Multiple Target Detection and Tracking

Final Technical Report

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MULTIPLE TARGET DETECTION AND TRACKING

Abstract

This project focusses on two projects for training two graduate students.

Any target detection and tracking system involves a model with unknown parameters. The first project deals with the estimation of the unknown parameters when the model itself is nonlinear.

The second project deals with adaptive processing methods for Anti Jam protection for GPS systems.

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I. Introduction

This work was performed under a supplementary AASERT Contract attached to the main SDIO/IST Contract "Integrated Detection and Estimation Using Multisensor and Distributed Processing" funded by SDIO/IST and monitored by ONR.

(A): Real time estimation of the parameters in a nonlinear system.

We consider the real time estimation of all the parameters in a system using scalar observations, which are a sum of signal and noise, the signal obeying a continuous time ARMA model or equivalently pocessing a rational spectral density. We use a state variable approach in a Bayesian framework. If we denote the augmented state vector to be 'v', made up of state vector and all unknown parameters, then we show that the posterior probability density of v(t) given all the observations till time t is gaussian. Both the conditional mean of v(.) and its conditional co-variance matrix obey recursive difference/differential equations similar in structure to ordinary kalman filter for state estimation only, except that the co-variance equation involves also the conditional mean estimate of the state and parameters.

The recursive procedure can be extended to estimate all the parameters in a system with noise corrupted vector observation, the signal obeying a m-dimensional continuous time ARMA model.

The procedure for developing the above recursive estimation is also used to handle the recursive estimation of parameters of the discrete ARMA model. However, in this case the posterior density of the augmented state vector given the observations is not strictly Gaussian. We give recursive equations for the estimates of the conditional mean vector and associated mean vector and the associated mean square error matrix.

The conditional mean and conditional covariance have a structure which similar to that of the ordinary Kalman filter for the state estimation with the conditional covariance equation obeying a matrix Riccati equation. However, the covariances are random variables and their equation does involve the state and parameter estimates. The Gaussian density allows the system to have sufficient statistic, i.e., all the information in continuam of observations till time t is represented by the estimate of the 3 n-dimentional augmented state vector and associated 3n X 3n dimensional co-variance matrix. Note again that, since Gaussian density is an approximation, even sufficient statistics is an approximation.

The next methods are generalized for vector outputs. Basically these are vector ARMA models in state variable form. In the continuous time case, the generalization is straight forward and the posterior density of the augmented state can be approximated by a gaussian density.

Next, the discrete time system is considered. A similar procedure is carried out. However, in this case the discretisation time is fixed and does not go to zero as in the continuous time case. Consequently the posterior density of the augmented state variable is not exactly Gaussian. The difference equation for the conditional covariance involves the expectation of quartic terms which is evaluated using the Gaussian formula. The smaller the discretisation time, the lower the approximation error will be.

The details are in the thesis by Chidambhara detailed in the publications.

(B): Space Time Adaptive Processing for Anti jam Protection for GPS Systems

This work was jointly supervised by Professor M. Zoltowski and Professor Kashyap.

Background:

The purpose of this research is to identify, develop, evaluate, and demonstrate innovative space-time adaptive processing schemes that protect GPS user equipment against intentional and unintentional interference. The anti-jam filter space-time filter should be capable of suppressing a mixture of interferer types, with particular emphasis on multiple broadband Gaussian noise interferers as dictated by the GPS Joint Programs Office. In addition to providing interference suppression, the filter should allow reception of GPS satellite signals in a stressed environment by maximizing the signal power to interference plus noise power (SINR) for acquisition and tracking of operation within the environment and dynamics characteristics of a high performance fighter aircraft. The goal is to demonstrate higher, yet affordable anti-jam capabilities for GPS user equipment on aircraft and other airborne weapons systems beyond the year 2000.

Protection Performance Versus Hardware/Computational Complexity:

The effort proposed in part of a system-level study of trade-offs between protection performance versus hardware and computational complexity for various integrated levels of processing. Two primary approaches will be investigated: (1) power minimization based space-time processing and (2) SINR maximization based post-correlation space-time processing.

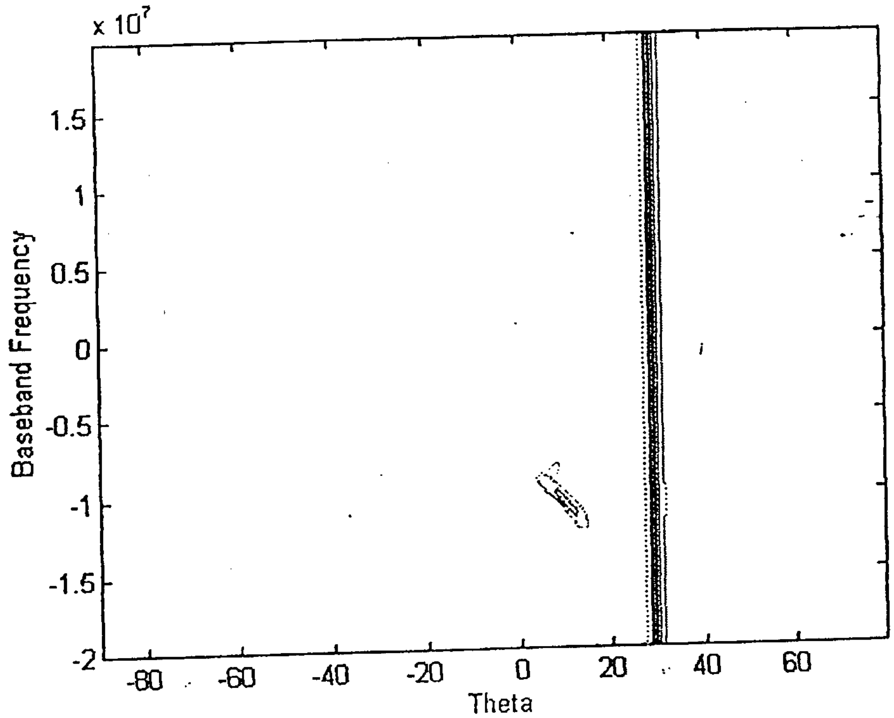
In the power minimization based space-time preprocessor, each sample value fed to the GPS receiver is formed from a linear combination of samples across both space and timer. The space-time goal of the preprocessor is to suppress jammers as best as possible while passing as many GPS signals as possible unaltered. Although the anti-jam space-time filter effected is not optimized for any one GPS satellite signal in terms of maximizing SINR, the advantage of this approach is that the anti-jam space-time filter is a separate component so that a standard digital GPS receiver may be employed.

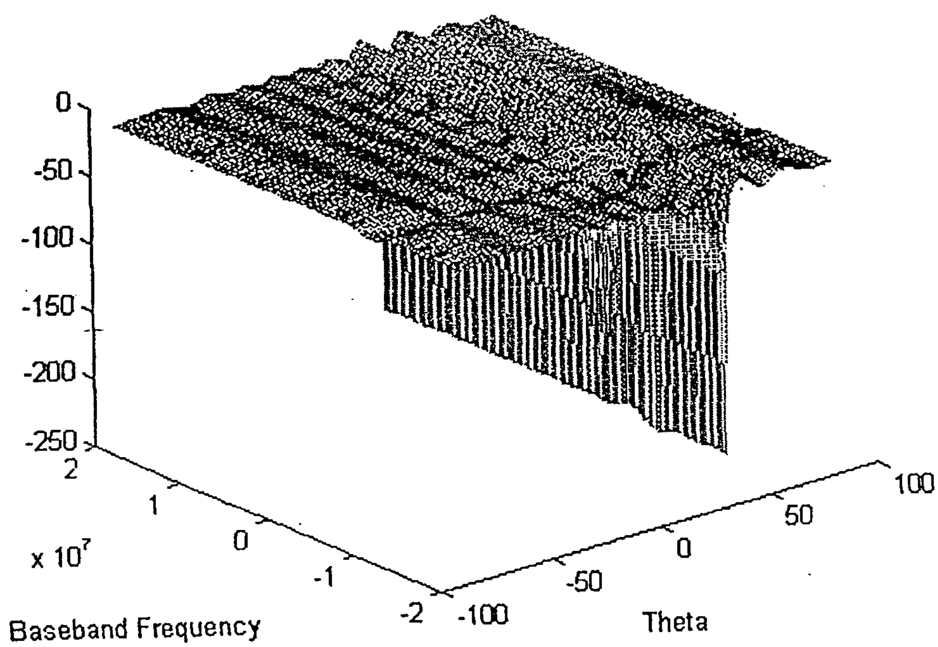
Three primary space-time preprocessors are proposed for investigation: (1) full dimension joint space-time preprocessor, (2) decoupled space-time preprocessor, and (3) reduced dimension joint space-time preprocessor based on a decoupled cross-spectral metric. Through theoretical performance analysis, extensive Monte Carlo simulations, and testing on "real" GPS data from an experimental antenna array, the performance of these three space-time adaptive preprocessing structures will be investigated in terms of the trade-offs amongst ouput SNR, convergence rate, and computational complexity.

Full dimension and reduced dimension joint space-time post-correlation processing base on SINR maximization will also be investigated. In order to avert processing at the chip rate, an additional post-correlation algorithm is proposed based on a blind adaptive beamforming algorithm developed previously by the PI for narrowband digital communications. This approach allows the use of a general purpose microprocessor employing a sampling rate equal to just several times the bit rate.

Current Research Results:

Of the power minimization methods mentioned the joint space-time preprocessor (using reduced dimensionality reduction via the cross-spectral metric) has been implemented in Matlab to illustrate the power minimization technique. The results are illustrated in the attached plot. The plot associated with this particular power minimization method represents the mesh and contour plots associated with frequency versus angle of incidence (relative to a linear array) of a wideband and narrowband jammer. This graph illustrates the optimal solution of the corresponding power minimization method by solving for the optimal weights without iterative techniques based on reducing the dimension of the space-time correlation matrix via the cross spectral metric. In this approach, each sample value fed to the GPS receiver is formed from a linear combination of samples across both space and time. A frequency of –10 Mhz was chosen for convenience, and the other parameters were selected for illustrative purposes assuming both jammers have equal power relative to the noise floor. It can be seen that both jammers have been minimized by this particular power minimization method. This is an initial step in testing the concepts associated with the power minimization techniques. The next step of the investigation is to implement this power minimization algorithm as well as the others based on techniques such as Least Squares, Recursive Least Squares, and possibly Least Squares Lattice algorithms. Once implementing the methods based on these techniques, hardware complexity issues can then be addressed.





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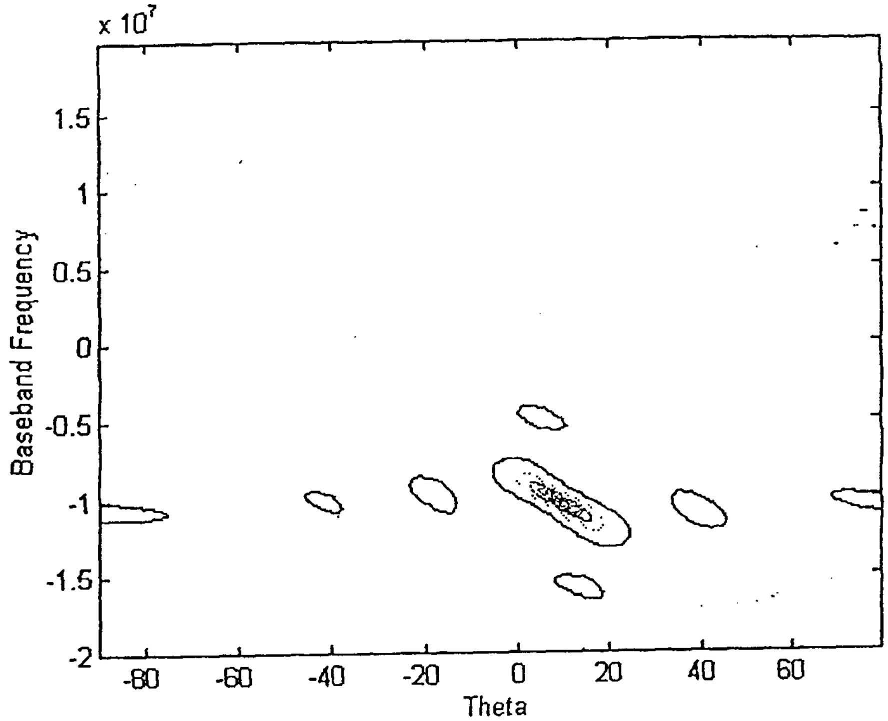
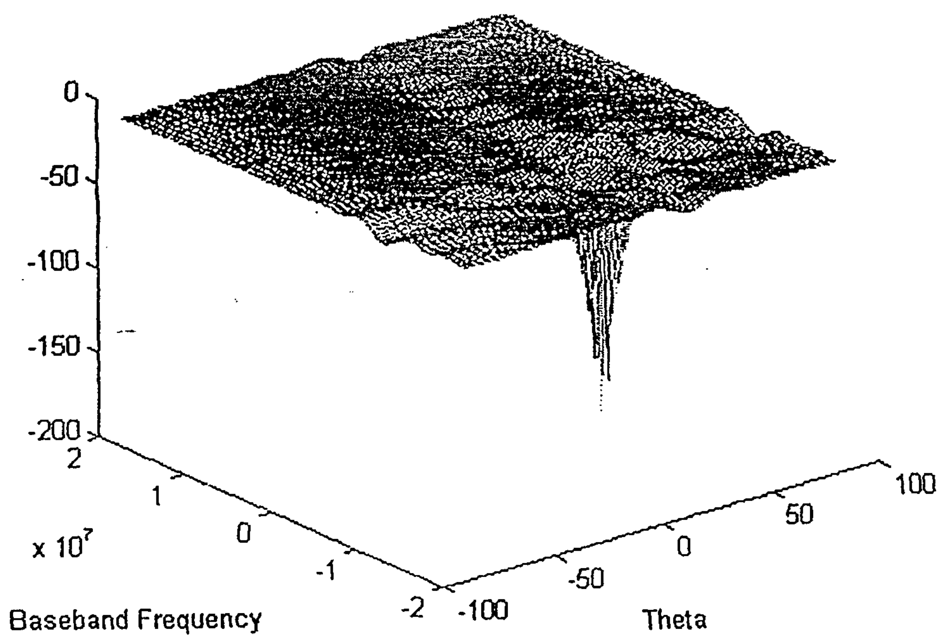
Frequency	-10Mhz						10 Element Linear
rel. to noise floor(db)	17.9	17.9					d=lamda/2
Sam. Rate	40Mhz						10 delay taps
Angle of Incidence	10	30					128pt FFT





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Frequency	-10Mhz						6 Element Linear
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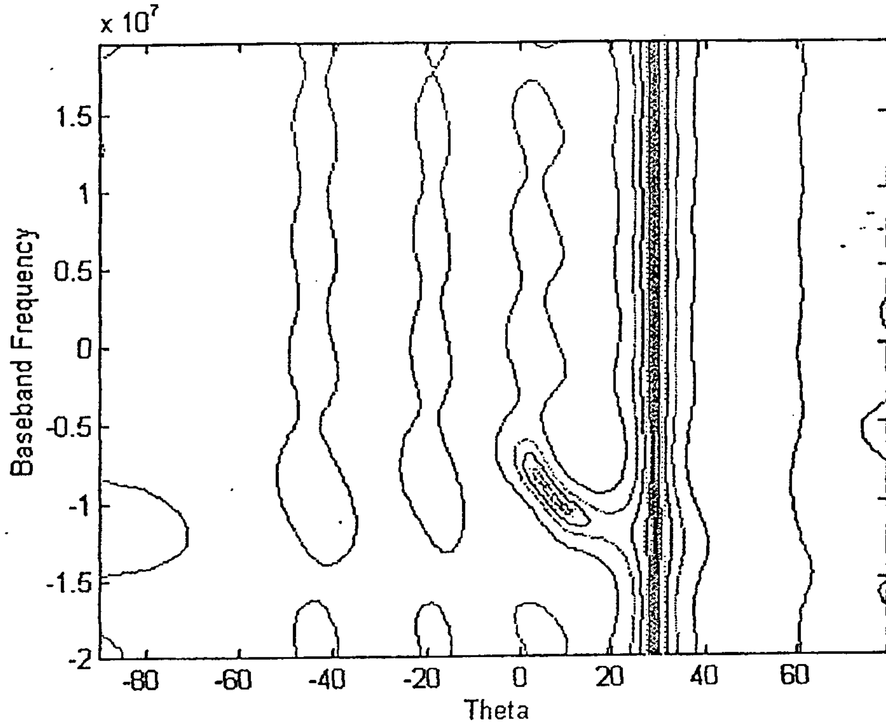

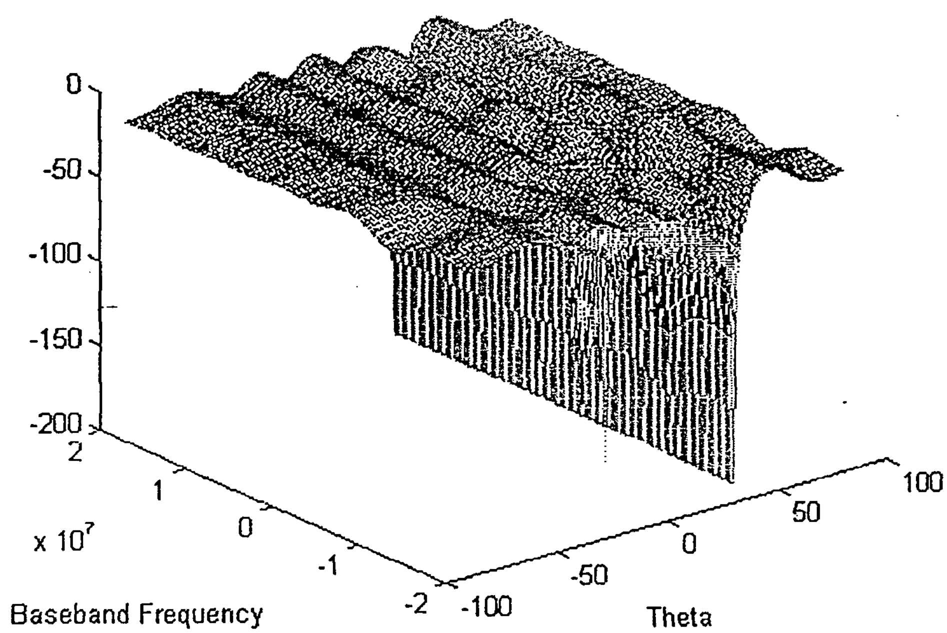

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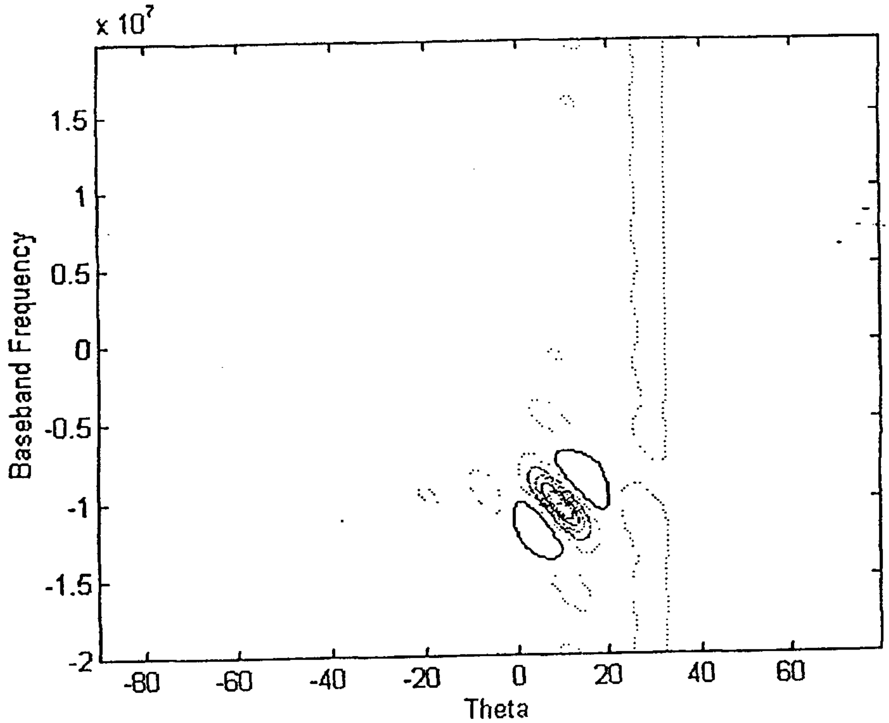

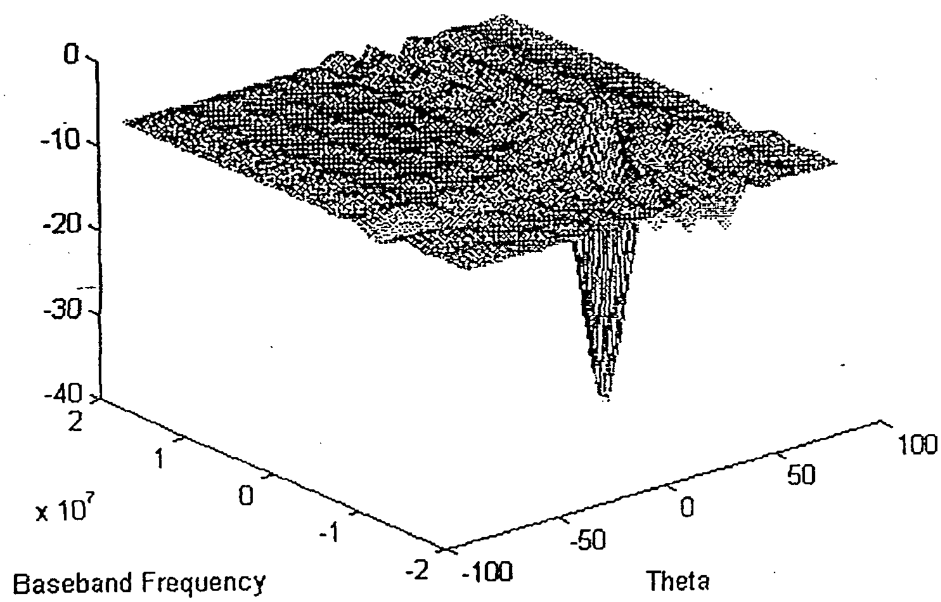

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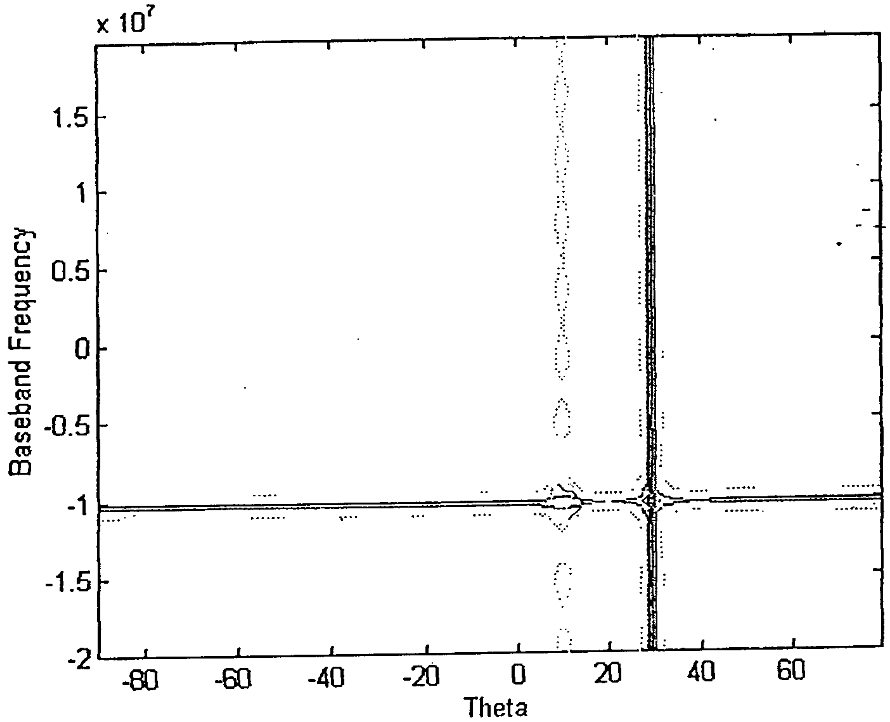

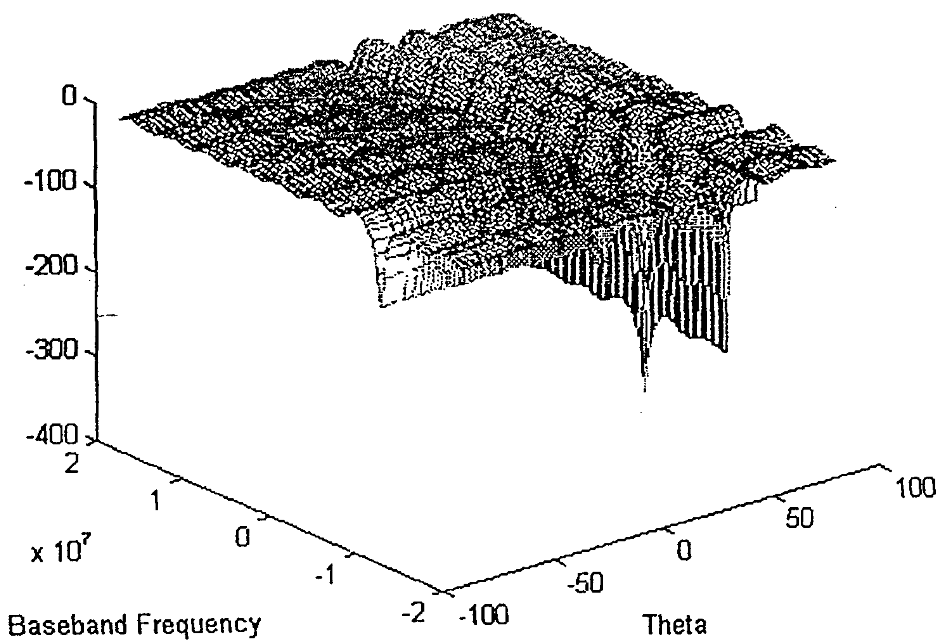

Method 2	NB 1	WB 1	NB 2	WB 2	NB 3	WB3	Array Parameters
Frequency	-10Mhz						10 Element Linear
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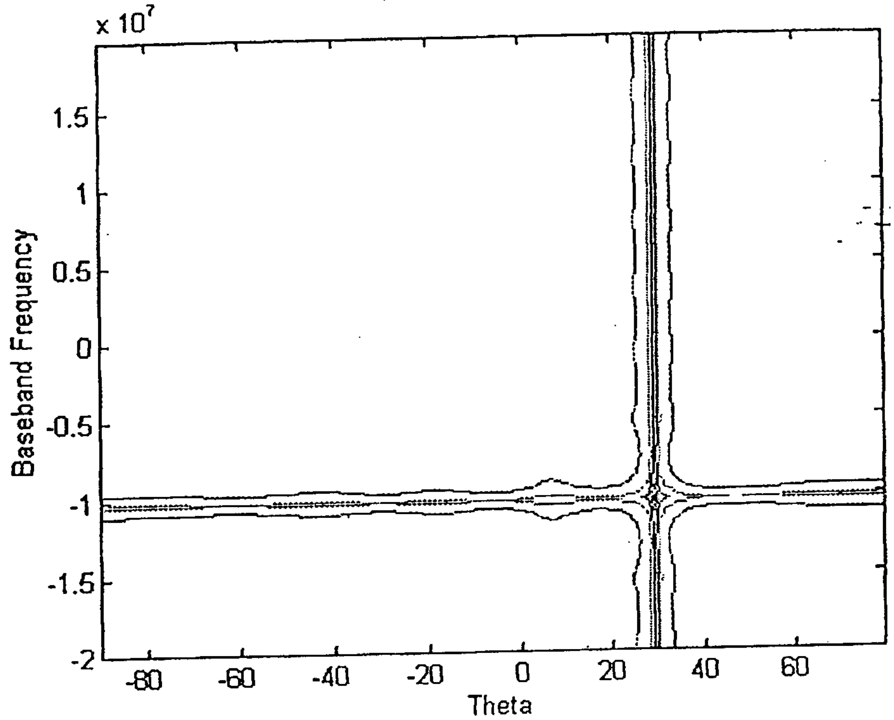

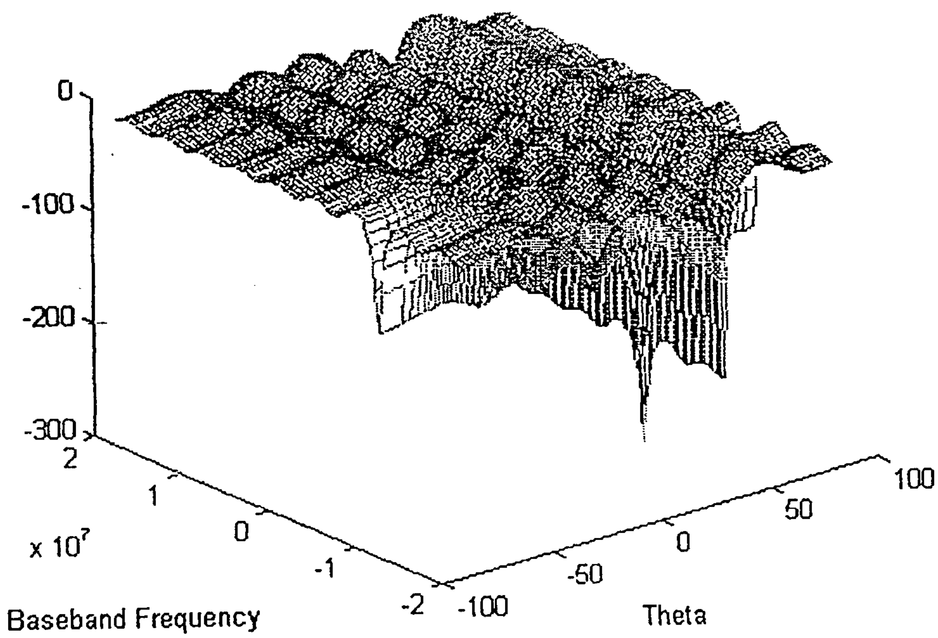

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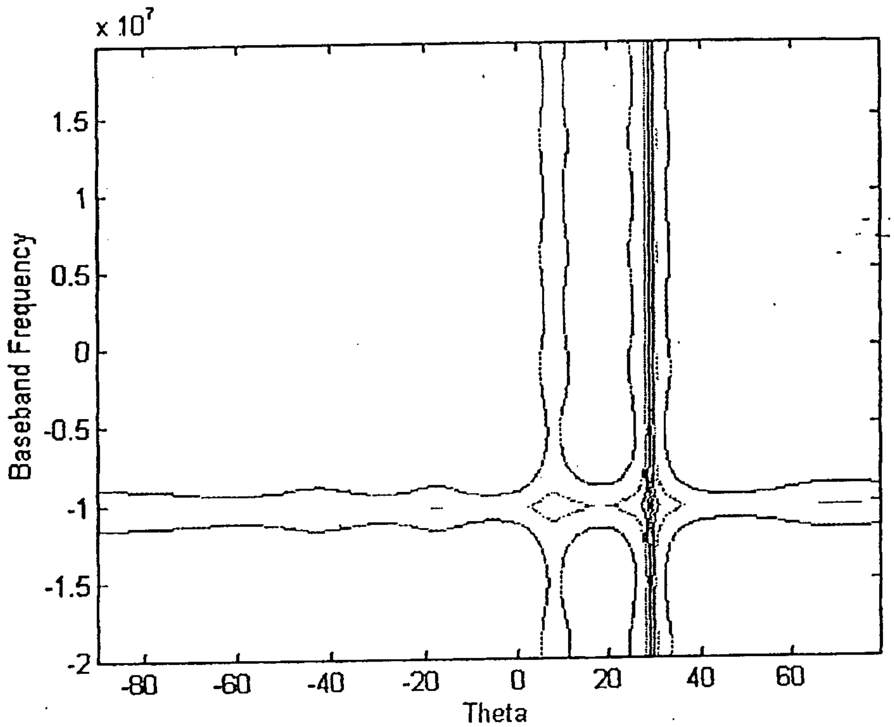

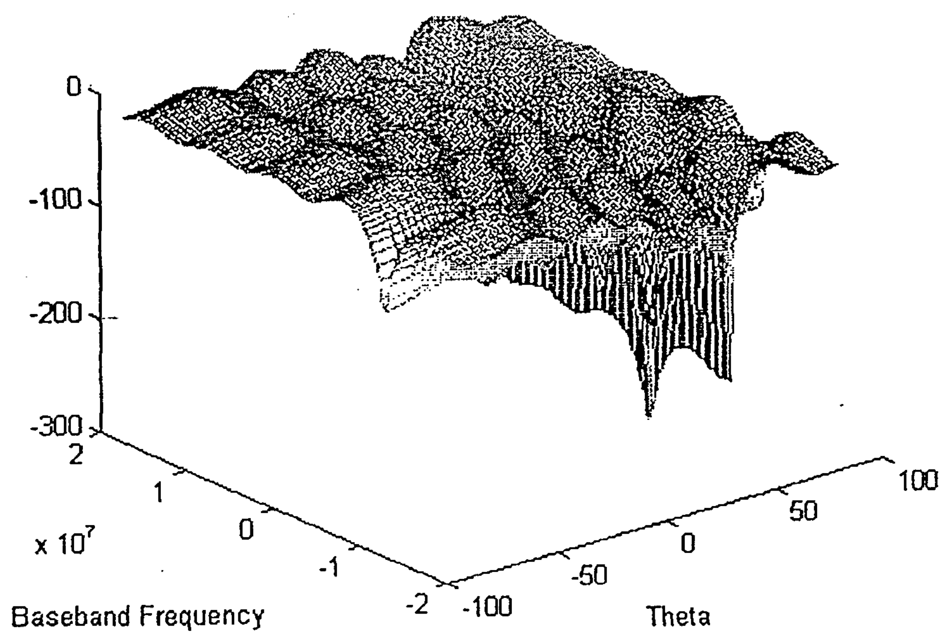

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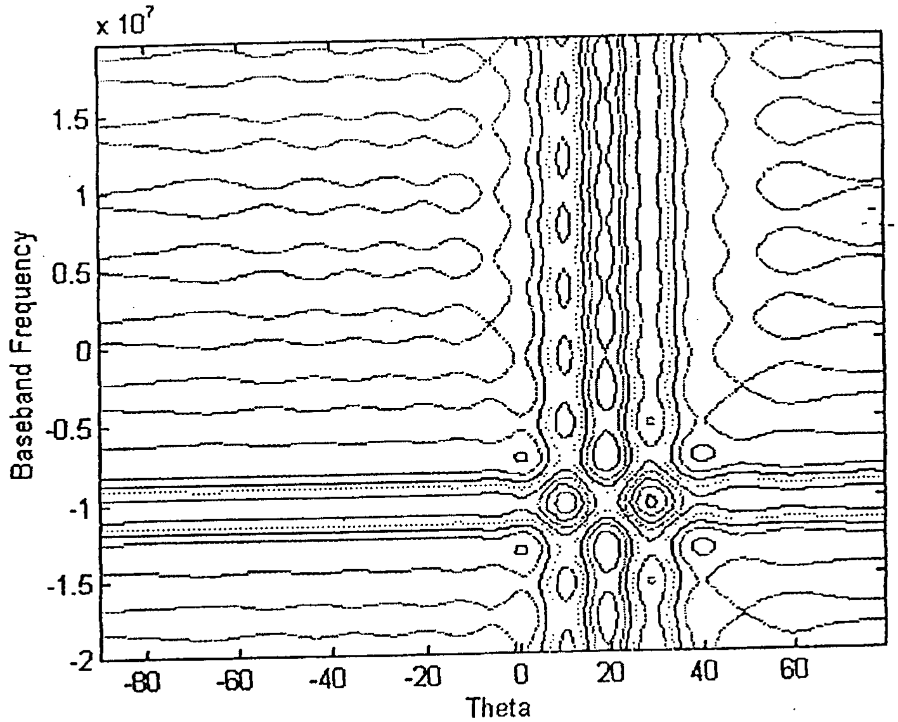

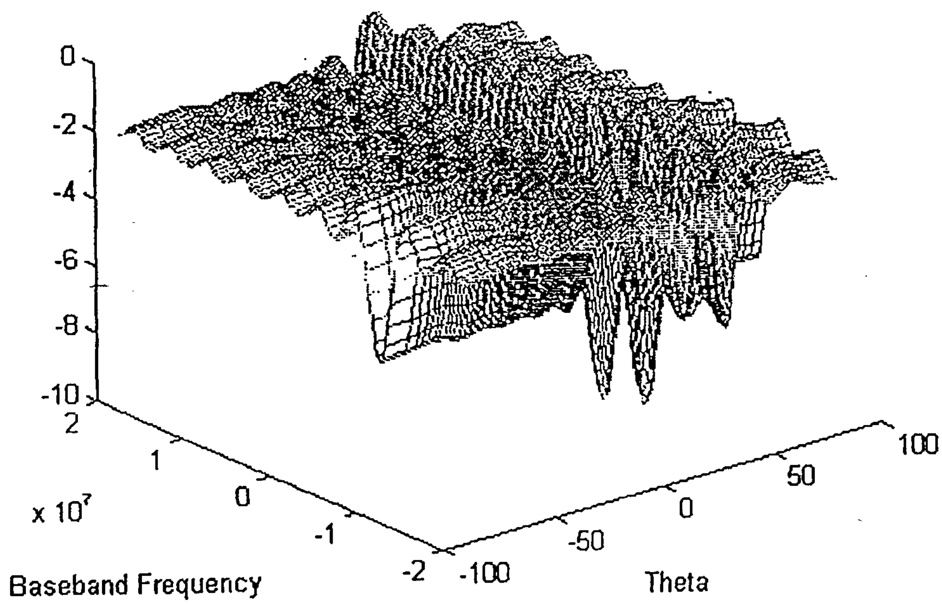

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III. Publications

Chidambara, M.S., M. S. E. E. thesis, Purdue University, August 1995. Bayesian Recursive Estimation of State and Parameter of Linear Systems with Noisy Observation.

[It may be pointed out that the main SDIO/IST/ONR Contract with which this AASERT is associated resulted in extensive achievements described in thirty publications which includes only papers in archieval journals and papers in the proceedings of national and international conferences.

IV. Personnel

Two students, both U.S. citizens, were hired who had expressed interest in pursuing a doctoral program. The first one was Madhukar Sastry (Aug. 1994 – 1995) who left the University after completing his masters degree (M.S.E.E.) and took a job in industry. The second one was Wilbur Myrick, who is currently working for his Ph.D. degree at Purdue.

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13. ABSTRACT *(Maximum 200 words)*

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Any target detection and tracking system involves a model with unknown parameters. The first project deals with the estimation of the unknown parameters when the model itself is nonlinear.

The second project deals with adaptive processing methods for Anti Jam protection for GPS systems.

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