Combined Multipath and Spatial Resolution for Multiuser Detection: Potentials and Problems

Howard C. Huang, Stuart C. Schwartz, and Sergio Verdú
Department of Electrical Engineering; Princeton University; Princeton NJ, 08544

I. Introduction

Mobile telephony in CDMA channels encounters a variety of communication challenges including fading due to multipath (MP) and multiaccess interference (MAI) due to simultaneous transmissions from interfering users. Detectors which employ multiuser detection and temporal (RAKE-type) combining have been shown [1] to provide near-far resistant solutions which effectively combat both of these impediments. In the first part of this paper, we address the potential gains of using spatial combining in conjunction with multiuser detection and temporal combining. In the second part of the paper, we examine an adaptive multiuser detector which is well suited for MAI-limited MP channels.

II. Multiuser Array Detection for Multipath Channels

Recently, efforts have been made to combine the use of temporal combining and spatial combining. Most of these efforts are based on conventional detection schemes which have been shown to be near-far limited. In the first part of this paper, we combine results from [1] and [2] to derive a class of near-far resistant detectors which uses a linear multiuser detector in conjunction with spatial and temporal combiners. It is shown that the optimum (in terms of near-far resistance) linear multiuser detector with an array of P sensors consists of a bank of match filters at each sensor matched to the users' delayed spreading codes, followed by a spatial combiner (which acts as a beamformer pointing in the direction of each users' MP signals), a temporal combiner (which coherently combines a user's MP components), and a linear transformation which decorrelates the users. Since this decorrelation process relies on the estimates of the signals' spatial and MP parameters, this detector (known as the spatial-temporal decorrelator (stD)) is near-far limited when the estimates are not exact. By interchanging the order of the three processors, we can obtain two suboptimum detectors, the sDt and Dst, which, respectively, retain their near-far resistant characteristics when there is MP parameter mismatch and when there is both MP and spatial parameter mismatch. If all of the system parameters are known exactly, we have the following relationship among their respective bit error rates as a function of the noise level: $P_{stD}(\sigma) \leq P_{sDt}(\sigma) \leq P_{Dst}(\sigma)$. This result is illustrated in Figure 1 for a 2-user synchronous, coherent system where each user contributes $L = 2$ MP components and where there are $P = 2$ sensors.

III. Blind Adaptive Detection for Multidimensional Signals

Motivated by the need for a noncoherent multiuser detector for MP channels which has no *a priori* knowledge of the interfering users, in the second part of the paper, we derive an extension of the blind adaptive detector [3] for differentially encoded, multidimensional signals. Such a detector is ideally suited for MP channels since, if we assume negligible ISI, the spanning set for the multidimensional subspace is given by the truncated, delayed translates of the desired user's spreading code. Given the L-dimensional subspace in which the desired user's signal lies, we can obtain an arbitrary orthogonal basis $\mathbf{z}_1 \ldots \mathbf{z}_L$. The resulting detector consists of a bank of L linear filters followed by an inner-product operation between the current filter bank output and that from the previous bit interval; the bit estimate is the hard-limit of this inner-product. The l^{th} filter consists of a real part $(\mathbf{z}_l + \mathbf{x}_l^R)/||\mathbf{z}_l + \mathbf{x}_l^R||$, $l = 1 \ldots L$ which operates on the real part of the received signal and a corresponding imaginary part. The $\mathbf{x}_l^R$ and $\mathbf{x}_l^I$ are each constrained to be orthogonal to all of the basis vectors $\mathbf{z}_1 \ldots \mathbf{z}_L$ and are obtained adaptively using the output energy of the respective real and imaginary part of the l^{th} filter. Each of the $\mathbf{x}_l^R$ and $\mathbf{x}_l^I$ can be adapted independently, exhibits global convergence, and requires knowledge of only $\mathbf{z}_l$ and the timing (bit-epoch) of the desired user. Hence this detector requires even less knowledge than the conventional RAKE receiver; yet as seen in Figure 1, for a 2-user system with $L = 2$, it essentially achieves the same performance as the optimum linear MP multiuser detector (equivalent to the differentially coherent stD with P=1).

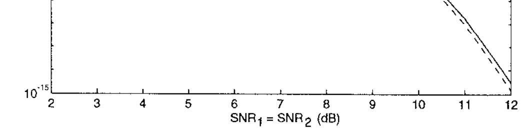

Figure 1: Performance of Multiuser Detectors ($L = 2$)

References

[1] H. Huang and S. Schwartz, "A comparative analysis of linear multiuser detectors for fading multipath channels," in *1994 Globecomm Proceedings*, pp. 11 – 15.

[2] H. Huang and S. Schwartz, "Robust multiuser detection using array sensors," submitted to *IEEE Transactions on Communications*.

[3] M. Honig, U. Madhow, and S. Verdú, "Blind adaptive multiuser detection," *IEEE Transactions on Information Theory*, July 1995.