University of Cape Town
Department of Electrical Engineering
Radar Masters Programme

EEE5120Z Introduction to Electronic Defence

September, 2017

Lecturer: Rodolfo Lima, D.Sc. – Brazilian Navy Research Institute – Brazil

Content

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1 Introduction

The exploitation of the electromagnetic spectrum (EMS) brought significant change to the world over the past decades. The rapid growth of electronic technologies and the fast growing applications in communications, sensing (including radar) and intelligence led the increasingly important utilization of the EMS. Similarly, this same revolution played (and plays) a significant role is shaping military organizational structures worldwide. Nowadays, Electronic Defence represents an important scientific discipline; it has become a serious field with numerous applications and will play an increasingly greater role in future conflicts.

One can find several definitions for Electronic Defence in the literature. Although these can differ in some ways, they all share the same core aspects. A basic or simple way to look at ED is to understand that its objectives are to ensure the full use of the electromagnetic (EM) spectrum for friendly forces and to deny, reduce or prevent its use by the opponents. Despite the civilian applications, it's usually a military discipline. ED consists of measures, activities and systems to fulfil these objectives. Electronic Defence is generally divided into three main disciplines: Electronic Support (ES), Electronic Attack (EA) and Electronic Protection (EP).

Among the Intelligence-Gathering disciplines, Signal Intelligence (SIGINT) is directly connected with ED. SIGINT is regarded as intelligence gathering from electronic signals and systems, such as communications systems, radars, and weapons systems. Under this optics, SIGINT consists mainly of Communications Intelligence (COMINT) – regarding communications signals – and Electronic Intelligence (ELINT) – regarding non-communications signals, here mainly radar signals.

The course will assess the fundamentals of Electronic Defence, focusing on radar applications.

After a brief historical overview, and introduction to ED, the class will step into Electronic Support, Attack and Protection – measures, activities, techniques and systems. Then some important aspects of ELINT will be briefly studied. Once having covered all these disciplines from the radar applications standpoint, the attention is then directed to communications ED, focusing in the EM communication channel (rather than COMINT). Finally, the application of Electronic Counter Measures against FM-based Passive Coherent Location (PCL) Radars will be addressed.

Throughout the course, emphasis will be given to the understanding of the concepts involved, with a glimpse on operational aspects to substantiate the learning process. Auxiliary math will be provided to consolidate these concepts. Practical sessions will support the learning process.

2 Lecturer Information

Lecturer: Rodolfo Lima, D.Sc.
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Lecturer background:

Dr. Lima has been a Researcher for the Brazilian Navy for more than 7 years and previously worked for 12 years in academia, as a Research Engineer at the Pontifical Catholic University of Rio de Janeiro (PUC-Rio). His main field of activity in Electronic Defence is microwave systems.

Graduated in Electrical Engineering, specialized in Electronics and Telecommunications, at PUC-Rio in 1994, where he achieved his M.Sc. Degree in Electrical Engineering in 1996, in the field of Applied Electromagnetism: Microwave and Optical Communications. Worked as a Research Engineer in the Center for Telecommunications Studies (CETUC) at PUC-Rio from 1996 to 2006, where he engaged in the D.Sc. Program, achieving his D.Sc. Degree in Electrical Engineering in 2008, also in the field of Applied Electromagnetism, Microwaves. In 2010 joined the Electronic Warfare and Radar Systems Group at the Brazilian Navy Research Institute (IPqM), where he works now as Associate Researcher.

Topics assessed in past activities: Electronic Defence Systems – architecture, development, evaluation; Radar ESM - Electronic Support Measures; microwave circuits, components and systems; microwave

measurement techniques; optical telecommunications components and systems, optical networks; data acquisition and automation; programming and simulation; 3D EM simulation.

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Course Convenor and lecturer for the PCL topic: Assoc. Prof. Daniel O'Hagan, Ph.D.
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3 Themes

- History of Electronic Defence

Electronic Defence actions can be traced back in history long before radar was invented or the concepts of ED were formally created. The development of technology is one of the factors that continuously shape the unfolding of international conflicts.

Looking back in history, significant events will be reviewed outlining the rise of ED and its historical developments. The invention of radar represented a tactical breakthrough and Electronic Defence emerged as its counteraction. The struggle between radar technologies and ED implies that the invention of new sensors and other systems simultaneously facilitates the creation of other systems for offsetting their threat.

- Overview of Electronic Defence – ED

Electronic Defence has developed into a scientific discipline and includes three main subdivisions: Electronic Support (ES), Electronic Attack (EA) and Electronic Protection (EP).

General aspects will be presented, including ED measures, activities and systems, along with some formal definitions, and then a taxonomy of ED will be proposed. This first overview will prepare the students to further understand each of the following themes, given the strong relation between them.

- Electronic Support – ES

ES is defined as the search for, the interception, the location and the classification of sources of intentional and unintentional radiated EM energy. It is the basis for most ED, since it is the discipline responsible for providing EMS information to all ED: tactical measures, activities, intelligence and even the development of new ED systems.

The students will be exposed to the basics of ES applications. System architectures, search, interception, location, deinterleaving and classification techniques will be presented. Later on, emitter evaluation and ELINT techniques will also be discussed.

- Electronic Attack – EA

EA is the part of ED related to its objective of denying the use of the EMS to the opponent, by means of degrading, neutralizing or destroying the opponent's electronic capability. This includes the old Electronic Counter Measures, ECM (jamming, chaff, and flares), but also includes anti-radiation weapons and directed-energy. The course will focus on ECM and the employment of EM energy to achieve EA "soft kill" objectives.

The students will be exposed to the basics of EA applications. System architectures, decoys and EA techniques will be presented

- Electronic Protection – EP

EP implies any action or technology employed to protect friendly use of the EMS. This comprises any effect of intentional or unintentional, friendly or adversary use of the electromagnetic spectrum that could degrade, neutralize, or destroy friendly electronic capability. EP is usually related to protecting friendly sensors and communications equipment from the effects of EA (jamming, deception or disruption) and to preventing adversary use of ES (avoid detection and/or identification).

The students will be exposed to the basics of EP applications and technological aspects commonly used in EP.

- Overview of Communications ED

All information presented in the preceding themes is focused on radar applications. An overview of ED applied to telecommunications is now presented, comprising ES, EA and EP. Some of the expected outcomes of COMINT will be quickly discussed.

The students will be exposed to the basics of ED applications on Communications, technological aspects and system design.

- Electronic Countermeasures(ECM) applied against Passive Coherent Location (PCL) Radar

Passive coherent location (PCL) systems are a variant of bistatic radar that detect and track objects by processing reflections from non-cooperative sources of illumination in the environment, such as commercial broadcast and communications signals. Without the need for a dedicated transmitter, PCL is inherently lower cost than conventional radar systems, and is imbued with a high level of concealability.

The application of ECM against FM-based PCL radar systems is investigated. The use of noise jamming could severely impede the use of PCL systems. A couple of jamming schemes is considered and the conditions in which jamming is most or less effective are pointed out.

4 Learning outcomes

Having successfully completed this course, students should achieve:

- Understanding of Electronic Defence main concepts
- Understanding of Electronic Support regarding its concepts and knowledge of ES measures and activities
- Understanding of Electronic Attack regarding its concepts and knowledge of EA measures and techniques
- Understanding of Electronic Protection regarding its concepts and knowledge of EP applications
- Understanding of Electronic Intelligence regarding its concepts and knowledge of ELINT activities and applications
- Understanding of the fundamentals of system architectures and basic signal processing techniques that are used in Electronic Defence

Electronic Defence comprehends an enormously broad field of knowledge. Once mastering its fundamentals, one can identify and choose one of the many topics to specialize in, with the appropriate basis to follow the chosen path. Supplementary textbooks are indicated so that the student can specialize and deepen his studies in a preferred related topic.

5 Prescribed Text and Relevant Material

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

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

This classic book offers a thorough survey of sophisticated weapon and Electronic Defence (ED) systems. It includes deep explanation of radar techniques, IR techniques and ED techniques and an introduction to Information Operations. It provides good understanding of how sophisticated ED systems work, and how the systems can be intercepted and electronically jammed. From search and tracking radar, IR systems, and communication systems. to electronic intercept systems, countermeasures, and counter-countermeasures, the book explores a broad spectrum of defence equipment. It explains how these systems operate, their advantages and drawbacks, and the theories on which these systems are based. (adapted from Amazon.com review)

A new revised 3rd Edition is due late 2017/early 2018, and covers all the important latest technological advances in this rapidly-changing area. This book is unfortunately not yet available, but students that choose this filed are encouraged to check this new edition.

Electronic material will be made available on the course website.

5.1 Relevant Material

The following supplementary textbooks provide useful reference information that would supplement the content presented during lectures as well as the prescribed textbook. These books provide valuable reference for the students that decide to seek for further information in the main topics of ED.

- David Adamy, Introduction to Electronic Warfare Modeling and Simulation, SciTech Publishing, 2006, ISBN 9781891121623.
- D. Curtis Schleher, Electronic Warfare in the Information Age, Artech House, 1999, ISBN 9780890065266.
- Naval Air Systems Command, 1999, Electronic Warfare and Radar Systems Engineering Handbook.

And the series:

- David Adamy, EW 101: A First Course in Electronic Warfare, Artech House, 1st edition, 2001, ISBN 9781580531696.
- David Adamy, EW 102: A Second Course in Electronic Warfare, Artech House, 1st edition, 2004, ISBN 9781580536868.
- David Adamy, EW 103: Tactical Battlefield Communications Electronic Warfare, Artech House, 1st edition, 2008, ISBN 9781596933873.

- David Adamy, EW 104: Electronic Warfare Against a New Generation of Threats, Artech House, 2015, ISBN 9781608078691.

Further reading:

- David A. Lynch, Introduction to RF Stealth, SciTech Publishing, 2013, ISBN 9781891121210.

6 Course format

The formal part of the course is given in a 5 (five) day, intensive format with thematic lectures and practices, along the week 18th to 22nd September 2017. The lectures are followed by 3 (three) seminar sessions, with 2h (two hour) each, over the remaining weeks up to the end of the semester, when the examination is held. The dates for the seminar sessions are set during the lecture week session, to accommodate as far as possible, student availability – but having in mind that the dates will be ultimately set at the lecturer's discretion.

The follow-on sessions are intended to provide support to the realization of the project, as well as to provide further explanation to topics in which students might have found difficulties in understanding. In order to maximize the benefit from the seminars, students are encouraged to read the support material and work on their projects throughout the assigned period. The lecturer recommends that specific doubts be sent by email up to 24h before each seminar.

Any interaction after the lecture week will be dealt with via e-mail.

7 Assessment

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.

- A written examination which will count 50% toward the final mark.
- An assignment which will count 20% toward the final mark.
- A project which will count 30% toward the final mark.

The written examination corresponds mainly to the theoretical part of the examination: it is a three (3) hour written exam and will comprise of theory and basic problems. The exam is closed book, i.e. no notes may be brought into the examination venue. However students are not expected to memorise all the formulas: all non-basic formulas and results will be supplied on the examination paper.

The course project corresponds mainly to the part of the examination regarding application of knowledge. The assessment and the project will be defined during the lecture week. Students are advised to spend time throughout the semester to ensure a comprehensive submission.

The Radar Masters Programme attendance requirements must be observed and respected.

8 Course Schedule and dates

- Thematic lectures/practicals and contact time.....18th to 22nd September 2017
- Project report .....October 31st 2017
- Written examination (on all study themes) .....During the week starting 6th November 2017; day to be agreed with class

8.1 Lecture Program

Refer to Table 1 for daily lecture topics and programme.

Table 1: Daily course programme.

	Time	Monday 18Sep	Tuesday 19Sep	Wednesday 20Sep	Thursday 21Sep	Friday 22Sep
Morning	09:00 to 10:30	Welcome and course overview	Electronic Support	Electronic Attack	EP	Passive Coherent Location Radar
		History of ED	ES	EA	ELINT	PCL
	10:30 (20min)	Tea break				
	10:50 to 12:30	ED Overview	ES	EA	General considerations	Electronic Counter Measures on PCL
		ED Overview	ES	EA	Communications ED	ECM on PCL
Lunch	12:30 (1 hour)	Lunch				
Afternoon	13:30 to 15:30	ED Fundamentals	ES	Electronic Protection	Com ED	Project assignment and exam briefing
		ED Fundamentals	ES	EP	Com ED	Discussion
	15:30 (20min)	Tea break				
	15:50 to 17:00	ED Fundamentals	Practical	Practical	Practical	Conclusion