m be the SF. Then, d_k is a noncentral chi-square random variable with degree of freedom 2^{n-k+1}. When $k \leq m$, the mean and variance of d_k are $2^{n+k}A^2 + 2^n\sigma^2$ and $2^{n+k+1}\sigma^4 + 2^{n+2k+2}\sigma^2 A^2$, respectively [4]. Thus, it is likely to happen that d_m is the largest among d_k, $k = 0, \cdots, m$ provided that the signal to noise ratio (SNR) is not too low. When $k > m$, the mean and variance of d_k depend on the transmitted data sequence during SF_n chips interval. If transmitted data have an unbiased repetitive pattern of $\{1, -1\}$, d_k, $k > m$, is likely to be smaller than d_m. Thus, we can estimate the SF from $\hat{m} = \arg\max_k d_k$ and $\hat{SF} = SF_{\hat{m}}$. However, some biased patterns, such as $\{1, 1, 1, 1, -1, 1, 1, 1\}$ may cause overestimation of the SF with high probability. In addition, it is impossible to retrieve the SF from received data themselves when the transmitted data are repetitive even without noise. For example, the case, where SF is 256 and the transmitted symbol is $\{1\}$, is indistinguishable with that where SF is 128 and the transmitted symbols are $\{1, 1\}$.

Now, consider the problem in the context of channel estimation. Transmitted data with identical symbols, such as $\{1, 1, 1, 1\}$, are likely to cause overestimation of the SF. In this case, however, the overestimation of the SF is more beneficial for channel estimation. Furthermore, since the decision of the transmitted data is erroneous, overestimation of the SF, with the transmitted data that are mostly comprised of biased patterns, is at least not a real problem and can even be more

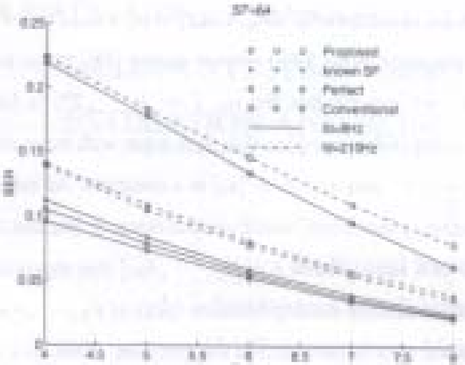

Figure 2: The bit error probabilities when the SF is 64.

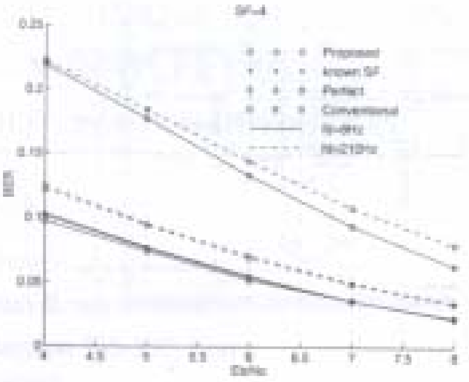

Figure 3: The bit error probability when the SF is 4.

beneficial than a perfect spreading factor detection in the context of channel estimation. For a simple numerical example, suppose that the transmitted data are $\{1,1,1,1,-1,1,1,1\}$, the SF is 32, and the decision is erroneous with probability 0.25. In this case, collecting the eight symbols after decision feedback gives roughly $10\log_{10}((8-8*2*0.25)^2/8) = 3$dB of SNR gain, since two out of the eight symbols are falsely detected in an average sense. However, if we assume that the SF is 256, the SNR of the symbol is $10\log_{10}(8^2/8) = 6.5$dB greater that that of each symbol with $SF = 32$. In AWGN channels, a 6.5dB SNR increase reduces the bit error rate (BER) from 0.25 to 0.076, which roughly yields $10\log_{10}((6-6*2*0.076)^2/8) = 5.1$dB SNR gain. Thus, it is not intuitive to present a detection probability of the proposed blind spreading factor detector as a performance in the context of channel estimation. It will be shown later that the performance of the data-aided channel estimator employing the proposed blind spreading factor detector is slightly better than that of the same channel estimator with known spreading factor.

3 Simulation Results

We consider the uplink of 3GPP specification as a system environment. The data channel and control channel are code multiplexed and the relative power of pilot to that of data is assumed to be -5.2dB. The chip rate is 3.84MHz and the SF of the control channel is fixed at 256 and that of the data channel can vary from 4 to 256. A slot-by-slot fast power control is assumed. Although the channel coding is not included, we assume that the symbol energy of data is -4.7dB of E_b (1/3 code rate assumed) to anticipate the performance with channel coding. In addition, we assume that the required uncoded BER is 0.1 to meet coded BER 10^{-3} with 1/3 rate channel coding. A bank of FIR lowpass filters designed for several values of MDFs is used. In order to estimate the MDF, a Doppler frequency estimator based on the zero-crossing rate (see [5]) is used. We assume that 2 antenna diversity is used at a base station and the channel is Rayleigh with 2 paths and isotropic scattering. The relative path gain of the second path to the first path is $-2dB$. Although it is not shown explicitly, the performance of the MDF estimator is good at the environment used in this simulation so that there is little loss between using estimated MDF and using known MDF. In Figs. 2 and 3, the uncoded bit error probabilities of the systems, using the proposed channel estimator and a pilot-only-aided channel estimator with a conventional lowpass filter whose passband is 750Hz are plotted when the SF is 4 and 64, respectively. It is seen that the performance of the system using the proposed channel estimator is much higher than that of the conventional system. The performance gain at bit error probability 0.1 is up to 2.8dB for the SF 4 and is up to 2.7dB for SF 64. Note that the performance of the proposed system with the MDF estimation and the SF detection is slightly better than the case where the SF and the MDF is known to the receiver. This is due to the fact that the proposed SF detector tends to overestimate the SF when the transmitted data are mostly comprised of biased pattern, and that overestimation can be more beneficial than perfect estimation in such cases.

4 Concluding Remark

In this paper, we proposed a data-aided channel estimator for coherent DS/CDMA communication systems. A blind SF detector and a MDF estimator were employed. It was seen that we could get up to 2.8dB gain at the uncoded bit error probability 0.1 with the proposed system, comparing to the conventional channel estimator. It was also seen that the performance of the proposed system was slightly better than that with the case where the SF and the MDF were known to the receiver. This was due to the fact that the proposed SF detector tended to overestimate the SF when the transmitted data, during a period corresponding to the maximum SF, were biased, which eventually improved the performance of the channel estimator.

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