Department of Electrical Engineering
Radar Remote Sensing Group
Professor Michael Inggs

Private Bag X3, Rondebosch 7701, South Africa
Room 7.16, George Menzies Building, Upper Campus
Tel: +27 (0) 21 650 2799 Fax: +27 (0) 21 650 3465
E-mail: Michael.Inggs@uct.ac.za

EEE5108W MATHEMATICS FOR RADAR AND ELECTRONIC PROTECTION

1 Prerequisites

This course requires students to have a good background in Engineering Mathematics, probably at an Honours Level (4 years of study). The coursework consists of 'pencil and paper' problems, which will require a limited amount of numerical computation in some of their solutions; an acquaintance with Mathematica would be useful, but is not essential.

2 Course Format and Dates

The course is given in a ten day, intensive format, followed by a further XXXX 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.

https://sites.google.com/site/radarmasters/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	Prof. M.R. Inggs	UCT	mikings(a)gmail.com
Lecturer:	Dr. R.J.A. Tough	Igence Radar	robert.tough(a)igence.com
Tutor:	Roaldje Nasjiasnagar	UCT	neddje(a)gmail.com

4 Course description:

This course provides a useful mathematical toolkit for the Radar Engineer. Topics chosen for their relevance to radar performance calculation are reviewed and extended to the point where they make contact with the research literature; emphasis is on practical calculation and useful 'tricks of the trade' rather than mathematical rigour. The mathematical principles underpinning detection and estimation, clutter modelling and simulation and performance calculations will then be discussed, to illustrate the application of the methods developed in the earlier sessions. A detailed set of notes covering the course material is provided. Specific course topics include:

4.1 Preliminaries

Overview of the course and review of elementary material: the way ahead; functions of real and complex variables and differential and integral calculus.

Vectors, Matrices and Determinants: Vector and matrix algebra, linear equations, eigenvalues and eigenvectors and the description of rotations.

Calculus in several variables: vector calculus, complex analysis and the calculus of variations.

4.2 More advanced material

Integral Transforms: Fourier series; Fourier, Laplace and Mellin transforms; sampling and interpolation, the DFT and the FFT; radar imaging and Fourier analysis.

Some useful special functions: Nineteenth century 'higher mathematics' demystified and made useful, with help from Mathematica.

Probability, stochastic processes and information: Discrete and continuous random variables; probabilities and PDFs; the evolution and analysis of temporal and spatial correlation; covariance and power spectra; Bayes' theorem; a brief introduction to information theory.

4.3 Applications to radar modelling

Detection, Estimation and Feature enhancement: Probabilities of detection and false alarm; ROC curves; the binary decision problem, the Neyman Pearson criterion and likelihood ratios; generalised likelihood ratios; large scale feature enhancement in correlated data; matched filters in Gaussian and non-Gaussian noise.

Clutter modelling: Random walks and clutter models; non-Gaussian (NG) clutter and the compound model; the K distribution; fluctuating populations and NG statistics; other NG clutter models; estimation of clutter parameters; impact of NG clutter on 'peak pick' detection.

Simulation methods : generating independent random numbers with a prescribed PDF; correlated Gaussian processes: Langevin equations, IIR filters and Fourier synthesis; generation of correlated gamma quantities by MNLT; impact of MNLT on correlation; some examples.

Case studies: (i) Sequential estimation and Kalman filtering – underlying principles and illustrative simulations. (ii) A versatile radar performance model, incorporating target fluctuations, multiple looks, non-Gaussian clutter and incomplete de-correlation through frequency agility

4.4 Software Expertise

Students must be sufficiently proficient in tools such as Mathematica or Simulink/Matlab to be able to construct 'scratch' numerical code for some of the exercises; some experience of Mathematica's formal manipulation capabilities would be useful, but is not essential.

5 Learning outcomes

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

Understand calculus, linear algebra, special functions and probability theory at a level that enables them to access and make use of the radar research literature;

Carry through detailed calculations based on this material;

Be able to identify mathematical techniques most appropriate to the analysis of a particular application;

Design and implement simple simulations of radar clutter;

Develop realistic radar performance models.

6 Textbook

A detailed set of notes and solutions to the exercises are provided; useful supplementary material for the latter part of the course can be found in "Sea Clutter: Scattering, the K Distribution and Radar Performance", K.D. Ward, R.J.A. Tough and S. Watts, IET Publishing, 2006.

7 Lecture Programme

Table 1: EEE5108W Mathematics for Radar and Electronic Protection 2011 Programme (topics expanded below)

Time	Mon 7/3	Tues 8/3	Wed 9/3	Thurs 10/3	Fri 11/3
08h00	Introductions				
08h30	S1	S2	S3	S4	S5
11h00	Tea	Tea	Tea	Tea	Tea
11h30	S1	S2	S3	S4	S5
12h30	Lunch	Lunch	Close	Lunch	Lunch
13h30	S1 workshop	S2 workshop		S4 workshop	S3 & S5 workshop
16h30	Tea	Tea		Tea	Tea
17h00	Informal Q&A	Informal Q&A		Informal Q&A	Informal Q&A
18h00	Close	Close		Close	Close

Time	Mon 14/3	Tues 15/3	Wed 16/3	Thurs 17/3	Fri 18/3
08h30	S6	S7	S8	S9	S10
11h00	Tea	Tea	Tea	Tea	Tea
11h30	S6	S7	S8	S9	S10
12h30	Lunch	Lunch	Close	Lunch	Lunch
13h30	S6 workshop	S7 workshop		S9 workshop	S10 & S8 workshop
16h30	Tea	Tea		Tea	Tea
17h00	Informal Q&A	Informal Q&A		Informal Q&A	Informal Q&A
18h00	Close	Close		Close	Close

Table 2: Descriptions of Topics

Code	Topics	Code	Topics

S1	Differential and Integral Calculus	S7	Detection and Estimation
S2	Vectors, Matrices and Determinants	S8	Clutter modelling and the K distribution
S3	Calculus in several variables	S9	Numerical simulation of clutter
S4	Integral Transforms	S10	Case studies – Kalman filters and performance calculations
S5	Special Functions		
S6	Probability and Information theory		

The workshop sessions allow informal discussions of the presented material and provide practice in working together on problems and presenting results. The group breaks up into several subgroups, and attack selected examples from the exercises together and with input from the presenter. They then outline their solutions to the whole group, as preparation for the problems set as drill exercises. The informal Q&A sessions cater for any general issues arising and feedback.

8 Exercises

Students are expected to work through a selection of the exercises that accompany the course, with the aim of consolidating and extending their understanding of the material presented. Interaction and discussion with fellow attendees are encouraged, rather than solitary competitiveness. Each session will include a preliminary run through the exercises to highlight their salient features and provide some guidance in their solution. Model, though quite possibly sub-optimal, solutions of the exercises are provided to supplement the 5 seminar opportunities of about an hour each with the lecturer, convener and tutors; students 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 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.

9 Course Assessment and Examination

The assessment of this course is wholly dependent on a three hour, written examination, with the Duly Performed (DP) requirement of 4 out of 5 seminars attended. 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 in their home location, provided satisfactory supervision of the examination can be arranged in good time.

10 Course Load

Item	Number	hrs/per	Hours
Lectures	10	2.5	25
Assimilation	56	1	56
Seminar Attendance	5	2	10
Q&A Sessions	8	1	8
Class workshops	8	3	24
Drill Problems	5	10	50
Examination preparation	1	24	24
Examination	1	3	3
TOTAL			200