Blind and Semi-Blind Detection and Estimation Techniques in Multiuser DS/CDMA Systems

By

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Submitted in fulfillment
of the requirements of the degree of
Doctor of Philosophy
to the

Indian Institute of Technology, Delhi
October 2003

Certificate

This is to certify that the dissertation entitled "Blind and Semi-Blind Detection and Estimation Techniques in Multiuser DS/CDMA Systems", being submitted by Mr. Abdul Karim Sadiq Al-Bayati, is in fulfilment of the requirements for the award of the degree of Doctor of Philosophy in Electrical Engineering of the Indian Institute of Technology, Delhi. This is a record of the candidate's own work carried out by him under our supervision and guidance. The matter embodied in this dissertation has not been submitted for the award of any other degree or diploma.

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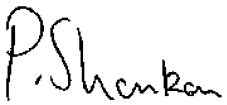

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Acknowledgments

I would like to express my deep gratitude and my sincere thanks to my supervisor Prof. Surendra Prasad for his able guidance, encouragement and support during all the stages of the work. His wide experience in the area of signal processing, and his insightful comments and suggestions and his patience were a continuous aid to me during the course of the work. I consider my self fortunate to have worked under his guidance.

I would also like to express my deep gratitude to my co-supervisor Dr. Shankar Prakriya for his valuable support and for useful discussions on various issues in the work. He was always ready for help and providing advice.

My sincere thanks are also due to the members of my research committee, Prof. S.D. Joshi, Dr. Arun Kumar, Dr. Subrat Kar, and Dr Ranjan Bose for their constructiuve discussions and continuous encouragement.

I am also grateful to Mr. Gandhi, Mr. Ravinder Pathak, Mr. Khanna and Mr. Negi for their help in the Lab.

I also express my gratitude for my fellow scholars, Anubala and Dharmendra and to several M, Tech. students who made working in the signal and information processing Lab an enjoyable experience.

Mere words will not suffice for my deep sense of gratitude and love to my Father and Mother who have always dreamed of me achieving this life-long goal.

Finally, my sincere thanks and deep gratitude to my wife Sarab for her great sacrifices and her generous and continuous support and patience. I dedicate this effort to her and to my beloved children Zaid, Mustafa and Mariam, who have helped me in every way they can.

Abdul Karim Sadiq

Abstract

In this thesis, we have developed new blind and semi-blind multiuser detection and estimation techniques that address some of the difficulties associated with the challenging multiuser (MU) DS/CDMA scenario in multipath channels. Our first focus is on systems with large number of users, and the use of space-time processing for reliable detection in such systems, while using only moderate data records for detection. This detection feature is very useful and important in dynamic channels (due to users' mobility) where channel stationarity is only valid over short periods, and in the presence of large number of users. For this purpose, we have investigated *the integration of space-time beamforming methods with multiuser detection techniques.* The high interference rejection capability of beamforming, that is based on space-time processing, followed by MU detection to cancel the in-beam interference, has led to promising detection performance in the above difficult scenario. We have also developed a novel Direction Of Arrival (DOA) estimation method that is generally useful in space-time receivers.

Our second focus is on the development of new blind multiuser receivers that are based on certain forms of data precoding which do not alter the data rate or the system bandwidth. The goal of this approach is to achieve multiuser detection with reasonable performance, while simultaneously providing some new desirable detection features. In particular, we have investigated multiuser receivers that are based on modifying the *modulus, phase,* and *color* properties of the data, uniquely for each user (prior to the spreading operation). The resulting receivers are seen to have reasonable performance, while having the advantage of avoiding the need for channel estimation, and consequently avoiding the possible channel estimation errors. These receivers are also near-far resistant and can operate properly even in systems that are nearly saturated, while some of them are robust against even severe carrier frequency offsets.

We first present a brief overview of some of the major approaches for multiuser detection in DS/CDMA systems. We also present the system model of interest in this thesis and follow this by

a brief introduction to the work described in this thesis. As mentioned above, the work in this thesis falls roughly into two categories. The first one deals with space-time receivers and techniques. The second category is concerned with precoding-based multiuser receivers.

We first present a new Space-Time (ST) detector that is based on the integration of the Constrained Minimum Variance (CMV) detection principle with a new beamforming approach. This beamforming method exploits a property of the null space of certain data matrices, constructed from observations at various antennas. Using the above property, joint beamforming/CMV detection can be formulated as a dual objective minimization problem. The proposed technique requires prior knowledge of the path delays of only the desired user. The new approach is shown to provide significant performance advantages compared to some existing methods in systems with large number of users, using only moderate block sizes (i.e. number of symbols) for detection. This is due to the equivalence of this ST receiver to a CMV receiver, which is preceded by an efficient interference cancellation stage.

Next we propose another ST receiver that is based on the integration of ST beamforming based on ESPRIT, with multiuser detection based on the constant modulus property of the transmitted symbols. This beamforming approach exploits the spatial shift invariance property of the received data matrices to effectively direct a beam towards a desired DOA, isolating the desired signal to within a small mixture of data vectors. The desired signal is then extracted from the small mixture of the in-beam signals, by exploiting the constant modulus property of the data, using the Analytical Constant Modulus Algorithm (ACMA) [53]. A small number of zero (off) symbols are inserted in each block for user association (hence the term semi-blind), so that the ACMA would yield a unique solution in a one shot procedure. The proposed receiver is demonstrated to achieve very low error rates in the above mentioned scenario, and its performance is even better than that of the earlier proposed space-time CMV-based receiver, due to its deterministic nature (at the cost of a very small reduction in system throughput).

In view of the importance of DOA estimation for space time processing in general, we next propose a blind method for path DOA estimation in a multipath channel, by exploiting the subspace structure of the DS/CDMA signal received by a linear antenna array. Here we utilize estimates of the effective space-time code vector over the receiver antenna array (which may be obtained blindly using subspace methods). We develop MUSIC-like search methods to perform joint DOA/code vector search so as to estimate the desired user path DOA's and directly

associate them to the appropriate path code vectors. Two search methods are developed for this goal. Results show that the two methods perform better than some of the existing methods and have a reasonable performance.

Following the work on space-time receivers and techniques, we consider time-only (though extendable directly to space-time) receivers, that are based on certain types of data precoding. First, we consider the use of the modulus pattern of the data to uniquely characterize the data of each user so that multiuser detection and association may be achieved *using only this property without the need for channel estimation or code knowledge.* This is achieved by varying the modulus of the data of each user over a block (prior to spectrum spreading), to within certain acceptable limits, in a unique manner for each user. This embedded property is used at the receiver to extract the data of any desired user, using the analytical constant modulus algorithm (ACMA). The resulting detector is shown to exhibit reasonable detection performance compared to existing multiuser receivers, besides being robust to the problems of near-far signals and Carrier Frequency Offsets (CFO) and nearly saturated systems.

We next propose a phase-precoding based MU detector for BPSK/DS-CDMA systems. In this method, the phase of the binary data is modified uniquely for each user (prior to spectrum spreading) over a block of data using a precoding sequence. Detection of a certain desired user involves an inverse phase change, using the known phase pattern (or precoding sequence) of that specific user, followed by obtaining the detector from the solution of a generalized eigenvalue problem. Hence the detection method avoids channel estimation and problems associated with it. The method is shown to achieve good performance compared to some standard multiuser detectors, and also compared to the *modulus* precoding based receiver, proposed earlier. This method, also, has the advantage of proper operation in nearly saturated systems. However, being dependent on phase, the method is sensitive to the CFO effect and requires an appropriate search/track procedure, which involves some extra complexity.

Finally, we propose a new multiuser detector that is based on modifying the data power spectrum of all users in a two-stage coloring/whitening procedure (prior to spectrum spreading). The coloring stage employs an FIR precoding filter that is identical for all users, while whitening is achieved by using precoding (PN) sequences that characterize each user. Detection is carried out by an inverse precoding (de-whitening) operation, using the precoding sequence of the desired user, followed by obtaining a linear detector for the colored data directly (without channel

estimation) from the solution of a generalized eigenvalue problem. Viterbi algorithm is then used to extract the white data from the recovered (colored) data. Performance of the method is shown to be reasonable, with advantages in the presence of severe CFO, or in nearly saturated systems. However, its performance is slightly worse than the *modulus* and *phase* precoding based receivers, possibly due to the statistical nature of the method, and its two-stage detection process.

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