UNIVERSITÀ DI PISA

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

Dottorato di Ricerca in Ingegneria dell'Informazione

Doctoral Course

"Array Processing"

Emeritus Professor Douglas Gray

School of Electrical and Electronic Engineering
University of Adelaide

Short Abstract: The course will present the fundamental mathematical and engineering principles underlying the design and use of phased arrays and will present techniques for various techniques for processing the outputs of phased arrays. It will cover conventional and optimum techniques for array beamforming and will present theoretical, computational and real data analysis illustrating the practical performance of the methods presented. The course will also address the estimation of the direction of arrival of signals incident upon the array. Finally extension topics of STAP (Space Time Adaptive Processing) and MIMO (Multiple Input/Multiple Output) radar will be presented.

Course Contents in brief:

- Phased Array Overview
- Beamforming and Beam Patterns
- Implementation of Phased Arrays
- Random Processes and Cross-spectral Matrices
- Optimum Beamforming and Random Processes
- High Resolution Direction of Arrival Estimation
- Space-time Adaptive Processing (STAP)
- Radar and GPS Case Studies
- MIMO Radar

Total # of hours of lecture: 9 Hours

References:

[1] H. d'Assumpcao and D. A. Gray "Beamforming and Array Processing"

[2] H.L. van Trees "Optimum Array Processing"

CV of the Teacher

Douglas A. Gray was Professor of Electrical Engineering at the Adelaide University and Director of the University of Adelaide Radar Research Centre and since his retirement in 2016 is an Emeritus Professor at the University of Adelaide. He received his Ph. D. from the University of Adelaide, in 1973 and then spent 20 years with the Defence Science and Technology Organisation applying signal processing to sonar and electronic warfare and leading various research and development programs. From 1993 to 2006 he was Deputy Director of the Cooperative Research Centre for Sensor Signal and Information Processing and led a number of programs and projects in radar, sonar and GPS. From 2010 to 2016 he was Director of the University of Adelaide Radar Research Centre and focused on the use of radar for environmental monitoring and surveillance. His current radar research interests are in array processing, MIMO radar, radar for monitoring weather and bushfires and synthetic aperture radar for surveillance and environmental monitoring

Room and Schedule

Room: *Aula Riunioni del Dipartimento di Ingegneria dell'Informazione (si veda sotto il dettaglio delle aule nei vari giorni)*

Schedule:

Day1 – 0830-1230 - Aula Riunioni del Dipartimento di Ingegneria dell'Informazione, Largo L. Lazzarino 1, Pisa – piano 6

Lecture 1 Introduction
- Scanning – electronic vs mechanical
- Examples of phased arrays
- Advantages of phased arrays
- System aspects

Lecture 2 Beamforming and Beampatterns
- Conventional beamformng - phase shifts
- Beamsteering and steering vector
- Beampatterns and their properties
- Beamwidth, sidelobes, nulls and grating lobes
- ULAs and arbitrary geometries
- Beam pattern multiplication theorem
- Phasor interpretation

Lecture 3 Implementation of phased arrays
- Multiple beams and # independent beams, picket fence effect
- Array shading : failed receivers and phase errors
- Wideband signals
  - Time delay and sum beamforming
  - Frequency domain beamforming
- Active vs passive Tx/Rx modules

Day2 – 0830-1130 - Aula Riunioni del Dipartimento di Ingegneria dell'Informazione, Via G. Caruso 16, Pisa – Ground Floor

Lecture 4 Beamforming – Random Processes
- Random process revision
- Cross-covariances
- Frequency domain - cross-spectral matrices

Examples
Role in conventional beamforming

Lecture 5 Optimum Beamforming

Optimisation – maximizing SNR
Conventional vs optimum
MVDR - examples
SMI : Estimation of cross-spectral matrices
Beam Space

Lecture 6 High Resolution Direction of Arrival Estimation

Array manifold
Signal and noise subspaces, projection operators
Role of eigen values
MUSIC

Day3 – 0830-1130 - Aula Riunioni del Dipartimento di Ingegneria dell'Informazione, Via G. Caruso 16, Pisa – Ground Floor

Lecture 7 Space-time Adaptive Processing (STAP)

Intro to STAP architecture
Tapped delay lines – stacked vectors
Optimisation
    Constraints
Adaptive approaches
Gradient descent and LMS
Convergence issues

Lecture 8 STAP – Radar Case Studies

Ground clutter
Range Doppler diagrams
STAP application

Lecture 9 MIMO Radar

Intro to MIMO principles
Comparison with phased arrays
Transmit/Receive schemes
Element vs beam or orthogonal vs correlated
Matched filters on receive
Coarrays
Examples