Statistical Signal and Array Processing

Professor Harry Van Trees
C3I Center Organization

- Over $30 million in research since 1989
- National reputation

- Center of Excellence in Command, Control, Communications and Intelligence
  - Systems Architecture Lab
    - Alexander Levis
    - Lee Wagenhals
  - Modeling and Simulation
    - Mark Pullen
  - Statistical Signal and Array Processing
    - Harry Van Trees
    - Kristine Bell
Array Processing
Representative Problems of Interest

• Detection of desired signals
• Estimation of parameters of signals
• Mapping the environment
• Forming images
• Tracking targets
Issues

- Performance
- Computational complexity
- Robustness
Application Areas

• Radar
• Sonar
• Communications
• Radio astronomy
• Medical diagnosis and treatment
• Seismology
• Fault inspection
Radar: Aegis Combat System
Radar: Space Surveillance

- 5184 transmit elements
- 4660 receive elements
Radar: Fighters
Sonar: Acoustic Arrays
Communications: Satellite Communications

- Iridium Satellite
Communications: Agile Antennas and Smart Skins
Radio: Astronomy
Medical Diagnosis: Ultrasound Volume Imaging
Seismology: Oil and Gas Exploration
Representative Research: Robust Adaptive Beamforming

• Problem: Maximize output from desired target
• Minimize output from interfering signals and noise
• Estimate statistics from input data
• Robust in the presence of signal mismatch
Adaptive Beamforming

[Graph showing beam pattern (dB) vs. u with three lines representing optimum signal and signal interferers]
Adaptive Beamforming, Finite Data
Adaptive Beamforming, Finite Data and Mismatch

Beam pattern (dB)

-40 -35 -30 -25 -20 -15 -10 -5 0

u

-1 -0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8 1

Optimum
us = 0.05, K=10N
signal
interferers
Adaptive Beamforming
Diagonal Loading

Beam pattern (dB)

-40 -35 -30 -25 -20 -15 -10 -5 0 5 10 15 20 25 30 35 40

Optimum
us = 0.05, K=10N
Diagonal loading
signal
interferers
Adaptive Beamforming
Quadratic Pattern Constraints

Optimum
us = 0.05, K=10N
Quadratic Constraints
Signal
Interferers
Outputs

- Books
- Research Papers
- Courses
- Students
Books
Courses

ECE 734
Detection and Estimation Theory

ECE 754 Optimum Array Processing I

ECE 755 Optimum Array Processing II

ECE 836 Special Topics in Detection, Estimation and Modulation Theory
Recent Doctoral Graduates

- John Uber, Ph.D, Electrical Engineering, Fall 2003 (Van Trees)
  *Estimation of the Dimensionality of the Signal Subspace*

- Xiaolan (Lillian) Xu, Ph.D, Information Technology, Fall 2002 (Van Trees)
  *Parameter Estimation for Spatially-Spread Sources*

- Roy Bethel, Ph.D, Electrical Engineering, Summer 2002 (Bell)
  *Joint Detection and Estimation in a Multiple Signal Array Processing Environment*

- Zhi (Gerry) Tian, Ph.D, Information Technology, Summer 2000 (Bell)
  *Blind Multi-User Detection with Adaptive Space-Time Processing for DS-CDMA Wireless Communications*

- Robert Zarnich, Ph.D, Information Technology, Spring 2000 (Bell)
  *A Unified Method for the Measurement and Tracking of Narrowband Contacts from an Array of Sensors*

- Brian Flanagan, Ph.D, Information Technology, Spring 2000 (Bell)
  *Self Calibration of Antenna Arrays with Large Perturbation Errors*

- Kristine Bell, Ph.D, Information Technology, Spring 1995 (Ephraim)
  *Performance Bounds in Parameter Estimation with Application to Bearing Estimation*

- Victor Larson, Ph.D, Information Technology, Summer 1995 (Van Trees)
  *Subspace Target Detector for Polarimetric Synthetic Aperture Radar Data*

- Hung Nguyen, Ph.D, Electrical Engineering, Spring 1994 (Van Trees)
  *Robust Beamforming Using Direction of Arrival Estimates*
Recent M.S. and B.S. Graduates

- Jay Gibble, M.S., Electrical Engineering, Spring 2000 (Bell)
- Xin Zhang, M.S., Electrical Engineering, Spring 2000 (Van Trees)
- Michael Butler, M.S., Electrical Engineering, Fall 1999, (Bell)
- Richard Bliss, M.S., Systems Engineering, Spring 1999 (Van Trees)
- Andrea Kraay, B.S. Electrical Engineering, Summer 1999 (Bell)
Recent Sponsors

- Office of Naval Research
- Navy: ASTO
- Army Research Labs
- Orincon
- Lockheed Martin
- AFCEA
- MITRE
- DSR
Summary

• Internationally recognized research group
• Mixture of theoretical and applied research
• Sequence of outstanding students