Department of Electrical Engineering
**Taught Masters in Radar and Electronic Defence**

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# EEE5121Z MICROWAVE COMPONENTS AND ANTENNAS

## 1 Prerequisites

The formal entry requirements are a South African 4 year bachelors degree or equivalent. A Science honours degree is acceptable with the appropriate subject content.

The course requires students to have a good background in Mathematics and Physics, the latter with an exposure to propagating electromagnetic waves. This course will provide some revision, but students may need to carry out extra reading. Students should also be familiar with the use of a computer to carry out calculations: the use of spreadsheets and a programming language is essential. Some packages may be introduced in the course.

## 2 Course Format and Dates

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

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

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|---|---|---|---|
| Convener | Associate Prof. D O'Hagan | UCT | danieloha@googlemail.com |
| Lecturers: | Associate Prof D O'Hagan | UCT | danieloha@googlemail.com |
| | Prof. B.J. Downing | UCT | barry.downing@uct.ac.za |
| Tutor: | Gabriel Lelouch | UCT | LLLGAB001@uct.ac.za |

## 4 Course description:

This course presents the technology underlying the implementation of the RF and Microwave parts of Radar Systems and Microwave Radio Systems. Although digital components and signal processing are very important for modern systems, high performance RF & Microwave Components and Antennas are key to overall system implementation. Specific course topics include:

### 4.1 Overview of Radar and Microwave Radio

Introduction, Radar, and Communications overview

*The Radar Range Equation*, which allows us to estimate the performance of a Radar System, and thus, to design Radars for a specific purpose.

*The Free Space Range Equation,* which highlights the fundamental difference between the system requirements for a Microwave Radio System versus the requirements for a Radar System

### 4.2 Circuits and Transmission Lines

*Revision of Transmission Line Theory and Circuits.* The majority of Radar Systems and Microwave Radio Systems operate in the microwave frequency range between 1GHz and 100 GHz. Lumped element passive devices such as resisters inductors and capacitors and interconnecting wires can also not be used. Transmission line circuits and special device packaging and techniques are required. It will be assumed that you have a basic understanding of transmission lines theory.

*Coaxial Microstrip and Waveguide Circuits.* There are many types of transmission line structures but the most common transmission lines used at microwave frequencies are coaxial, microstrip and waveguide transmission line circuits. The theory and different structures will be covered in this section of the course.

*Waveguide Circuits and waveguide modes* Two wire transmission lines are quite lossy at microwave frequencies and waveguides are more commonly used to interconnect waveguide components when the distances involve more than a metre or two. This section will describe the operation of rectangular and circular waveguides and waveguide modes.

### 4.3 Microwave Oscillators

*Solid State Oscillators operation and design* including Gunn, Impatt and FET Oscillators are covered in this section. The power limitations are discussed and the design and operation of a Magnetron explained.

### 4.4 Microwave Amplifiers

*Power Amplifiers and Low Noise Amplifiers* This section covers the design and operation of Power Amplifiers and Low Noise Amplifiers with particular emphasis on GaAs MESFET's. The frequency and power limitations for use in both Radar Systems and Microwave Radio systems is discussed. The design and operation of Travelling Wave Tube amplifiers is discussed.

### 4.5 PIN Diodes in Switches and Limiters

*PIN diodes* are used to electronically switch power propagating along a transmission line by connecting the diode in series or parallel in a transmission line. Improved isolation is achieved by connecting several diodes in series and in parallel. Several PIN diode circuits will be described and analysed. PIN diode circuits which produce a phase shift usually consist of a combination of a PIN diode switch and propagation delay from a length of transmission line.

### 4.6 Mixers and Receivers

*Noise in receivers* plays a large part in determining the range performance of a Radar or Microwave Radio System. The effect of bandwidth, antenna gain and other critical components of a Microwave receiver will be considered in some detail. The effect of added noise introduced by amplifier stages and mixers will be dealt with. Different types of mixers and mixer circuits will be considered including single ended mixers and balanced mixers.

### 4.7 Antennas

All wireless EM transmission/reception systems necessarily require antennas of some description. This part of the course focuses on developing a solid appreciation of the function of antennas. A detailed analysis of the ubiquitous dipole antenna will be provided, which will be used as a basis from which to develop a profile of the salient characteristics of antennas in general (such as directivity, efficiency, gain, radiation resistance, etc.). Upon establishment of the basics, the course will consider the operation of some commonly used antenna elements for radar, EW and communications applications. Elements under consideration include horn antennas and parabolic reflectors. From single-element characterisation, the course then progresses to analyse the basics of antenna arrays for typical radar and EW requirements. The final section of the course involves a lesson in phased array antennas, which when deployed on combat-aircraft, are generally known as ESAs. The section on phased arrays and ESAs will examine passive and active implementations and the merits thereof. Enabling technologies for ESAs will be discussed such as advances in semi-conductors and high-speed digital processing.

Upon completion of this course student will be converse in the important parameters of antenna systems. They will have strong appreciation of the important properties of antennas and will be familiar with antenna systems, whether single elements or array configurations, implemented in many radar and EW systems.

## 5 Learning outcomes:

Having successfully completed this course, the student will have:

### 5.1 Knowledge Base:

1. Understand EM wave propagation in guiding structures used to implement distributed RF and Microwave components;
2. Understand the use of modern solid state devices and circuits in Microwave Radio systems and Radars systems and the use of high power valve devices for long range Radar Systems.
3. Understand the range restrictions introduced by noise generated in receivers;
4. Understand the important parameters of antennas.
5. Familiarity of antenna systems as implemented in many advanced radar and EW systems.

### 5.2 Engineering ability:

1. Explain in simple words the working principles and basic RF and Microwave building blocks of different types of Microwave Radio and Radar systems;
2. Be able to identify the best RF and Microwave technology to implement a Microwave Radio and Radar architecture;
3. Have a high level of understanding of important parameters relating to subsystems to be able to design a Microwave Radio and Radar system with a given performance.

### 5.3 Practical skills:

Carry out high level designs and trade-offs of RF and Microwaves devices, taking into account the important characteristics of the subsystems and other factors;

## 6 Textbook

"Microwave Engineering," Pozar,

"Antennas," 2nd Edition, J. D. Kraus,

"Introduction to Airborne Radar," 2nd Edition, G. W. Stimson

## 7 Lecture Schedule

| Time | Mon 14th July | Tue 15th July | Wed 16th July | Thu 17th July | Fri 18th July |
|---|---|---|---|---|---|
| **08h00** | Overview | Gunn Oscillators | Noise in Receivers | Dipoles and folded dipoles | Revision of the topics covered |
| **09h00** | Revision of Transmission line theory | Gunn Oscillators | Noise in Receivers & Mixers | Horns and parabolic reflectors | Introduction to phased array antennas |
| **10h00** | Transmission line Theory | Tutorial | Tutorial | Tutorial | Tutorial |
| **11h00** | Tea | Tea | Tea | Tea | Tea |
| **11h30** | Tutorial | Other Oscillators | Mixers | Introducing array antennas | Enabling technologies |
| **12h30** | Lunch | Lunch | Lunch | Lunch | Lunch |
| **13h30** | Waveguides | Amplifiers | **Antennas -** Introduction | Array theory | Common functions of phased array radars |
| **14h30** | Waveguides | Amplifiers & PIN Diodes | Developing characteristics | Beamforming concepts | Assessing antenna systems on common radar platforms |
| **15h30** | Tutorial | Tutorial | Tutorial | Tutorial | Tutorial |

Students are 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 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 organise their own venue and projection facilities. Within reason, and with prior arrangement, students can approach the tutor / and / or the lecturer for help with problem sets.

## 8 Course Assessment and Examination

The assessment of this course is based on a three hour, written examination, as well as the Duly Performed (DP) requirement of 4 out of 5 seminars attended. Tutorial material will be marked and count 20% of the course mark.

The examination is closed book. Students may write the examination in their home location, provided satisfactory supervision of the examination can be arranged in good time.

## 9 Course Load

| Item | Number | hrs/per | Hours |
|---|---|---|---|
| Lectures | 40 | 1 | 40 |
| Assimilation | 40 | 2 | 80 |
| Seminar Attendance | 5 | 2 | 10 |
| Drill Problems | 5 | 12 | 60 |
| Examination preparation | 1 | 8 | 8 |
| Examination | 1 | 3 | 3 |
| TOTAL | | | 201 |