EEE5119Z INTRODUCTION TO RADAR

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). Many of the problems can be solved using a spreadsheet, since they are largely parametric studies. The treatment is at systems level, so the depth of knowledge of these fields can be corrected with some extra reading while working through the course.

2 Course Format and Dates

The course is given in a five day, intensive format, followed by a further five tutorial, seminar sessions over the weeks following the intensive session and an assignment related to system design. 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 is checked frequently) for your Vula registration.

3 Staff

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4 Course description:

This course presents the principles and techniques fundamental to the operation of a radar system. Radar Engineering is very much a system level topic, as the field requires at least some knowledge of a wide range of other engineering specialties. The course follows the recommended text book very closely. Specific course topics include:

4.1 Overview

Introduction and Radar Overview, covering the basic concepts of radar and the format of the course itself.
The Radar Equation, which allows us to estimate the performance of a radar system, and thus, to design radars for a specific purpose.
Radar search and overview of detection and interference, which improves our models of performance, to be used in design.

4.2 External Factors

Propagation Effects and Mechanisms investigates the influences of the atmosphere on the EM waves used in radar systems.
Clutter refers to unwanted signals from the surface of the earth (trees, buildings, and so on), as well as reflections from raindrops and other atmospheric targets in the radar beam.
Target Reflectivity is an overview of the properties of targets that makes them good or bad radar reflectors, also key to performance prediction.
Target Fluctuation Models predict the real behavior of scattering objects, whose aspect to the radar is changing, leading to fluctuations in the returned power, and hence, changes in radar performance.
Doppler Phenomenology and Data Acquisition discusses the apparent shift in target reflection wave frequency due to motion of the target or, the radar itself, as well as how this shift in frequency can be measured.

4.3 Subsystems

Radar Antennas are key in coupling radar energy to the propagating medium, and allowing for special responses that can be used to locate the target in angle.
Radar Transmitters are examples of microwave power engineering, and are essential for creating suitable waveforms for the radar, at a level sufficient to allow for detection of targets.
Radar Receivers are responsible for processing of received energy, without adding significant thermals noise and susceptibility to other EM signals. The energy is then presented for signal processing.
Radar Exciters are specialized hardware for creating radar waveforms and synchronizing the radar circuitry.
Radar Signal Processing is responsible for taking the radar signals from the receiver and processing them further to extract target information. This topic is taken up in much more detail in another course in this series.

4.4 Systems

A *tracking radar* performs its operational functions in a very specific way, requiring a few techniques different from surveillance radar.
FMCW radar systems exhibit specific design issues, having an impact on the selection of system parameters and on the performance.
A *case study of a radar system design* serves the understanding of the process of selecting subsystem parameters and their impact at system level.

4.5 Radar System Design assignment

A *laboratory assignment* shows that radar system design is an iterative process, where theoretical analyses and experimental verification provide justification for the choice of parameters and the robustness against real life conditions.

4.5 Software Expertise

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

5 Learning outcomes:

Having successfully completed this course, students should have learned the following skills:

5.1 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 which kind of radar sensor is best for a particular application;
4. Identify the key effects of the propagation medium on sensor performance and some countermeasures;
5. Describe the properties of targets and their fluctuations;

5.2 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;

5.3 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).

6 Textbook

Only copies of presentation material are available for this course through the Vula system; all students are expected to have a copy of the textbook "Principles of Modern Radar" Volume 1, Ed. Richards, Scheer and Holm, Scitech Publishing. A few extra readers will be made available through the Vula system complementing this textbook.

7 Lecture Program

The first day of lecturing will be Monday March 2nd , 2015.
The detailed schedule is:

Lecture nr	Subject
1	Structure of the course; definition of system design case study; video of real life radar PPI
2	Basic functional architecture of radar systems
3+4	Radar Range equation and Doppler effects
5	RCS and fluctuation models
6	Detection
7	Integration
8	Wrap up of first day
9+10+11	Clutter of land, sea and precipitation
12	Other false alarms
13	Recap of Fourier analysis
14+15+16	Antennas for radar
17+18	Receivers
19+20	FMCW radar
afternoon	Site visit[1]
21	Transmitters
22	Pulse Compression
23+24	Level diagrams showing SNR and interferences in subsequent stages down the signal flow
25	Propagation effects
26	Precision
27	Tracking radar
28	Track-while-Scan data processing
29+30+31	Detailed radar system design (case study)
32	Recent developments
33	Assignment issues

Half hour tea breaks are included in the schedule after the second morning lecture, and the second afternoon lecture, while a one hour lunch break is scheduled after the fourth morning lecture. Daily time of start will be 08h, while closing will be at 18h.

8 Drill Problems

Students will receive a set of practicing problems structured by lecture. Detailed solutions are included. Students are further expected to complete five sets of Drill Problems, handed out after the intensive lecture period. Students will be provided with at least 5 seminar opportunities of about an hour each with

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

the lecturer, convener and tutors, and will be expected to attend 4 out of the 5 seminars, and attendance is only credited if the solutions have been submitted. 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 organize 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.

9 Assignment

Students are expected to complete an assignment consisting of three tasks. The first two tasks let them evaluate a set of problems that are organized around the main themes of the course, using a computer based tool. The third task, the main one, concerns the evaluation of data acquired in real life campaigns in South Africa aimed at selecting the best set of parameters for a problem of detecting a target against a clutter background.

10 Course Assessment and Examination

The assessment of this course is based on a three hour, written examination and the report on the assignment, with the Duly Performed (DP) requirement of 4 out of 5 seminars attended. The examination is open book, i.e. notes, readers and the textbook may be brought into the examination venue.
Students may write the examination in their home location, provided satisfactory supervision of the examination can be arranged in good time.

11 Course Load

	number	hrs/per	hours	Rel. weight in final grade
Lectures	40	1	40	
assimilation	40	2	80	
seminar attendance	5	2	10	
Drill problems	5	2	10	0%
exam preparation	1	8	8	
exam (open book)	1	3	3	70%
Assignment				30%
Task 1 Guided problems	1	2	2	
Task 2 Open ended problems	1	2	2	
Task 3 Design task	1	50	50	
Total			**205**	