Pilot Interference Cancellation in a WCDMA wireless Repeater

Sunho Kim[1] and Sungbin Im[2]
School of Electronic Engineering, Soongsil University
511 Sangdo-dong, Dongjak-gu, Seoul 156-743, Korea
E-mail: [1]Serika@ssu.ac.kr, [2]sbi@ssu.ac.kr

Abstract: In this paper, we propose a mitigation method to reduce the effect of pilot interference at the wireless repeater. Using an adaptive estimation algorithm, we estimates undesired pilot signals from neighboring base stations and eliminate these interference signals from the received signals. This approach is based on the conventional pilot signal cancellation techniques for a user equipment. This improves the signal to interference ratio (SIR), and enables increased cell capacity and/or better bits error rates (BER) performance in the wideband code division multiple access (WCDMA) systems. Simulation studies have been carried out to verify the proposed approach and promising results are observed.

1. Introduction

Recently, the third generation (3G) cellular mobile communication system has been grown significantly with commercial and technical sides. WCDMA with variable spreading factor (SF) and multi-code modulation as a multi-rate technique is emerging as one of the air interfaces for the 3G mobile communications system. the high and different user data rates and the large number of users together with multipath dispersive fading channels cause severe inter-cell and intra-cell multiuser interference [1][2].

The WCDMA downlink signals for different physical channels within a cell are transmitted synchronously by the base station. Typically, orthogonal spreading codes are assigned to distinct physical channels, thereby creating mutually orthogonal downlink signals. If the channel does not have delay spread, the orthogonality can be maintained at the despreader output of the receiver, thereby removing all multiple access interference from the same cell. However, for dispersive channels, the orthogonality can no longer be maintained at the receiver, giving rise to intra-cell multiuser interference, which will result in performance degradation. Such performance degradation could be severe if the near-far problem occurs.

In the WCDMA system, there are some types of physical channel signaling categories: common pilot channels, synchronous channels, common control physical channel, random access channels, etc [1]. The base station sends a scrambling code on the common pilot channel. The mobile station keeps listening to a pilot signal while searching for a base station of the strongest power level. The pilot signals of the base station are typically assigned relatively large fixed transmit power because of their important roles. It determines WCDMA network coverage and performance including cell identification, synchronization, timing acquisition and tracking, user-set handoff, multipath exploration, channel estimation, and so on.

A wireless repeater deployed in the WCDMA system, has the capability to communicate with multiple base stations whenever it is located in the fringe areas covered by overlapping base stations. However, it is not desirable for an overlap area to contain pilot signals from a large number of base stations. When a wireless repeater has received signals and is located at the fringe area among more than two base stations, this is the pilot interference scenario. Furthermore, a mobile station in the cell receives undesired pilot signals from neighboring base stations through a wireless repeater at the fringe area [3].

Due to the interference signals, the forward link capacity of the WCDMA system is reduced. The pilot signal received from a neighboring base station is also one of the interference signals. But, if the pilot signal is a priori known to all the wireless repeaters, the pilot interference signal can be cancelled by the serving repeater using interference cancellation techniques.

Study on the pilot interference cancellation has been widely carried out, but its focus is limited to receivers, that is, user equipments [3][4][5][6]. In this paper, however, we propose a mitigation method to reduce the effect of pilot interference signals received from neighboring base stations in a wireless repeater.

Especially, a major issue with interference canceller is the maintenance of simplicity. That is, in order to effectively apply a cancellation algorithm to the wireless repeaters, fast real-time estimation is required. Thus, an interference canceller should require low complexity and provide rapid processing time for smoothing communication service under practical situations. Therefore, we are using the normalized least mean square (NLMS) adaptive estimation algorithm for estimate pilot channel to anihilate interference signals. Since the NLMS algorithm has a faster convergence speed and is more stable compared to the conventional LMS algorithms, it is suitable to solve the pilot interference problem. In this study, the NLMS adaptive filtering technique is utilized for the channel estimation [7].

The mitigation of pilot interference at the wireless repeater improves the signal-to-interference/noise ratio (SINR), which enables increased cell capacity or better bits error rates (BER) performance in the WCDMA system [1][3]. Simulation studies have been carried out to verify the appropriateness of the proposed approach and we obtained promising results.

This paper is organized as follows. Section 2 provides signal models considered in this study and problem definition overview. Section 3 represents describes of the proposed method. Section 4 summarizes simulation results. Finally, the conclusion of the paper is given in section 5

2. Signal Models

Generally, the generation process of the pilot code starts by multiplying the output of the chip shaping filter $P_{Tc}(t)$ with nine pilot code values [-1,1] to construct a unique pilot code (c(k)) for the base station. Consequently, this code signal is sent using a single carrier frequency $\cos(2\pi ft)$ over the communication channel. This code given by the following equation [8]:

$$C^{(k)}(t) = \sum_{i=0}^{i=N-1} B_i^{(k)} P_{Tc}(t - iT_c) \qquad (1)$$

where $B_i^{(k)} \in [1,-1]$ is the i^{th} values of the pilot code belonging to the base station k^{th}, P_{Tc} is a chip shaping filter's characteristic function, T_c is a chip duration, and N is a number of bits in the short pilot code.

3. Proposed method

The proposed approach is an extension of the method developed for mobile stations [3]. A schematic diagram of the proposed approach is presented in Fig. 1, where $d(n)$ is the desired signal that the repeater will serve, $\hat{d}(n)$ is an estimate of the desired signal $d(n)$, $i(n)$ is the pilot signal of the base station BS2 through a channel $H(z)$ and $\hat{i}(n)$ is an estimate of the BS2's pilot signal in a wireless repeater. In the repeater, PG represents a pilot signal generator with a psuedo noise (PN) code of BS2, which is known a priori to the repeater, and $\hat{H}(z)$ is an estimate of the channel $H(z)$, whose time-domain model is described by the coefficient $\hat{w}(n)$.

As shown in Fig. 1, the signal from base station BS1 and the one from neighboring base station BS2, the interference source to the base station BS1, are received at the antenna of the repeater. The pilot cancellation unit inside the repeater generates an estimate of the undesired pilot signal using a priori known pilot information of base station 2. The estimate is applied to the received signal to remove the undesired pilot signal.

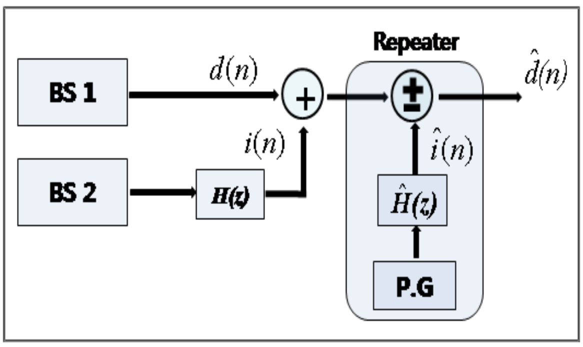

Fig. 1. Schematic diagram of the proposed approach

If the unwanted pilot signal from the adjacent base station is effectively cancelled in the repeater, user equipments consider the signal, which has damaged correlation, as meaningless noise, and then neglect them. This approach assumes that the repeater can obtain the pilot signal's information (scrambling code) in a cancellation unit.

The NLMS adaptive filtering technique is utilized for the channel estimation [7]. The NLMS updates the filter coefficient $\hat{w}(n)$ using the following equation:

$$\hat{w}(n+1) = \hat{w}(n) + \frac{\tilde{\mu}}{\delta + \|u(n)\|^2} u(n) e^*(n) \qquad (2)$$

where $\delta > 0$ is a non-zero offset value, $\tilde{\mu}$ is an adaptation constant, $e(n)$ is an error value given by $e(n) = i(n) - \hat{w}^H(n)u(n)$ [7], and $u(n)$ represents the signal from the PG in Fig. 1.

No matter how strong the carrier signal is, the signal-to-interference ratio (SIR) value is a reasonable measure to evaluate the level of the pilot interference signal. The SIR equation as following:

$$SIR = \frac{E_c}{I_o} = \frac{1/N_{pc}}{(1 - 1/N_{pc})} \qquad (3)$$

where E_c is signal energy in one chip duration of pilot signal, I_o is a power spectrum of the interference and noise. The signal energy E_c is proportional to the mean value of the demodulated pilot chips and I_o is proportional to the interference and noise power. The integer N_{pc} is the number of chips in the pilot signal. BER calculation is given by $Q(\sqrt{E_b / N_0})$ in QPSK modulation, where the notation $Q(\cdot)$ is the Q function and (E_b / N_0) is a bit energy to noise power ratio [3][8][9][10].

4. Simulation result

The objective of the simulation is to assess the performance of the proposed pilot interference cancellation approach from the viewpoint of signal estimation and cancellation. For this simulation, we modified the transmitter/receiver model provided by MATHWORK's MATLAB system simulation tool package. In the simulations, we consider static (AWGN) channels and multipath propagation channels, which are defined in the specifications of 3GPP. Especially, the simulation results presented in this paper are obtained based on the definition of the fading case 1 of the multipath channel [9]. Table 1 shows environment parameters for simulation works. Specific channel parameters are presented in Table 2.

Table 1. Simulation parameters

Carrier frequency f_c	5MHz
Chip rate	3.84Mcps
Modulation	QPSK
Spreading code	Walsh-Hadamard
Power level adjustment	DPCH : -5.5 dB P-CPICH : -10 dB PICH : -15 dB P-CCPCH : -12 dB SCH : -12 dB
Pulse shaping filter	Root-raised cosine filter with roll-off factor 0.22

Table 2. channel parameter

Channel	**Power Profile (dB)**	**Delay Profile (ns)**	**SNR (dB)**	**Speed of Terminal (Km)**
Static	0	0	-1	0
3GPP case 1	0,-10	0,976	0,-10	3

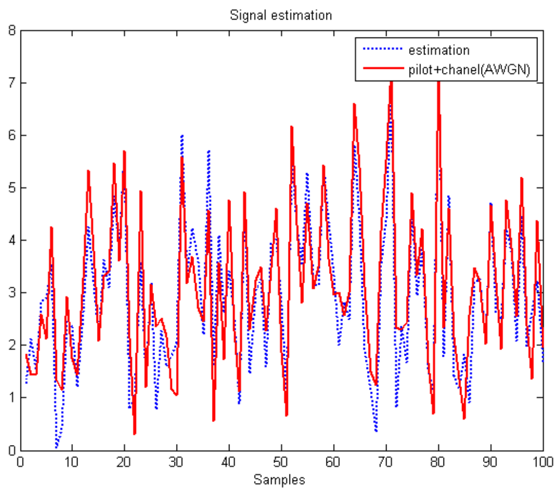

Fig. 2. Waveforms of the pilot interference and its estimate for AWGN channel.

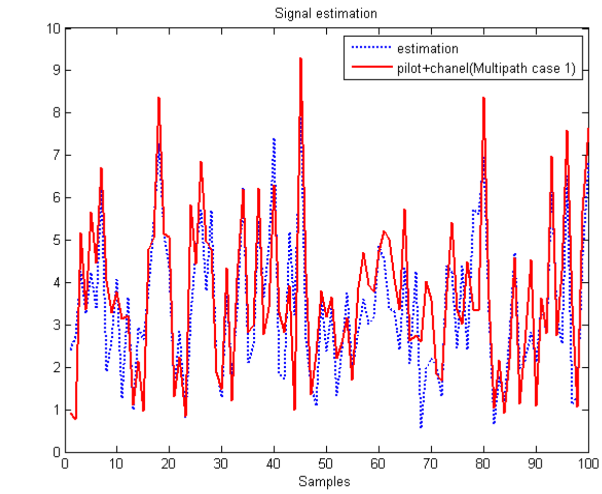

Fig. 3. Waveforms of the pilot interference and its estimate for fading case 1.

Figs.2 and 3 are comparing sections of the pilot signal waveform of the neighboring base station and its estimate by the NLMS algorithm in the AWGN channel (the required SNR is -1 dB in the 3GPP specification.) and fading case 1 environment (details of this channel can be found in [10]), respectively. We set $\tilde{\mu}$ factor to 0.88, which gives the minimum among the errors obtained by the simulations with various $\tilde{\mu}$'s from 0.01 to 1 by step size of 0.01. The mean squared error is 0.006 for AWGN channel while that is 0.0094 for fading case 1.

In order to evaluate the efficient cancellation of the undesired pilot signal by the proposed algorithm, we measured the uncoded bit error rate (BER). In this experiment, we assume that there are two base stations and set the BS2's pilot signal power 3dB-lower than the BS1's [9] while increasing the noise power. The BER performance is illustrated in Fig. 4.

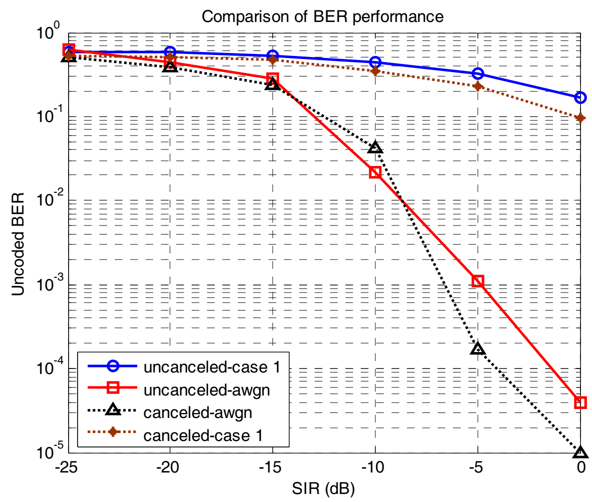

Fig. 4 Comparison of BER performance with respect to SIR.

The BER's for the uncancelled set are measured for the combined signal from base stations 1 and 2 while those for the canceled set are measured after removing the undesired pilot signal from the combined one using the proposed approach. As observed in the figure, the proposed algorithm clearly achieves better performance than the system without cancellation.

5. Conclusion

This paper has considered the performance of pilot interference cancellation, an advanced repeater technology being considered for third generation WCDMA cellular networks. We proposed a mitigation method to reduce the effect of pilot interference signals received from neighboring base stations in a wireless repeater. The mitigation of pilot interference at the wireless repeater improves the SINR, which enables increased cell capacity or better BER performance in the WCDMA system. The attractiveness of this technology derives from the link-level benefits described above and from the negligible complexity/cost associated with pilot interference cancellation implementation in a repeater not in an user equipment. Simulation studies have been carried out to verify the appropriateness of the proposed approach and we obtained promising results.

The fact that pilot interference is canceled in the wireless repeater provides increased flexibility in the setting of the pilot power levels. Since the method adds a degree of freedom in optimizing WCDMA networks, it enables us to increase pilot power in order to improve coverage, location-finding ability, and demodulation performance.

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