Department of Electrical Engineering

Taught Masters in Radar and Electronic Deference

EEE5112F Radar Systems Modelling

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EEE5112F RADAR SYSTEMS MODELLING 2014

1 Course Description

A practical course which requires a sound knowledge of Radar Systems and Signal Processing, and teaches you how to used that knowledge to synthesise the design of a system to a requirement. 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 parameters, 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.

4 Staff

Convener	emProf B.J. Downing	UCT	Barry.Downing(a)uct.ac.za
Lecturers:	Prof. M.R. Inggs	UCT	mikings(a)gmail.com

	Kumaran Naicker	CSIR	KNaicker@csir.co.za
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Tutor:	Gabriel Lellouche	UCT	gabriel.lellouch@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

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

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 Principles of angle search and measurement in a surveillance radar

Scanning and coherent techniques for determining the angle of an object sensed by the radar. Measurement vs detection. Generic Measurement principles. Angle measurement accuracy analysis. Sources of angular measurement error. First order modelling of angular measurement for design.

5.16 L16 Range and Doppler Measurement uncertainties

Application of measurement processes to the modelling of range and Doppler measurement accuracy. Sources of range and Doppler measurement error.

5.17 L17 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.

5.18 L18 Modelling the detection process

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

5.19 L19 Design Trade-offs in Pulse-Doppler radar and considerations

System design trade-offs in a pulse-Doppler search radar design. A focus on some of the finer intricacies involved in pulse Doppler radar design. The lecture should leave the student with a view of the type of thinking required when attempting radar design, as opposed to radar analysis through the use of a design example.

5.20 L20 Introduction to System Engineering

A (short) introduction to the systems engineering approach is presented. Description of the system engineering process. The iterative nature of the process, which is often misunderstood. How to go from requirements, through requirement analysis to design, testing and verification. Levels of technology readiness.

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. Have a top level understanding of important parameters relating to subsystems (antennas, amplifiers, transmitters, targets) to be able to design a radar system.
4. 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

No notes are given for this course and all students are expected to have a copy of, “Principles of Modern Radar” Volume 1, Ed. Richards, Scheer and Holm, Scitech Publishing, 2010.

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. Radar Front end constraints
09h00	2.Seminar	6.Blake 2	10.MTI Definitions	14. Pulse Doppler Processing	18. Modelling the detection process
10h00	Tea	Tea	Tea	Tea	Tea
10h30	3.ATC Needs	7.Clutter	11.Antenna	15. Angle measurement in a surveillance radar	19. Design Trade-offs in Pulse-Doppler radar and considerations
11h30	4.ACTR Family	8.Targets	12.Reliability	16. Modelling measurement uncertainties	20. Short introduction to System Engineering
12h30	Lunch	Lunch	Lunch	Lunch	Lunch
13h30	A.Calculations	E.Data Flow	Site visit	I.Blake Chart	M. Course Project Definition
14h30	B.SARSIM	F.SystemVue	Site visit	J. Pulse Doppler	N. Guided session: Requirements analysis
15h30	Tea	Tea	Tea	Tea	Tea
16h00	C.ATCR 33	G.Radar Library	Site visit	K.AREPS	O. Guided session: Initial design I
17h00	D.Exporting	H. Experiments	Site visit	L.Site Select	P. Guided session: Initial design II
18h00	Close	Close	Break	Close	Close

9 Projects

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 present. This counts 5% towards the assessment.

Students will be set a design project, counting, in total, 40% 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.

The project report is split into two minor submissions, aimed at assisting the student in the execution of the project as a whole, which will count about 10% 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 (10% together) 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
Design Reports	1	90	90
Examination preparation	1	8	8
Examination	1	2	2
TOTAL			203

12 Versions for 2014

V1.0 First issue.