Radar Principles - Study Notes
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1 Overall aims of course

The principal aim of this course is to introduce students to the fundamental principles underlying radar systems and to enable them to understand and apply these principles to generic radar systems. The subject is specifically structured around these aims.

On successful completion of this course, students will be able to:

- describe the main principles underlying radar systems.
- understand the role of each component of a radar system.
- use the radar equation to describe the performance of radar systems.
- understand how target and environmental characteristics affect the choice of system design parameters.
- describe and assess the relative advantages of different types of radars.

2. Material

Copies of slides used during the lecture will be placed on the course web page prior to lectures A set of brief lecture notes summarizing main points can be found on the web but lectures may not follow these notes in strict order and students are encouraged to use appropriate reference books to follow up more detailed aspects of the course.
The main reference text is M.A. Richards, J.A.Scheer and W.A. Holm (Eds) *Principles of Modern Radar –Basic Principles* but the book G W Stimson *Introduction to Airborne Radar is* also an excellent introduction.
Tutorials are focused on the application of the theory covered in lectures to data and some examples using Matlab may be made available to students during the course.

2.1 Assumed knowledge

An understanding of the basic ideas of RF propagation, physics, probability, statistics, random processes and signal processing is assumed. It would be an advantage but is not essential to have some understanding of the principles of Detection and Estimation, Antenna Theory, Signal Processing, Beamforming and Array Processing.

2.2 Course Outline

The course covers the areas listed below
Overview of Key Principles,
Radar Components and Processing, Radar System Functions, Radar Types, Radar Applications
Radar Range Equation
Point target derivation, System Noise, SNR, System Losses
Radar Waveforms and Ambiguity Function
CW**,** Single Pulse**,** Pulse Doppler**,** Coherent vs incoherent**,** Range estimation and range ambiguities**,** Ghosts**,** Sensing Doppler frequencies – Doppler ambiguities,,Pulse compression, FMCW, Phase coding, Other waveforms eg, Passive radar, noise radar Ambiguity Function definition and properties

Transmitters
Waveform generation, Power conversion, Mixers, Duplexors , RF devices – magnetrons and travelling wavetubes, Synchronisation and Timing Issues
Antennas and Phased Arrays
Radiation patterns, Beamwidth, sidelobes and gain, Antennas,Phased arrays
Propagation, Scattering and Clutter
Propagation, Attenuation, Refraction, Diffraction, etc, Scattering, Radar cross-section, Target fluctuation, Clutter, Surface and Volume clutter Ground clutter for airborne radar
Radar Receivers RF aspects
Preamplifiers, Down-conversion, Limiters, Noise Figures
Radar Signal Processing
Matched filters, Range processing, Doppler processing, Fourier transforms, Conventional phase shift beamforming, STAP
Detection and the Radar Equation
Detection Principles, Statistical Detection Theory, Pulse Envelope Detector, Radar Equation, Integration, CFAR
FMCW radars
Doppler effect, FMCW/Pulse compression, FMCW,Ambiguities
Parameter Estimation and Tracking Radars
Key basics of estimation theory, Range accuracy, Frequency estimation, Direction of arrival, Tracking radars – lobing and monopulse
Synthetic Aperture Radar
Cross-range resolution, Synthetic aperture and resolution, Azimuthal chirps, SAR image formation, MoComp,

2.3 Reference Material

2.3.1 Course Reference Texts

1. M.A. Richards, J.A.Scheer and W.A. Holm (Eds) *Principles of Modern Radar –Basic Principles*
2. G W Stimson *Introduction to Airborne Radar*

2.3.2 Background References

3. M I Skolnik *Introduction to Radar Systems*
4. M I Skolnik *Radar Handbook*
5. B R Mahafza *Radar Systems Analysis and Design using Matlab*.

2.3.3 General Course References

6. G Morris and L Harkness *Airborne Pulsed Doppler Radar*
7 N Fourikis *Advance Array Systems, Applications and RF Technologies*
8 R Klemm *Space-Time Adaptive Processing*
9 A Farina Antenna-Based *Signal Processing Techniques for Radar Systems*
10 R.J. Mailloux *Phased Array Antenna Handbook*

3 Course Delivery :

The lectures will be delivered in short course format from Monday February 3 2014 to Friday February 7 2014. A detailed lecture schedule is presented at the end of this document.

Following the lectures there will be a series of weekly tutorials/seminars organized by UCT. In preparation for these tutorials students will be provided with a problem sheet or a short quiz and will be expected to submit their solutions electronically prior to the tutorial. These solutions will not be marked but credit will be given attempting and submitting solutions and for tutorial attendance and participation.

During the course some additional exercises will be set - these are not for assessment but it will be useful if students try them to ensure proper mastery of the subject.

4. Assessment (subject to slight variations)

Assignment 1: Sheet of problems	10%
Assignment 2: Sheet of problems	10%
Examination	70%
Tutorial participation	10%

An optional supplementary assignment of an essay that can contribute up to 10% of marks will be offered to students who do not do well in Assignments 1 and 2.

4.1 Assignments

Assignments will contain both specific technical problems and generic issues.

The submission dates for assignments is firm unless you have a valid medical or personal reason. Certificates are required for medical reasons.

Submissions must reach the lecturer by 1700 on the due date and you must submit your submissions electronically either scanned or in pdf format. Neat handwritten solutions scanned in will be accepted.

4.2 Examination

This will be a 3 hr exam run by UCT.

5 Contact Information

You are encouraged to contact the lecturer with questions by email (dgray@eleceng.adelaide.edu.au) after the short course has finished. I will try to reply to email questions within two days. When replying to questions I may remove the identity of the student and broadcast both the question and answer to everyone.

Introduction to Radar– 3-7 February 2013 Lecture Timetable

Monday February 3 Hrs

0900-1030 **Introduction and Overview** 1.5

POMR Chapter 1

- Radar History
- Overview of radar principles
- Key physical attributes, Range, Doppler, Azimuth and Elevation
- Overview of types of radar systems

1030-1100 Morning tea break

1100-1230 **Radar Range Equation** 1.5

POMR Chapter 2.1 to 2.10, 2.15, 2.16

- Point target derivation
- System Noise
- SNR
- System Losses
- Search and Track implications

1230-1330 Lunch

1330-1500 **Radar Waveforms Part I** 1.5

POMR Chapter 8

- CW
- Single Pulse
- Pulse Doppler
- Coherent vs incoherent
- Range estimation and range ambiguities
- Ghosts
- Sensing Doppler frequencies – Doppler ambiguities

1500-1530 Afternoon tea break

1530-1700 **Tutorial and Demonstrations** 1.5

- Working through various problems and Matlab examples

Tuesday February 4

0900-1030 **Radar Waveforms Part II** 1.5

- POMR Chapter 20
- Pulse compression
- FMCW
- Phase coding
- Other waveforms eg, Passive radar, noise radar
- Ambiguity Function

1030-1100 Morning tea break

1100-1230 **Transmitters** 1.5

- POMR Chapters 10 and 12
- Waveform generation
- Power conversion
- Mixers
- Duplexors
- RF devices – magnetrons and travelling wavetubes
- Synchronisation and Timing Issues

1230-1330 Lunch

1330-1500 **Antennas and Phased Arrays** 1.5

- POMR Chapter 9
- Radiation patterns
- Beamwidth, sidelobes and gain
- Antennas
- Phased arrays

1500-1530 Afternoon tea break

1530-1700 **Tutorial and Demonstrations** 1.5

- Working through various problems and Matlab examples

Wednesday February 5

0900-1030 **Propagation and Scattering** 1.5

POMR Chapters 4,6 and 7

Propagation
Attenuation
Refraction, Diffraction, etc
Scattering
Radar cross-section
Target fluctuation

1030 -1100 Morning tea

1100-1230 **Clutter** 1.5

POMR Chapter 5

Surface and volume clutter
Airborne Radar and Clutter
Clutter and MTI

1230-1330 Lunch

1330-1500 **Radar Receivers RF aspects** 1.5

POMR Chapter 11

Preamplifiers
Down-conversion
Limiters
Noise Figures

1500-1530 Afternoon tea break

1530-1700 **Tutorial and Demonstrations** 1.5

Working through various problems and Matlab examples

Thursday Feb 6 Hrs

0900-1030 **Radar Signal Processing I** 1.5

POMR Chapters 14 and 17

Matched filters - general
Range processing
Doppler processing

1030-1100 Morning tea break

1100-1230 **Radar Signal Processing II** 1.5

POMR Chapter 9

Phase shift beamforming
Conventional beamforming
STAP

1230-1330 Lunch

1330-1500 **FMCW radars** 1.5

Doppler effect
FMCW/Pulse compression
FMCW
Ambiguities
Examples

1500-1530 Afternoon tea break

1530-1700 **Tutorial and Demonstrations** 1.5

Working through various problems and Matlab examples

Friday Feb 7

0900-1030 **Radar Detection Theory** 1.5

POMR Chapters 3.3,15 and 16.2

Detection Principles
Statistical Detection Theory
Pulse Envelope Detector
Integration
CFAR
Swerling Models

1030-1100 Morning tea

1100-1230 **Parameter Estimation and Tracking Radars** 1.5

POMR Chapters 18, 18.9, 9.5

Key basics of estimation theory
Range accuracy
Frequency estimation
Direction of arrival
Tracking radars – lobing and monopulse

1230-1330 Lunch

1330-1500 **Synthetic Aperture Radar** 1.5

POMR Chapter 21

Cross-range resolution
Synthetic aperture

1500-1530 Afternoon tea break

1530-1700 **Tutorial and Demonstrations** 1.5

Working through various problems and Matlab examples