

Delay and DOA Estimation in CDMA Communication Systems Via Maximum Likelihood Techniques

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Abstract — We present a maximum likelihood method for delay estimation in a CDMA wireless communication system. An antenna array is used at the receiver, which facilitates the concomitant estimation of the direction of arrival (DOA) of each user. In addition, the amplitude of each user is also estimated. A single path is considered for each user thereby resulting in uncorrelated signals at the receiver. The delay estimation reduces to the solution of a set of quadratic equations while the DOA estimation problem is equivalent to an eigenvalue problem.

I. INTRODUCTION

We assume a K -user direct sequence CDMA system with BPSK (Binary Phase Shift Keying) modulation with each transmitted signal limited to $[0, T]$. Each user transmits a zero mean bit sequence with i.i.d components and different users are independent of each other. The bitstream of each user is further modulated by a spreading sequence of length N , which is assumed to be periodic with the bit interval. In this development we will assume a single path channel; each of the users transmits through a different time varying channel whose parameters, we will assume, are constant in the time taken to estimate them.

The first stage in the demodulation is the so-called *acquisition* stage wherein the receiver attempts to lock onto the phase of the desired user's code [1]. The acquisition algorithm in this paper is based on a computationally elegant ML algorithm for direction of arrival (DOA) estimation presented in [2]. The receiver at the base station incorporates an antenna array of M sensors in a specified geometry. It can be shown that increasing the number of sensors in the receiver improves detection performance especially with linear multiuser detectors. We extend the ML algorithm discussed in [2] to the *simultaneous* estimation of DOA as well as code delay. We assume the transmission of training sequences by all the users that are being acquired. By incorporating the single path assumption the received bit streams are rendered uncorrelated. The additive noise is assumed to be a circularly complex zero mean Gaussian random vector; however no *a priori* knowledge is assumed of its covariance structure.

II. ML ALGORITHM

The observation vector across the array at the i^{th} time index, $\mathbf{r}_i \in \mathbb{C}^{MN \times 1}$, is obtained by sampling the outputs of chip matched filters at each of the M sensors at the chip rate; N successive time samples are collected to form an $N \times 1$ vector at each sensor and these are concatenated together to produce \mathbf{r}_i . The additive noise at time i is written as a sum of two components: receiver noise that is uncorrelated

across the array and background noise from other cells that is correlated across the array (and is symptomatic of cellular systems). The resulting noise covariance matrix \mathbf{K} , across the array can be written as a kronecker product of two smaller matrices, $\mathbf{K} = \mathbf{K}_1 \otimes \mathbf{K}_2$. The log-likelihood function of a window of L successive observations is to be maximized over the $3K$ parameters being sought: the delay τ_k , DOA θ_k and amplitude w_k for $k = 1, \dots, K$. At the outset this $3K$ -dimensional optimization problem is seemingly computationally intractable. We now make use of the uncorrelatedness of the arriving signals to decouple the problem across users [2], thus converting it to a set of K , 3-dimensional problems in $\{\tau_k, \theta_k, w_k\}$. The amplitude estimate is obtained by simple differentiation. To further decouple the 2-dimensional delay-DOA estimation for each user we exploit the kronecker noise structure. We are now able to estimate all the users' delays and DOAs separately. Estimating the code delay can be reduced to rooting a set of quadratic equations and finding the maximum of N real numbers. If a uniform linear array (ULA) is used at the receiver, DOA estimation can be shown to be equivalent to calculating the minimum eigenvalue of a 2×2 system.

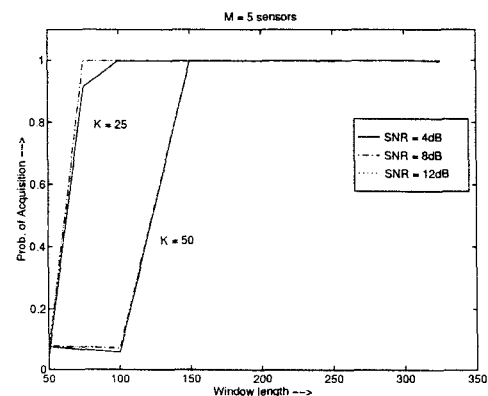


Fig. 1: Probability of acquisition as a function of window length L , for SNRs of 4, 8 and 12dB. Number of users $K = 25$ and 50. A ULA with $M = 5$ sensors was used.

REFERENCES

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