UNIVERSITY OF CAPE TOWN
IYUNIVESITHI YASEKAPA • UNIVERSITEIT VAN KAAPSTAD

Introduction to Electronic Defence EEE5120Z

P. F. Potgieter and J. D. Vlok

January 30, 2014

Contents

1 Introduction

Electronic Defence (ED) is a military action whose ultimate aim is to control the electromagnetic spectrum (EMS). The objective is to exploit, reduce or prevent hostile use of the EMS while still retaining friendly use thereof. ED comprises of three main disciplines, which have found numerous electromagnetic (radio frequency (RF), optical etc.) as well as acoustic civilian and military applications.

1. Electronic Support (ES), previously known as Electronic Support Measures (ESM).
2. Electronic Attack (EA), previously known as Electronic Countermeasures (ECM).
3. Electronic Protection (EP), previously known as Electronic Counter-Countermeasures (ECCM).

These disciplines are shown in Figure 1 and are described in detail in subsequent study themes.

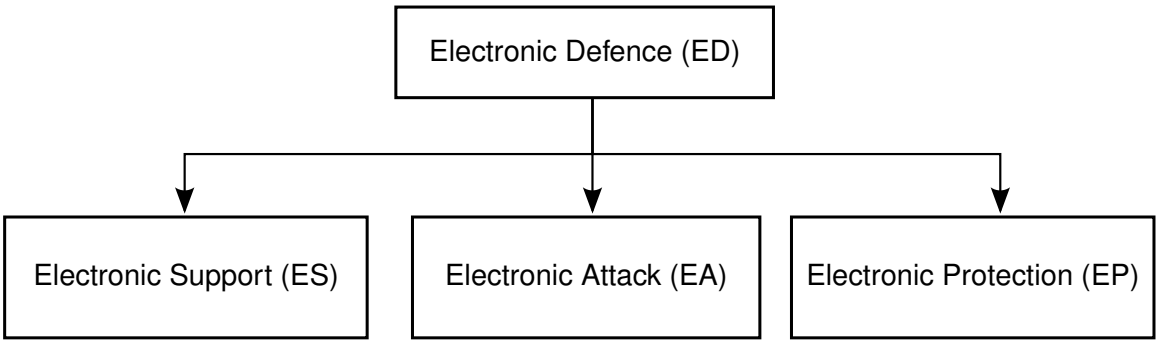

Figure 1: Breakdown of the main Electronic Defence disciplines.

2 Lecturer Information

Lecturer:	Mr P. F. Potgieter	Mr J. D. Vlok
Office:	Building 44, Room B404 CSIR Main Campus Brummeria, Pretoria	Building 44, Room B406 CSIR Main Campus Brummeria, Pretoria
Telephone:	+27 (12) 841-3151	+27 (12) 841-2488
E-mail address:	pfpotgieter@csir.co.za	jvlok@csir.co.za
Consulting hours:	By appointment. The preferred method of contact is via e-mail.	

Secretary:	Miss Jessica Mtileni
Telephone:	+27 (12) 841-2822
Fax number:	+27 (12) 841-2455
E-mail address:	jmtileni@csir.co.za

3 Course Objectives and Study Themes

The course aims to introduce the student to RF Electronic Defence. A good prior knowledge on the topics of digital signal processing, electromagnetics, mathematics and statistics is highly recommended for this course. A good knowledge on subjects of radar and communications is also required. Students should be competent in using scientific programming languages such as Matlab or Octave.

Students have to master fundamental concepts in Electronic Defence on a high-level (identification of tactics and applications) as well as on a detail level (the design of a suitable detector to required specifications). Students are required to link theoretical concepts in Electronic Defence to typical applications and to solve problems of an engineering nature.

3.1 Theme 1: The History of Electronic Defence

Ever since long distance radio transmission was invented by Guglielmo Marconi, the potential to communicate and sense influenced the way militaries and societies function. Alongside this work, Heinrich Hertz showed that radio waves reflected off metallic objects, but it wasn't until the early 1930's when many nations independently developed their own versions of radar. Radar presented nations with a great tactical advantage and the countering thereof gave rise to what is now referred to as Electronic Defence.

Theme objective: To review how the developments in radar gave rise to Electronic Defence and how critical conflicts such as World War II, the Six-Day war and the first Gulf war shaped this kind of defence.

Study material: Lecture material, literature supplements, history texts and internet references.

Theme outcomes: The student should be able to identify the approach, techniques and mechanisms developed at each point in history that counteracted the capabilities of radar or communications.

3.2 Theme 2: Overview of Electronic Defence

Since the early days, Electronic Defence has developed into such a critical capability that it has become a subject of study on its own. It has found applications in many domains such as communications, electro optics, acoustics and cyber. The key to successful Electronic Defence is an intimate knowledge of the *target*, whether it be radar or infra-red (IR) missile seekers.

Theme objective: Given the historical developments of advanced sensors, the student will be exposed to the formal definition of Electronic Defence and the three main disciplines thereof. After a brief review of relevant radar and communication concepts, students will learn about the application of ED.

Study material: The prescribed textbook, lecture material as well as literature supplements.

Theme outcomes: The student should be able to recognise and apply any of the main Electronic Defence principles to case studies. Case studies are typically formulated in a setting where radar and/or communications are exploited for a given objective.

3.3 Theme 3: Electronic Support

Practically every Electronic Defence operation starts by performing ES. It provides the necessary information, description and intelligence to enable (or support) effective ED. ES is defined as *the search for, the interception, the location and the classification of sources of intentional and unintentional radiated EM energy*. The detection of low probability of intercept (LPI) emissions is very valuable. In turn the accurate estimation of emitter parameters would enable successful exploitation (via EA) or avoidance (via EP) thereof.

Theme objective: The student will learn about the various approaches to ES against radar and communications systems. Here, the technical details and capabilities are presented that make each approach unique. LPI radar will be a case study and search, detection, location and classification principles will be applied.

Study material: The prescribed textbook, lecture material as well literature supplements.

Theme outcomes: The student should have an understanding of ES and be able to analyse emitter detectability and design (in concept) a suitable ES solution in a given scenario.

3.4 Theme 4: Electronic Attack

Electronic Attack deals with the deliberate actions taken to radiate or reflect EM energy in order to disable or degrade the EMS to enemy capabilities. EA comprises of impairing, disrupting and deceiving enemy sensors (or assets) to gain control in a given scenario. A typical EA case would be an aircraft having to create phase front distortion towards a tracking radar in order to break its track. There are many different methods in EA. Commonly referred to as jamming, spoofing and deception jamming. EA may be categorised further into, active radiation of EM energy, passive EA (for example, chaff and passive decoys) and the reduction of radar observations of targets.

Theme objective: The student will learn about the various EA techniques and the radar or communications components that are targeted. Here, the technical details of EA are presented. Both radar and communication jamming will be cases of study.

Study material: The prescribed textbook, lecture material as well as literature supplements.

Theme outcomes: The student should have an understanding of EA and be able to analyse jamming effectiveness and design (in concept) a suitable EA solution in a given scenario.

3.5 Theme 5: Electronic Protection

Actions taken to protect facilities and equipment from any effects of friendly or enemy EA is commonly referred to as Electronic Protection. Many designers of radar and communication systems regularly make use of EP. The following strategies are regarded as *protecting* facilities against EA:

1. Overpowering of reactive jammers.
2. Intelligent signal design to reduce jamming effectiveness.
3. Preventing receiver overload.

4. Radar versus jamming signal discrimination.

5. Avoiding jamming signals altogether.

Examples of EP are emissions control and communication security. By controlling where, when, how often and on which frequency you are transmitting the would-be jammer will find it difficult to meet all the conditions for effective EA. Furthermore, securing transmitted data using encryption protects the content of data even if it is intercepted.

Theme objective: The student will learn about the various aspects of EP. Here, the technical details of EP are presented.

Study material: The prescribed textbook, lecture material as well as literature supplements.

Theme outcome: The student should have an understanding of EP and its relevance in radar and communication system design.

4 Prescribed Text and Relevant Material

The prescribed text book will be used as a guideline, with reference to many other sources during the course. The prescribed book for this course and a short description thereof follows,

D. Curtis Schleher, *Electronic Warfare in the Information Age*, Artech House, 1999, ISBN 9780890065266.

This book is an advanced guide through the concepts and threats associated with modern ED. It identifies and explains relevant radar and communications threats, and provides ED and radar engineers, managers, and technical professionals with practical, “how-to“ information on designing and implementing EA and EP systems.

4.1 Relevant Material

The following text provides useful reference information that would supplement the content presented during lectures as well as the prescribed textbook. An electronic copy of this book will be made available on the course website.

Naval Air Systems Command, 1999, *Electronic Warfare and Radar Systems Engineering Handbook*.

Other supplementary textbooks:

Flippo Neri, *Introduction to Electronic Defense Systems*, 2nd Edition, SciTech Publishing, 2006, ISBN 9781891121494.

David Adamy, *Introduction to Electronic Warfare Modeling and Simulation*, SciTech Publishing, 2006, ISBN 9781891121623.

5 Recommended Approach

It is strongly advised to interact and participate during the lecture week, as it provides the only opportunity for face-to-face contact time. The lecture material, practicals, assignments and the exam may be discussed during that week. Any interaction after the lecture week will be dealt with via e-mail.

6 Assessment

6.1 Grading Policy

This course is worth **20** credits toward the degree requirements for the Radar Masters Programme. The final mark for EEE5120Z will consist of a combined mark as follows.

- The combined score for both assignments will count 20% toward the final mark.
- The project will count 50% toward the final mark. The course project is the knowledge application part of the examination. It will be assessed externally along with the written exam paper. The project is defined in Section 6.4 and students are advised to spend time throughout the semester to ensure a comprehensive submission.
- The written examination will count 30% toward the final mark. The written exam will also be assessed externally as the theoretical part of the examination.

6.2 Marking Guidelines

As a general guideline, each assessment component (assignments and exam) will be evaluated based on the following levels (or corresponding marks) of grading:

0–Severely Deficient (Essentially no attempt was made). There was nothing useful to evaluate and no marks could therefore be awarded.

1–Poor (An attempt was made but mostly incorrect). Methodology, answers, results and/or implementations are mostly incorrect, superficial and have critical errors or problems. The answer shows little or no understanding and depth of the material. Presentation has fundamental problems in terms of structure, number of errors and technical quality.

2–Fair (An attempt was made but contains many errors, with a minimal level of description). Methodology, answers, results and/or implementations are basically correct but have major errors or problems, or have limited depth. The answer shows a basic understanding of the material but limited depth. Presentation meets minimum standards but has significant problems in terms of structure, errors and technical quality.

3–Average (A basic attempt was made with some errors, and a basic level of description). Methodology, answers, results and/or implementations are mainly correct but have moderate errors and detail, or are suboptimal. The answer shows moderate depth and understanding of the material. Presentation is generally good but has minor problems in terms of structure, errors and technical quality.

4–Good (A complete and correct attempt together with sufficient level of description). Methodology, answers, results and/or implementations are mainly correct and detailed but have minor errors, or are not optimal. The answer shows a very good depth and understanding of the material. Presentation is mostly well-structured and error free, and of good technical quality.

5–Excellent (A comprehensive and detailed submission). Answers and results are correct and detailed, as is the working and methodology used to obtain them. The answer shows an excellent, deep and synthesised understanding of the material. A degree of critical analysis is evident and alternatives have been explored. Additional research has been done (as appropriate) and references have been provided. The implementations are flexible and modular facilitating application on new problems. The material is well-structured, error free and of high technical quality.

6.3 Assignments

There are two (2) assignments scheduled for this course. Each assignment will be due at 13:00 on the day specified in the course schedule. Assignments must be submitted electronically and must be self contained in a single document, unless specified otherwise. The combined score for both assignments will count 20% toward the final mark.

6.3.1 Late Assignments

Any assignment submitted late will be penalised as follows:

- A maximum mark of 65% can be obtained for assignments up to one (1) day late.
- A maximum mark of 50% can be obtained for assignments up to two (2) days late.
- A maximum mark of 40% can be obtained for assignments up to three (3) days late.
- Any assignment handed in later than three (3) days after the deadline will not be accepted for marking and will result in a zero mark.

6.3.2 Declaration of Originality

Plagiarism is considered a serious offence by the University of Cape Town. Whenever you do written work you must differentiate between your own ideas and those (which you did not think of yourself) but which you have read elsewhere. You must distinguish what you have written from what you are quoting in your submission. The University of Cape Town requires that all material submitted, including assignment answers to be accompanied by a signed Declaration of Originality. The first page of any submitted material must be a title-page. The second page must be the signed declaration. A template of the declaration is provided in Appendix A. **NOTE: No assignments will be accepted for marking without a signed declaration**.

Students may choose their own convention of attribution and acknowledgement in written work. The preferred style of referencing for engineers is that of the Institute of Electrical

and Electronics Engineers (IEEE), for more information students may consult the IEEE Style Manual.

For more information on plagiarism and the University's policy, students are encouraged to familiarise themselves with guidelines to avoiding plagiarism at the following link. The **Library Staff**, the **Writing Centre** and the **Centre for Information Literacy** are willing to assist students, by providing details of referencing conventions, and help in using them.

6.3.3 Assignment 1

This assignment will cover introductory concepts in Electronic Defence from significant historical events. Do a literature survey on the following two events in history:

1. The invasion of Normandy during World War II.
2. Operation Desert Storm.

Identify the disciplines (or the actions) of ED in each of the two events. Be sure to point out the type of intelligence associated with each element. Students are encouraged to make use of web sources as well as textbook literature.

6.3.4 Assignment 2

This assignment will cover the EA and EP study themes. It will be introduced and discussed during the lecture week.

6.3.5 Assignment Formatting

- An electronic copy of the assignment submission must be compiled in the portable document format (pdf).
- Use the IEEE article style with a single column and 11 pt font size.
- The main body of the assignment may not exceed 5 pages.
- Include a list of references when consulting other sources of information or when substantiating any claims.
- The assignment submission must be accompanied with a signed declaration of originality.

6.4 Project

The project is the knowledge application part of the course examination. It will count 50% toward the final mark. Students are required to submit a paper and electronic copy of their project report on the day of the written exam. There will be no extensions for project report submissions.

6.4.1 Project Brief

Design an ES receiver to intercept a surface based navigation radar. The receiver must have the following characteristics:

- Detecting the presence of the radar signal.
- Finding the direction of origin of the radar signal.
- Estimate at least three (3) other radar signal parameters.
- Operate in the S-Band (3.5 to 4 GHz) of frequencies.
- Achieve 100% Probability of Intercept (POI).
- Detect the radar at a range of 20 nmi at least 80% of the time.
- Have angular resolution of 5°.

Assume that information on the navigation radar waveform(s) is unknown. However, it does have a directional scanning antenna with the following specifications:

Antenna beamwidth	2° (azimuth) and 28° (elevation)
Antenna gain (main beam)	30 dB
Antenna sidelobe level	0 dB
Antenna scan rate	20 rpm
Transmitter output power	25 W

The design must include:

- A description of the system operating concept(s).
- A system functional flow diagram.
- Clear motivations for your design decisions.
- Any additional assumptions made if any.
- Performance calculations of critical signal processing functions (such as estimation accuracy) and other system characteristics (such as sensitivity).

6.4.2 Project Report Formatting

- The electronic copy must be compiled in the portable document format (pdf).
- Use the IEEE article style with a single column and 11 pt font size.
- The main body of the report may not exceed 25 pages.
- The project report must be accompanied with a signed declaration of originality.
- The report must contain the following sections; introduction, system design, assumptions, analysis, results (interpretation), conclusions and references.

6.5 Written Exam

This exam will test the student on every study theme in the course. It is a two (2) hour closed-book written exam and will comprise of theory and basic problems. The score for the written will count 30% toward the final mark. Arrangements regarding the venue will be communicated during the course of the semester.

7 Course Schedule 2014

Date	Event
7 to 11 April	Thematic lectures and contact time
7 April	Assignment 1: History and introductory concepts
18 April	Assignment 2: Electronic Attack/Protection
6 June[a]	Project report
13 June[a]	Exam (on all study themes)

[a] This is a preliminary date.

Lectures will be held in the L6 Seminar Room, Level 6, George Menzies building, Library Road, Upper Campus. Practical sessions will be held in the Blue Lab.

7.1 Lecture Programme

Refer to Table 1 for daily lecture topics and programme.

Table 1: Daily course programme.

Time	Monday 7 April	Tuesday 8 April	Wednesday 9 April	Thursday 10 April	Friday 11 April
08h00	Welcome and Course Overview	Theme 3: ES Introduction	ED in Communications	Theme 4: EA Introduction	Theme 5: EP Introduction
09h00	Theme 1: History of ED	Emitter Search and Detection	ED in Communications	Expendables and Decoys	Sidelobe Blanking and Cancellation
10h00	History of ED	Emitter Location and Classification	ED in Communications	EA Techniques	RCS Reduction and Stealth
11h00	**Tea**				
11h30	Theme 2: ED Overview	Signal Deinterleaving and LPI Intercept	Communications ED Practical	Cross-eye Jamming and Directed Energy	EP for Search and Tracking radar
12h00	Overview of ED	Receiver Architectures	Conclusion of Theme 3	EA System Architectures	Conclusion of Theme 5 and Assignment 2
12h30	**Lunch**				
13h30	ED Fundamentals	ES Practical	Communications ED Practical	EA Practical	Course Conclusion
14h30	ED Fundamentals	ES Practical	Communications ED Practical	EA Practical	Course Assessment and Exam Briefing
15h30	ED Fundamentals	ES Practical	Communications ED Practical	EA Practical	
16h00	Conclusion of Themes 1 & 2 and Assignment 1	ES Practical	Communications ED Practical	Conclusion of Theme 4	
17h00	**Close**				

A Declaration of Originality Template

DECLARATION OF ORIGINALITY

UNIVERSITY OF CAPE TOWN

INTRODUCTION TO ELECTRONIC DEFENCE
EEE5120Z

Declaration

1. I know that plagiarism is wrong. Plagiarism is to use another's work and pretend that it is one's own.
2. I have used the _____ convention for citation and referencing. Each contribution to, and quotation in, this assignment/report/_____ from the work(s) of other people has been attributed, and has been cited and referenced.
3. This assignment/report/_____ is my own work.
4. I have not allowed, and will not allow, anyone to copy my work with the intention of passing it off as his or her own work.
5. I acknowledge that copying someone else's assignment or report, or part of it, is wrong, and declare that this is my own work.

Student Name: _____

Signature: _____ **Date:** _____