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OFFICE OF NAVAL RESEARCH
PUBLICATIONS/PATENTS/PRESENTATIONS/HONORS REPORT
FOR
1 OCTOBER 1992 THROUGH 30 SEPTEMBER 1993
CONTRACT N00014-89-J-1070

SIGNAL PROCESSING IN THE LINEAR STATISTICAL MODEL

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6. AUTHOR(S) Louis L. Scharf and Clifford T. Mullis	
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Electrical & Computer Engineering University of Colorado Campus Box 425 Boulder, CO 80309-0425	8. PERFORMING ORGANIZATION REPORT NUMBER AR 1993
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11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT Unclassified	12b. DISTRIBUTION CODE
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13. ABSTRACT (Maximum 200 words)

This research program has produced the following results: (1) a method of estimating power spectra using multiple orthogonal time-division windows; (2) an exact likelihood procedure for estimating frequencies and arrival angles for propagating plane waves that are detected by multisensor arrays; (3) a theory of oblique projections for solving estimation problems; (4) a method for designing matched subspace detectors for detecting subspace signals in subspace interference; (5) a method for designing data-adaptive and reduced-rank estimators for solving least squares problems; and (6) a method for bounding the probability of a subspace swap in SVD methods. Work is continuing on (1) general quadratic performance bounds for estimation; (2) complex exponential frames for modeling discrete-time sequences; (3) discrete wavelet frames and filter banks; (4) projection operator decomposition of ℓ_2 ; and (5) representation and synthesis of periodically-correlated time series using subband decompositions.

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ONR PUBLICATIONS/PATENTS/PRESENTATIONS/HONORS REPORT
1 October 1992 through 30 September 1993

R&T Number:

Contract/Grant Number: N00014-89-J-1070

Contract/Grant Title: Signal Processing in the Linear Statistical Model

Principal Investigators: Louis L. Scharf and C. T. Mullis

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- a. Number of Papers Submitted to Refereed Journals but not yet published: 9 (list attached)
- b. Number of Papers Published in Refereed Journals: 1 (list attached)
- c. Number of Books/Chapters Submitted but not yet Published: 0 (list attached)
- d. Number of Books or Chapters Published: 0
- e. Number of Technical Reports & Non-Refereed Papers: 0
- f. Number of Patents Filed: 0
- g. Number of Patents Granted: 0
- h. Number of Invited Presentations at Workshops or Professional Society Meetings: 2 (list attached)
- i. Number of Contributed Presentations at Workshops or Professional Society Meetings: 6 (list attached)
- j. Honors/Awards/Prizes for Contract/Grant Employees: 2 (list attached)
- k. Total number of Graduate Students and Post-Docs Supported at Least 25% This Year Under This Grant: Graduate Students: 2 Post-Docs: 1

Of these:

- # Female Graduate Students: 0 # Female Post-Docs: 0
- # Minority Graduate Students: 0 # Minority Post-Docs: 0

Note: Minorities includes African Americans, Hispanics, American Indians, and Aleutians only.

- l. (added by PI) Work in Progress: 5

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a. Papers submitted to refereed journals (and not yet published):

M. P. Clark and L. L. Scharf, "Two-Dimensional Modal Analysis Based on Maximum Likelihood," accepted and to be published in *IEEE Trans Signal Proc* (June 1994).

R. T. Behrens and L. L. Scharf, "Signal Processing Applications of Oblique Projection Operators," accepted and to be published in *IEEE Trans Signal Proc* (1993).

L. L. Scharf and S. T. Voran, "Polar Coordinate Quantizers," accepted and to be published in *IEEE Trans Signal Proc* (1994).

A. J. Thorpe and L. L. Scharf, "Data Adaptive Reduced-Rank Methods for Solving Least Squares Problems," submitted to *IEEE Trans Signal Proc* (1994).

M. Vis and L. L. Scharf, "A Note on Recursive Maximum Likelihood for Autoregressive Modeling," submitted to *IEEE Trans Signal Proc* (September 1993).

L. L. Scharf and B. Friedlander, "Matched Subspace Detectors," submitted to *IEEE Trans Signal Proc* (July 1993).

K. Aas and C. T. Mullis, "Minimum Mean-Squared Error Transform Coding and Subband Coding," submitted to *IEEE Trans Signal Proc* (January 1993).

L. L. Scharf and S. T. Voran, "Noise Rejecting Quantizers," submitted to *IEEE Trans Signal Proc* (January 1993).

J. K. Thomas, L. L. Scharf, and D. W. Tufts, "Probability of Subspace Swap in the SVD," submitted to *IEEE Trans Signal Proc* (July 1993).

b. Papers published in refereed journals:

M. P. Clark and C. T. Mullis, "Quadratic Estimation of the Power Spectrum using Orthogonal Time-Division Multiple Windows," *IEEE Trans on Signal Proc* SP-41:1 (January 1993).

c. Books (and sections thereof) submitted for publication:

None.

d. Books (and sections thereof) published:

None.

e. Technical reports and nonrefereed papers:

None.

f. Patents filed:

None (one in preparation).

g. Patents granted:

None.

h. Invited presentations at topical or scientific/technical society conferences:

L. L. Scharf and B. Friedlander, "Matched Subspace Detectors," 1993 Workshop on Underwater Acoustic Signal Processing, Kingston, RI (September 1993).

L. L. Scharf and L. T. McWhorter, "Quadratic Estimators of Covariance: Theory and Application," to be presented at SYSIN, Copenhagen (July 1994).

i. Contributed presentations at topical or scientific/technical society conferences:

M. P. Clark and L. L. Scharf, "Frequency-Wavenumber Spectrum Analysis." *Proc 1992 Workshop on Statistical and Array Processing*, Victoria, BC (October 1992).

M. Spurbeck, "Causal Wiener Filtering of Periodically Correlated Sequences." SIAM Conf on Linear Algebra, Signal Systems, and Controls, Seattle (August 1993).

M. P. Clark and L. L. Scharf, "Efficient Frequency-Wavenumber Spectrum Estimation using Sliding Time-Division Windows." 1992 Asilomar Conference on Signals, Systems, and Computers, Pacific Grove, CA (November 1992).

J. K. Thomas, L. L. Scharf, and D. W. Tufts, "Probability of Subspace Swap in the SVD." to be presented at 27th Annual Asilomar Conf on Signals, Systems, and Computers, Asilomar, CA (October 1993).

L. L. Scharf and B. Friedlander, "Matched Subspace Detectors," to be presented at 27th Annual Asilomar Conf on Signals, Systems, and Computers, Asilomar, CA (October 1993).

L. L. Scharf, "Geometrical Ideas in Detection, Estimation, and Time Series Analysis," to be presented at 7th SP Workshop on Statistical Signal and Array Processing, Quebec City (June 1994).

j. Honors/awards/prizes:

C. T. Mullis promoted to full Professor effective January 1, 1993.

L. L. Scharf appointed National Distinguished Lecturer for IEEE Society for Signal Processing (1993-1994).

k. Graduate students and post-doctorals supported under the contract for the year ending 1 October 1993: (no female/minority)

John K. Thomas

Mark Spurbeck

Knut Aas (post-doctoral)

l. Work in Progress:

F. Ziel and C. T. Mullis, "Discrete Wavelet Frames and Filter Banks," to be submitted to *IEEE Trans Signal Proc.*

J. K. Thomas, "Automatic Bandwidth Estimation in Spectral Analysis," to be submitted.

M. Spurbeck, "Wavelet Decompositions of ℓ^2 ," to be submitted.

L. L. Scharf and M. Vis, "Signal Subspace MUSIC Algorithm," to be submitted.

J. K. Thomas, "Nonstationary Spectrum Analysis," to be submitted.