Department of Electrical Engineering

Radar Remote Sensing Group

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EEE5105F FUNDAMENTALS OF RADAR SIGNAL PROCESSING

1 Prerequisites

This course requires students to have a good background in Mathematics, Physics, and computer programming, probably at an Honours Level (4 years of study). In addition, it is highly recommended that the student should have completed an introductory course in Radar Systems (such as EEE5104F/S), or have had practical exposure to radar systems in the work place, or as part of an undergraduate course in Radar Systems.

Students must be proficient in tools such as Octave, MathCad, Mathematica, Simulink/Matlab, spreadsheets (OpenOffice, Excel), as they are used extensively in the analysis and design examples. Students will use the tools most familiar to themselves.

2 Course Format and Dates

The course is given in a five day, intensive format, followed by a further four tutorial and seminar sessions over the weeks following the intensive session. These sessions are based on problem sets, which the student must attempt in order to gain benefit from the seminars. In addition, students may book appointments with the Course Convener and the Tutor.

The course Calendar is the governing document for planning: please monitor it frequently.

http://radarmasters.co.za/schedule/

Course interaction is via the UCT Vula System. You will have access to this information once you have registered for the course. It is important that you provide your preferred email address (one that it checked frequently) for your Vula registration.

3 Staff

Convener	Dr. Amit K Mishra	UCT	amit.mishra@uct.ac.za
Lecturer:	Dr. Amit K Mishra	UCT	amit.mishra@uct.ac.za
Tutor:	Gabriel Lellouch	UCT	gabriellellouch(a)yahoo.fr

4 Course description:

This course presents the principles and techniques fundamental to the operation of the signal processing found in a radar system. The course follows the recommended text book very closely. Specific course topics include:

4.1 Fundamentals for Radar Signals & Signal Processing

Radar range equation; RCS statistics; Data cube; Sampling and Quantisation; Review Fourier Analysis and the Z-Transform; Digital Filtering and Random Signals and signal integration; Correlation and Matched Filters

4.2 Threshold Detection of Radar Targets

Detections strategies and optimal detectors; Statistical models for noise and target RCS, threshold detection.

4.3 Constant False Alarm Rate Detectors

CFAR Detectors, including Cell Averaging; Robust CFAR and comparisons

4.4 Doppler Processing

Doppler and the Pulsed Radar; Moving Target Indication, pulse doppler; Clutter mapping, pulse pair processing

4.5 Radar Measurements

Radar signal model and accuracy of measurements; Parameter Estimation: Range; Parameter estimation: phase, doppler and range rate; RCS estimation and angle measurements, coordinate systems.

4.6 Radar Tracking Algorithms

Basic tracking, kinematic motion; Measurement models and radar track filtering; Measurement-to-track data association and track performance assessment.

4.7 Fundamentals of Pulse Compression Waveforms

Matched filters for pulse compression and range resolution; Straddle loss; Pulse compression waveforms, compression gain, LFM; Matched filter implementation, range sidelobe reduction

Ambiguity Functions and LFM Summary; Phase-coded waveforms, biphase; Polyphase codes, summary

4.8 Overview of Radar Imaging

General imaging considerations and resolution/sampling; Data collection and image formation.

Image phenomenology and summary

5 Learning outcomes:

Having successfully completed this course, students should be able to:

5.1 Knowledge Base:

- Understand the design and processing of signals to be able to execute the fundamental operation of radar to measure distance, angle, velocity, using a modulated carrier;
- Describe the key techniques for extracting moving targets from clutter;
- Be able to identify which kind of signal processing is best for a particular application;
- Understand the operation of basic imaging radar;
- Understand the basics of target tracking.

5.2 Engineering ability:

- Specify the properties of important signal processing blocks in a radar;
- Model radar signal processing using appropriate mathematical and computational techniques;
- Be able to gauge the amount of processing required to implement a radar signal processor.

5.3 Practical skills:

- Implement radar signal processing mathematically;
- Simulate all or part of a radar signal processor system using computer software;
- Predict performance of processing blocks using mathematics and / or simulation.

6 Textbook

"Principles of Modern Radar" Volume 1, Ed. Richards, Scheer and Holm, Scitech Publishing, 2010

"Fundamentals of Radar Signal Processing", Mark A. Richards, McGraw-Hill, New York, 2005

Lectures will be closely following the text-books. Both being by the same authors, are 99% identical. You can follow any one of them or any other classic RSP type book.

Slides will be uploaded on Vula.

7 Lecture Programme

Table 1: EEE5105F Fundamentals of Radar Signal Processing 2015 Programme (topics expanded below)

Time	18 May 2015	19 May 2015	20 May 2015	21 May 2015	22 May 2015
08h00	Overview	S7	S14	S18	S25
09h00	S1	S8	S15	S19	S26
10h00	S2	S9	S16	S20	S27
11h00	Tea	Tea	Tea	Tea	Tea
11h30	S3	S10	S17	S21	S28
12h30	Lunch	Lunch	Lunch	Lunch	Lunch
13h30	S4	S11	Break[1]	S22	S29
14h30	S5	S12	Break	S23	S30
15h30	S6	S13	Break	S24	Conclude
16h30	Tea	Tea	Break	Tea	
17h00	T1	T2	Break	T3	
18h00	Close	Close	Break	Close	

[1]It is likely that a visit to a radar installation will be organised during the afternoon.

Table 2: Descriptions of Topics

Code	Topics	Code	Topics
S1	Sampling and Quantisation	S16	Parameter estimation: phase, doppler and range rate.
S2	Review Fourier Analysis and the Z-Transform	S17	RCS estimation and angle measurements, coordinate systems.
S3	Digital Filtering and Random Signals and signal integration	S18	Basic tracking, kinematic motion.
S4	Correlation and Matched Filters	S19	Measurement models and radar track filtering.
S5	Detections strategies and optimal detectors	S20	Measurement-to-track data association and track performance assessment.
S6	Statistical models for noise and target RCS, threshold detection.	S21	Matched filters for pulse compression and range resolution.
S7	Overview Detection Theory and False Alarm, sensitivity	S22	Straddle loss
S8	CFAR Detectors, including Cell Averaging	S23	Pulse compression waveforms, compression gain, LFM
S9	Robust CFAR and comparisons	S24	Matched filter implementation, range sidelobe reduction
S10	Adaptive CFARS	S25	Ambiguity Functions and LFM Summary
S11	Doppler and the Pulsed Radar	S26	Phase-coded waveforms, biphase
S12	Moving Target Indication, pulse doppler	S27	Polyphase codes, summary
S13	Clutter mapping, pulse pair processing	S28	General imaging considerations and resolution/sampling
S14	Radar signal model and accuracy of measurements	S29	Data collection and image formation.
S15	Parameter Estimation: Range	S30	Image phenomenology and summary

8 Drill Problems, Simulation Assignments & Term Project

Students are expected to complete four sets of Drill Problems and five sets of simulation assignments, handed out after the intensive lecture period.

Drill Problems

Students will be provided with at least 4 sets of drill problems and 4 seminar opportunities of about an hour each with the lecturer, convener and tutors, and will be expected to attend 3 out of the 4 seminars. The student's solutions to the problem set must be submitted on Vula before the start of the seminar. The seminars will be carried out with access by Skype for students off campus after the lecture session. For bandwidth reasons, the number of parallel sessions will have to be limited. For example, all students resident in the same city will be expected to attend at a common venue, and students will have to organise their own venue and projection facilities. Screen sharing will be enabled, but it is unlikely that video will be supported, again due to bandwidth limitations. Within reason, and with prior arrangement, students can approach the tutor / and / or the lecturer for help with problem sets.

Assignments

Students will be given 5 simulation assignments. Assignment submission should consist of a report (preferably written using Latex or LYX) with the following components:

- problem statement
- approach or preliminary calculations
- results (with graphs or tables)
- discussion (if any) on the results
- appendix giving the code for the assignment (code should be
- properly commented and written in C/Matlab/Octave)
- strictly no plagiarism (plagiarism = no credit!)

Term Project

Term project will be a small piece of independent work to be carried out by individual students. Students are expected to choose an advanced topic in the field of Radar signal processing with consultation to the convenor and try to repeat the results shown in them. Project work will be evaluated based on a project report to be submitted by the student.

9 Course Assessment and Examination

The assessment of this course will be as per follows:

Item	Student hours needed (total = 200)	% of total marks
Start of the course assignment	15 (approximately 2 days)	5
Simulation based assignments	5x4 = 20	5x3=15
Term project	30	20
End of term examination (2 hour exam)	2 + 18 = 20	60

The examination is closed book, i.e. no notes may be brought into the examination venue. Students are not expected to memorise any formulas: all formulas and results will be supplied on the examination paper. Students may write the examination at their home location, provided satisfactory supervision of the examination can be arranged in good time.

10 Course Load

Class hours = 7x5 = 35 Hrs

Tutorial questions and revision = 4x7.5 = 30 Hrs

Total = 15 + 20 + 30 + 20 + 35 + 0 = 150 Hrs