# LMS FILTERS FOR CELLULAR CDMA OVERLAY

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ABSTRACT

This paper extends and complements previous research we have performed on the performance of non-adaptive narrowband suppression filters when used in cellular CDMA overlay situations. In this paper, an adaptive LMS filter is applied to cellular CDMA overlay situations in order to reject narrowband interference.

**Introduction**: In our recent paper [1], the effects of using Wiener filters (or non-adaptive filters) for rejecting narrowband interference in cellular CDMA overlay are investigated. However, in practice, since cellular CDMA users are mobile, there are Doppler frequency-shifts. Also, since the cellular channel is fading, the signal and interference statistics are rarely constant. Thus, the Wiener filter must be made adaptive. The work concentrates on the uplink, steady-state, performance of CDMA overlay systems with adaptive LMS filters, assuming convergence has been achieved.

**Performance analysis**: A receiver operating in a cellular CDMA overlay environment and which incorporates the use of a Wiener filter was described in [1]. By replacing the Wiener filter with an adaptive LMS filter, the adaptive CDMA receiver is constituted. As in [2], the adaptive LMS filter is modelled as consisting of a Wiener filter and a misadjustment filter operating in parallel (see Fig. 1).

It is assumed that in the cellular system, there are $C$ cells, each of which contains $K$ active users and one base station. Therefore, there are $CK$ active users, for the entire cellular system. The cellular mobile channel between a mobile user and a base station is assumed to be multipath Rician fading channel, where there are $L$ paths associated with each user.

As shown in Fig. 1, the receiver consists of the following parts: a bandpass (BP) filter, an adaptive LMS filter, a DS-despreader and a hard decision device. The input signal $r(t)$ to the adaptive filter is the sum of all CDMA signals, a narrowband *BPSK* representing the signal which is overlaid by the CDMA network, and band-limited AWGN. That is,

$$r(t)=\mathrm{Re}\left\{\sqrt{2P}\sum_{k=1}^{CK}\sqrt{\varepsilon(\gamma,c_k,k)}\sum_{l=1}^{L}\left[A_{kl}\exp(j\phi_{kl})+\beta_{kl}\exp(j\psi_{kl})\right]b_k(t-\tau_{kl})a_k(t-\tau_{kl})\exp(j2\pi f_0 t)\right.$$
$$\left.+\sqrt{2J}d(t)\exp\left[j(2\pi f_0 t+\theta)\right]\right\}+n(t) \qquad (1)$$

where $\gamma$ is a propagation exponent, and $c_k$ denotes the cell in which the $k$th user is located; the users are numbered such that $c_k=\mathrm{int}[1+(k+1)/K]$, where $\mathrm{int}(x)$ stands for integer part of $x$. The function $\varepsilon(\gamma,c_k,k)$ represents the $\gamma$th power of the ratio of the distance of the $k$th user to its own base station ($c_k$th cell) to the distance of the $k$th user to the first cell base station ($c_k=1$). For the first cell (cell of interest), we

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assume $\varepsilon(\gamma, c_k, k)\big|_{c_k=1} =$ because of perfect adaptive power control. The parameter $f_0$ denotes the CDMA carrier frequency, $b_k(t)$ is the $k$th binary information sequence with bit duration $T_b$, $a_k(t)$ is a random spreading sequence with chip duration $T_c$ and processing gain $N$ $(N = T_b/T_c)$, and $A_{kl}$ $(0 \le A_{kl} \le 1)$ and $\phi_{kl}$ are gain and phase of the specular component of the $l$th path from the $k$th user, respectively. It is assumed that $A_{kl} = A$ for all $k$ and $l$, and $\phi_{kl}$ is uniformly distributed in $[0, 2\pi]$, respectively. The random gain $\beta_{kl}$ and phase $\psi_{kl}$ of the fading component of the $l$th path of the $k$th user have a Rayleigh distribution with $E[\beta_{kl}^2] = 2\rho_{kl} = 2\rho$ for all $k$ and $l$, and a uniform distribution in $[0, 2\pi]$, respectively. The path delay, $\tau_{kl}$, is uniformly distributed in $[0, T_b]$ and, to simplify some of the analysis to follow, we assume $\left|\tau_{kl} - \tau_{k\hat{l}}\right| \ge T_c$ for $l \ne \hat{l}$. The gains, delays and phases of different paths and/or of different users are assumed to be statistically independent. Furthermore, $J$ and $\theta$ denote the received non-fading BPSK narrowband interference power and phase, respectively, and $d(t)$ is the binary data sequence of the narrowband interference, $J(t)$, having bit duration $T_j$.

The parameter $p$ is defined as the ratio of the interference bandwidth to the spread bandwidth (i.e., $p = T_c/T_j$). Finally, $n(t)$ is band-limited AWGN with two-sided power spectral density $N_0/2$ and bandwidth $2T_c^{-1}$. Note that, for simplicity, while we have bandlimited the noise, we have assumed that the BPF passes the signal undistorted.

The adaptive filter output is given by $r_f(t) = \sum_{m=-M}^{M} (\alpha_m + \upsilon_m) r(t - mT_c)$, where $\alpha_m, m = -M, \cdots, M$, denotes the $m$th tap weight of the Wiener filter, and $\upsilon_m, m = -M, \cdots, M$, denotes the $m$th steady-state tap-weight of the misadjustment filter.

Most often, via a central limit theorem, it is argued that the steady-state tap weights of the misadjustment filter are jointly Gaussian [3] for small enough adaptation step size. Hence, with the joint Gaussian assumption, the tap-weight covariance matrix completely defines the statistics of the misadjustment filter. When it is assumed that the sum of all active CDMA signals is Gaussian, the steady state covariance matrix of the tap weight vector can be obtained (approximately) by solving the following equations:

$$\sum_{n_1=1}^{2M}\left[(R_r)_{m_1n_1}(R_\upsilon)_{n_1m_2} + (R_\upsilon)_{m_1n_1}(R_r)_{n_1m_2}\right] \approx 2\mu E\left[(e^*)^2\right](R_r)_{m_1m_2}$$
$$+2\mu E\left[(e_j^*)^2 j_{m_1} j_{m_2}\right] - 2\mu E\left[(e_j^*)^2\right] E\left(j_{m_1} j_{m_2}\right), \qquad m_1, m_2 = 1, \cdots, 2M, \tag{2}$$

where $R_r$ and $R_\upsilon$ are the covariance matrices of the input signal sample vector and the tap weights of the misadjustment filter, respectively, and $(R)_{m_1n_1}$ denotes the $m_1$th row and $n_1$th column element of R. $\mu$ is the adaptation step size, and $e^*$ and $e_j^*$ are the Wiener prediction error for the composite input signal and the narrowband component of the input, respectively, and are defined as $e^* = \sum_{m=-M}^{M} \alpha_m r(t - mT_c)$ and $e_j^* = \sum_{m=-M}^{M} \alpha_m j_m$, respectively, where $j_m$ is the narrowband component of the input.

Assuming the $l$th path of the $i$th user (reference user) of the cell-of-interest is the reference path, and $\tau_{il} = \phi_{il} = 0$, the despreader output is given by

$\xi(\lambda) = \int_{\lambda T_b}^{(\lambda+1)T_b} r_f(t) 2a_i(t)\cos(2\pi f_0 t)dt$, which consists of a useful signal term, a narrowband interference term and multi-access interference terms. From those terms, the bit error rate (BER) can be derived. It is assumed that the ratio of the interference bandwidth to the spread spectrum bandwidth is 10% ($p = 0.1$). The processing gain and the number of taps on each side of a suppression filter are set at $N = 255$ and $M = 2$, respectively. The number of paths, the propagation exponent and the ratio of the specular component power to the fading component power are assumed to be $L = 3$, $\gamma = 3$ and $H = 7\ dB$, respectively. The narrowband interference power to the useful signal power ratio is assumed to be $J/S$=20 dB. Note that $\gamma = 3$ means that the adjacent cell interference $\langle r \rangle = .97$. That is, the interference from all adjacent cells is 97% of the interference of the cell-of-interest. Finally, the adaptation step size is selected as $\mu = \frac{1}{10\lambda_{max}} \leq \frac{1}{20M\rho_r(0)}$, where $\lambda_{max}$ and $\rho_r(0)$ are the maximum eigenvalue of the covariance matrix of the input signal and the power of the input signal, respectively.

Fig. 2 illustrates the BERs of the adaptive CDMA overlay system as a function of average signal to white noise ratio ($E_b/N_0$). It is seen that the adaptive LMS filter is very effective in rejecting the narrowband interference.

**Conclusions**: In this paper, the effect of an adaptive LMS filter in a cellular CDMA overlay situation is investigated. It is shown that the adaptive filter is very effective in rejecting the narrowband interference.

## REFERECES

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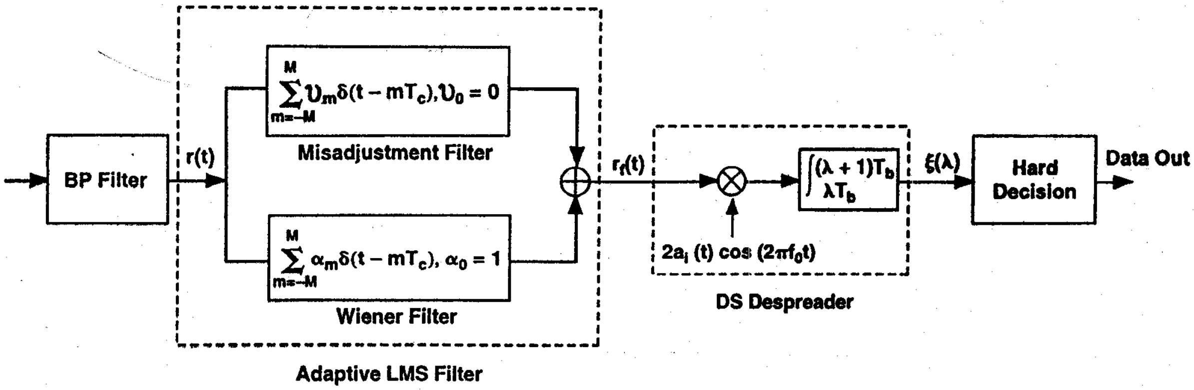


Fig. 1 An adaptive CDMA receiver model.

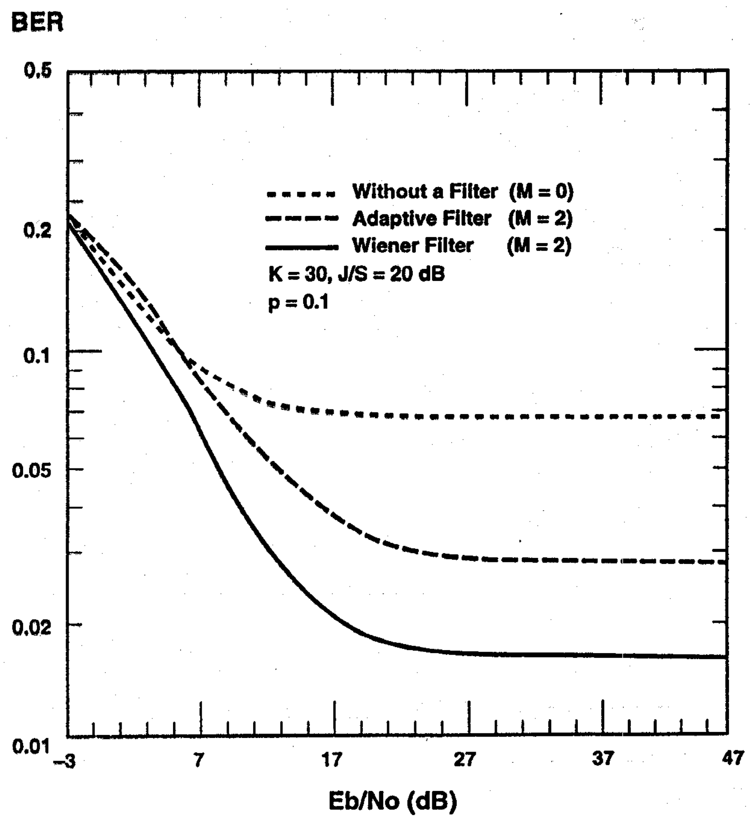


Fig. 2 BER performance of the CDMA overlay system vs. $E_b/N_0$.