Department of Electrical Engineering

Taught Masters in Radar and Electronic Deference

EEE5112F Radar Systems Modelling

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EEE5112F RADAR SYSTEMS MODELLING 2016

1 Course Description

A practical course which requires a sound knowledge of Radar Systems and Signal Processing, and teaches you how to use that knowledge to synthesise the design of a system to a requirement, but, also to be able to model alternative designs, and assess the suitability of such designs. This skill is essential when involved with the design of a sensor, or evaluating the usefulness of a sensor for specific applications. The approach taken is in two parts: firstly, we analyse an existing system, to predict and compare performance against advertised radar performance. This is followed followed by the design of improvements to the system, based on practicals and project work by the student. The system considered is just one example of the broad field of radar, i.e. Air Traffic Control radar, but the systems thinking is widely applicable.

2 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). Furthermore, the student should have completed courses in basic radar systems, as well as an introduction to radar signal processing (for example, the material of the *Principles of Modern Radar Volume 1*). The student will be introduced to many of the tools that can be used for radar system design, but time precludes an in-depth exposure to these.

3 Course Format and Dates

The course is given in a five day, intensive format, followed by 5 further tutorial and seminar sessions over the weeks following the intensive session. These sessions are forums to discuss the ongoing project work. 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.

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. You may have more than one Vula email address.

4 Staff

Convener	Assoc. Prof. D. O'Hagan		Daniel.OHagan(a)uct.ac.za
Lecturers:	Prof. M.R. Inggs	UCT	mikings(a)gmail.com
	Dr. Yunus Gaffar	UCT	yunus.abdulgaffar@uct.ac.za
	Doreen Agaba	UCT	doreen.agaba1@gmail.com
Tutor:	Pokai Cheng	UCT	pokai0519@gmail.com

5 Overview

5.1 L1 Introduction

Course overview, collection of pre-course assignment.

5.2 L2 Seminar

A randomly selected member of the class will give a 15 to 20 minute seminar based on the paper distributed for the assignment. This is followed by an open discussion by members of the class.

5.3 L3 What is Air Traffic Control?

What is the application area in which an air traffic control (ATC) sensor must operate? We view some short documentaries discussing the growth in global air traffic, and the needs of the ATC operators.

5.4 L4 The ATCR Family

We examine the family of radars described in the review paper, examining in more detail the precursors, the specifications, the technology used. What might we be able to contemplate in the new millenium?

5.5 L5 Blake's Analysis 1

Mostly about range prediction, taking into account: range equations, definitions, evaluation of range, minimum detectable SNR, System noise temperature.

5.6 L5 Blake's Analysis 2

Continuing the analysis: propagation, pattern factor, loss factors, blip / scan ratios, jamming and clutter. A systematic procedure for range prediction.

5.7 L7 Clutter

The origins, modelling methods, surface clutter, volume clutter, temporal characteristics of clutter.

5.8 L8 Targets

Definitions, modelling, motion, measuring.

5.9 L9 The ATCR Processing Chain

How does a magnetron radar achieve coherency (to measure targets with changing phase with time i.e. doppler)? Using the radar's beams against clutter. Retaining dynamic range, adaptivity.

5.10 L10 Moving Target Indicator

More about moving target indicators. IEEE definitions.

5.11 L11 Antennas

How do we determine the needs of the radar, what is achievable, how do we model antennas. Different types of radar technology.

5.12 L12 Reliability

How do we specify reliability? Can we model it while designing? Definitions.

5.13 L13 Basics of Pulse Doppler (YG)

The Doppler shift phenomenon and how this is measured by the radar. Mapping of measured Doppler shift to target radial velocity. Low, medium, high pulse repetition frequency (PRF) operation. Velocity resolution and ambiguity.

5.14 L14 Pulse Doppler Processing (YG)

Doppler processing gain in the radar range equation. What is Doppler filtering? Introduction to the range-Doppler map. What is the Doppler improvement factor. Effects of clutter ambiguity. Resolving range and Doppler ambiguities.

5.15 L15 Radar Front end constraints

An overview of the most important hardware subsystems in a pulse Doppler radar system. The effect that hardware imperfections have on the pulse Doppler radar is investigated. Systems level modelling and design of the radar front-end.

5.16 L16 Modelling the detection process

Detection techniques available to a pulse Doppler radar is presented along with the models used to predict radar detection performance.

5.17 L17 AREPS for Propagation Modelling

AREPS is a propagation modelling used by operational vessels of the US Navy. We demonstrate it as an example of what can be achieved with modelling.

5.18 L18 CARPET

This is a phenomenological model for radar systems.By this we mean that performance curves are the output data for the system, rather than signal level data.

5.19 L19 Bistatic Radar

When the transmitter and receiver are a large distance apart, we call this a bistatic system.

5.20 L20 NetRAD and its Database

NetRAD is an example of a monostatic and bistatic radar. We introduce its hardware and the large database of sea clutter and target measurements.

6 Learning outcomes:

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

6.1 Knowledge Base:

1. Understand the fundamental operation of radar to measure distance, angle, velocity using a modulated carrier;
2. Describe the key subsystems of a typical radar sensor;
3. Be able to identify signal and data processing suitable for extracting targets embedded in clutter;
4. Identify the key effects of the propagation medium on sensor performance and some countermeasures;
5. Describe the properties of targets and their fluctuations;

6.2 Engineering ability:

1. Explain in simple words the working principles and basic building blocks of a different types of radar system;
2. Model radar systems using appropriate mathematical techniques, including probability distributions, link power budgets, effects of clutter;
3. The role of simulators; the three ways: mathematics, measurements, simulations.
4. Have a top level understanding of important parameters relating to subsystems (antennas, amplifiers, transmitters, targets) to be able to design a radar system.
5. Formulate an approach to improve the performance of a system.

6.3 Practical skills:

1. Carry out top level designs and trade-offs of radar sensors, taking into account the important characteristics of the subsystems and other factors;
2. Simulate all or part of a radar system using computer software;
3. Calculate results of designs using programming techniques (languages or spreadsheets).

7 Textbook

The notes given during the course are overview in nature, and students are expected to have a copy of, "Principles of Modern Radar" Volume 1, Ed. Richards, Scheer and Holm, Scitech Publishing, 2010, or, similar.

8 Lecture Programme

Table 1: EEE5112F Radar System Modelling (topics expanded below)

Time	Jun 09	Jun 10	Jun 11	Jun 12	Jun 13
08h00	1.Introduction	5.Blake 1	9.ATCR Chain	13. Basics of Pulse Doppler	17. AREPS for propagation modelling.
09h00	2.Seminar	6.Blake 2	10.MTI Definitions	14. Pulse Doppler Processing	18. CARPET
10h00	Tea	Tea	Tea	Tea	Tea
10h30	3.ATC Needs	7.Clutter	11.Antenna	15. Radar Front end constraints	19. Bistatic Radar
11h30	4.ACTR Family	8.Targets	12.Reliability	16. Design Trade-offs in Pulse-Doppler radar and considerations	20. NetRAD and its database
12h30	Lunch	Lunch	Lunch	Lunch	Lunch
13h30	A. Calculations with SMathStudio	E. SARSIM2 introduction	Site visit	I. Introduction to FERS	M. Pulse compression of NetRAD.
14h30	B. Radar examples: NetRAD	F. NetRAD / ATCR33 simulation	Site visit	J. FERS demonstration	N. Comparison real data and simulation with NetRAD.
15h30	Tea	Tea	Tea	Tea	Tea
16h00	C. ATCR 33 examples	G. Export from SARSIM2	Site visit	K. SystemVue demonstration.	O. Project discussion
17h00	D. continued	H. Verification of SARSIM2	Site visit	L. Pulse Doppler radar in SystemVue	P. TBD
18h00	Close	Close	Break	Close	Close

9 Projects

9.1 Review of ATCR

The students have to read a background paper and make a presentation on the paper on the first day. All presentations will be reviewed, but only one student will presented. This counts 5% towards the assessment. All students shall hand in a presentation as part of the assessment.

9.2 Upgrade of ATCR 33R

Students will be set a design project, counting, in total, 35% of the course assessment. These projects are individual efforts, but students may (are encouraged to) work in groups. Each report is expected to cover all aspects of the design tasks being presented, in an insightful way i.e. if the student is using another person's work (clearly, fully acknowledged), it must be presented in a way that demonstrates complete understanding.

All reports must, on the cover, list the contributors. Formats for the cover sheets will be provided, including plagiarism statements, and complete list of references.

9.3 Progress Report 1 and Progress Report 2

The project report is split into two minor, progress submissions, aimed at assisting the student in the execution of the project as a whole, which will be, together, 5% of the course mark.

10 Course Assessment and Examination

The assessment of this course is based on a two hour, written examination (55%), and a class mark (45%) based on two reports (5% and 40%). The major project report is split into two preparatory reports (5% each) and 30% for the main report. The 2 hour 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 pertinent information will be supplied on the examination paper. Students may write the examination in their home location, provided satisfactory supervision of the examination can be arranged in good time.

11 Course Load

Item	Number	hrs/per	Hours
Lectures	24	0.75	18
Assimilation	24	1.5	36
Paper Review	8	3	24
Practicals	20	1	20
Seminar Attendance	5	1	5
Project Report	1	90	90
Examination preparation	1	8	8
Examination	1	2	2
TOTAL			203

12 Marks Allocations

Item	Marks
ATCR Review	5
Examination	55
Project	35
Progress 1	2.5
Progress 2	2.5
TOTAL	100

13 Versions

V1.0 First issue.

V1.1 Revisions to MRI practical work and Project sessions on the Friday.

V1.2 2016 first release.