Universidad Politécnica de Cartagena

Centro Universitario de la Defensa

General Air Force Academy

Course unit description:

Electromagnetic Exploration Systems

Degree/s: Industrial Organization Engineering

1. Subject data

Name	Electromagnetic Exploration Systems				
Subject area	Electromagnetic Exploration Systems				
Module	511103011				
Code	Industrial Organization Engineering Degree				
Degree programme	2009 (Decreto 269/2009 de 31 de julio)				
Curriculum	University Centre of Defense at the Spanish Air Force Academy				
Centre	Elective				
Type	Electromagnetic Exploration Systems				
Length of subject	Four-month course (1 semester)	**Semester**	2nd	**Course**	4th
Language	English				
ECTS	7.5	**Hours / ECTS**	25	**Total workload (hours)**	187.5

2. Lecturer data

Lecturer in charge	Nina Skorin-Kapov		
Department	Department of Engineering and Applied Technologies		
Knowledge area	Telematics		
Office location	Office 24 @ CUD building		
Telephone	+34 968 189 911	**Fax**	+34 968 189 923
email	nina.skorinkapov@cud.upct.es		
URL / WEB	Aula Virtual UPCT		
Office hours	Tuesday and Thursday at 12:50-14:25 (prior appointment by email)		
Location	Office 24 @ CUD building		

Qualification/Degree	Doctor of Electrical Engineering, Field Telecommunications and Informatics. Associate Professor of Telematics.
Academic rank at CUD-UPCT	Contratado Doctor at an associated center
Year of admission in CUD-UPCT	2013
Number of five-year periods (*quinquenios*) if applicable	2
Research lines (if applicable)	Optimization and planning in telecommunications, WDM wide-area optical networks, (meta)-heuristic algorithms, network security and attack management
Number of six-year periods (*sexenios*) if applicable	Under evaluation
Professional experience (if applicable)	University of Zagreb, Croatia, 2003-2013 (2003-6 Teaching and Research Assistant, 2006-7 Postdoc, 2008-12 Assistant Professor, 2012-13 Associate Professor) Telecom ParisTech (Ecole nationale supérieure des télécommunications), Paris, France, 2006-7 (Postdoc)
Other topics of interest	See: https://sites.google.com/site/ninaskorinkapov/

Lecturer	María Teresa Martínez Inglés		
Department	Department of Engineering and Applied Technologies		
Knowledge area	Telecommunications		
Office location	Office 2 @ CUD building		
Telephone	+34 968 189 916	**Fax**	+34 968188780
email	mteresa.martinez@cud.upct.es		
URL / WEB	Aula Virtual UPCT		
Office hours	Tuesday and Thursday at 12:50-14:25 (after prior appointment by email)		
Location	Office 2 @ CUD building		

Qualification/Degree	Doctor of Telecommunication Engineering, Field Telecommunications. Associate Professor of Telecommunications.
Academic rank at CUD-UPCT	Ayudante Doctor at an associated center
Year of admission in CUD-UPCT	2016
Number of five-year periods (*quinquenios*) if applicable	-
Research lines (if applicable)	Characterization and Modeling of the radio channels for systems with large bandwidth in the millimeter frequency band Experimental study of multiple Diffraction phenomenon in the millimeter band
Number of six-year periods (*sexenios*) if applicable	
Professional experience (if applicable)	3 years AQUILINE: Software engineer UPCT: Engineer. Studies about the viability of cognitive systems
Other topics of interest	Doctor of Telecommunication Engineering, Field Telecommunications. Associate Professor of Telecommunications.

3. Subject description

3.1. General description

The course "*Electromagnetic Exploration Systems (EES)*" is an elective course in the 4th year of the undergraduate program in Industrial Organization offered at the University Centre of Defence (CUD) as part of the formation of future Air Force officers at the Spanish Air Force Academy (AGA). Specifically, the main objective is for students to learn the basic theoretical and practical concepts of radar and radionavigation systems, and thus, develop the skills needed to apply them in their future professional practice.

Radar systems apply the concepts of electromagnetic wave propagation to detect objects (targets) and determine their distance (range). Modern radar systems can be used to track, identify, and image targets, and have numerous military and civilian applications, such as aircraft and missile detection and tracking, fire control, weather radar, and airport surveillance. The first part of this course covers the basic elements of radar systems, their underlying principles of operation, design issues and applications. It develops upon the basic concepts on radar systems introduced in course Security and Defense Technology.

In addition to the aforementioned radar applications, exploiting the properties of electromagnetic wave propagation is widely used in navigation systems to determine the position of moving objects with respect to a reference, referred to as radionavigation. The second part of this course covers a wide range of air radionavigation aids, including both terrestrial systems (point source systems, aircraft landing systems, and hyperbolic systems) and satellite systems.

The complex and practical character of the course will also be aimed at developing skills such as teamwork, independent learning, quality concern and critical thinking.

3.2. How the subject contributes to a professional career

Radar systems have extensive military applications, including target tracking, surveillance, and reconnaissance missions, as well as military and civilian applications in air traffic control and weather detection. Thus, knowledge of the underlying principles of operation of radar systems is critical for military officers with direct responsibilities in the areas mentioned. Furthermore, understanding the foundations of various radionavigation systems, specifically air navigation aids, including both terrestrial and satellite systems, form an integral part of the formation of future Air Force officers. This course is meant to provide the fundamental knowledge needed to understand the theoretical workings and design of radar and radionavigation systems, and thus prepare the students with a solid theoretical background to face their practical training within the Spanish Air Force.

3.3. Relationship with other subjects in the programme

The course further develops concepts introduced in course Security and Defense Technology (3rd year), Block II, and also complements the course Networks and Communications Services (3rd year).

3.4. Incompatibilities defined in the programme

Nonexistent.

3.5. Recommendations to do the subject

It is recommended that students have basic knowledge of electromagnetism and Fourier analysis. These topics are covered in first year subjects Physics and Calculus, respectively. Furthermore, it is recommended that students have basic knowledge of electromagnetic wave propagation, signal modulations, and antenna basics, covered in course Security and Defense Technology in the 3rd year of the degree.

3.6. Special provisions

Special measures will be taken to allow for successful completion of the students´ military & aeronautical training activities which run in parallel to the course. Specifically, working groups will be formed to promote cooperative learning for students with limited availability; scheduled tutoring activities will be available and lecture notes will be provided on the course website.

4. Competences and learning outcomes

4.1. Basic curricular competences related to the subject

KC3. Students must have the ability to collect and interpret important data (normally within their area of study) in order to make judgments considering relevant social, scientific or ethical issues.

4.2. General curricular competences related to the subject

GC2. Application of general technologies and fundamental subjects in the industrial domain for the solving of engineering problems.

4.3. Specific curricular competences related to the subject

SC30. Analyze topics applied to engineering and aircraft systems operations.

4.4. Transversal curricular competences related to the subject

CCC4. Effective use ofinformation resources

4.5. Subject learning outcomes

The main objective of the course is to understand the underlying principles of operation and capabilities of modern radar and radionavigation systems. Specifically, the student should be able to:

1. Explain the principles of electromagnetic wave propagation and radio detection
2. Enumerate the basic elements of radar systems
3. Explain the workings of radar subsystems and the influence of external factors
4. Identify the problematics associated with radar system design
5. Distinguish between different types of radar and modern radar applications and identify their capabilities and limitations
6. Explain positioning methods used in radionavigation
7. Explain the basic principles of operation of terrestrial navigation systems (point-source systems and aircraft landing systems)
8. Explain the basic principles of satellite navigation systems
9. Describe the capabilities and limitations of terrestrial radionavigation systems and global satellite navigation systems

5. Contents

5.1. Curricular contents related to the subject

Radio determination. Air navigation aids. Ground equipment. Onboard equipment. Radar.

5.2. Theory syllabus (teaching modules and units)

BLOCK I. RADAR SYSTEMS

Unit 1: Introduction to radar systems
- Lecture 1: Introduction and Basic Concepts
- Lecture 2: The Radar Range Equation

Unit 2: Radar Subsystems and External factors
- Lecture 3: Propagation effects
- Lecture 4: Radar Cross Section
- Lecture 5: Detection of Signals in Noise
- Lecture 6: Pulse Compression
- Lecture 7: Radar antennas
- Lecture 8: Clutter
- Lecture 9: Signal Processing - MTI and Pulse Doppler Techniques
- Lecture 10: Tracking and Parameter Estimation
- Lecture 11: Transmitters and Receivers

Unit 3: Selected Radar Applications
- Lecture 12: Air Traffic Control Radars

BLOCK 2. RADIONAVIGATION SYSTEMS

Unit 4: Introduction to radionavigation systems
- Lecture 13: Introduction and Basic Concepts

Unit 5: Terrestrial systems

Point source systems:
- Lecture 14: Direction Finding: Nondirectional Beacons (NDB), Automatic Direction Finding (ADF), VHF Direction Finding (VDF)
- Lecture 15: VHF Omnidirectional Range (VOR), Distance Measuring Equipment (DME), Tactical Air Navigation (Tacan)

Aircraft Landing Systems:
- Lecture 16: Aircraft Landing Systems: Instrument Landing System (ILS), Microwave Landing System (MLS)

Unit 6: Satellite Systems
- Lecture 17: Satellite Systems: Global Navigation Satellite Systems (GNSS); fundamentals of satellite navigation; Global Positioning System (GPS); Global Orbiting Navigation Satellite System (GLONASS), Galileo, Compass

5.3. Practice syllabus (name and description of every practical)

Practical 1: Radar Range Equation. In this practical, students will become familiar with the radar range equation which describes the response of radar systems and involves the main design parameters.

Practical 2: Signal Analysis in a Continuous Wave Radar. The different signals involved in the transmission and reception of this type of Radar will be analyzed.

Practical 3: Signal Analysis in a Pulsed Radar. In this practical, the signals corresponding to the transmission, reception and processing processes of a pulsed radar will be simulated.

Practical 4: Pulsed Wave Radar. Different experiments will be carried out in a Pulsed Radar to study the different characteristics and functionalities of this radar.

Practical 5: Characterization of pulsed radars. In this practical, the students will analyze the different characteristics and benefits of the most relevant radars, both civilian and military.

Risk prevention

Promoting the continuous improvement of working and study conditions of the entire university community is one the basic principles and goals of the Universidad Politécnica de Cartagena.

Such commitment to prevention and the responsibilities arising from it concern all realms of the university: governing bodies, management team, teaching and research staff, administrative and service staff and students.

The UPCT Service of Occupational Hazards (*Servicio de Prevención de Riesgos Laborales de la UPCT*) has published a "Risk Prevention Manual for new students" (*Manual de acogida al estudiante en materia de prevención de riesgos*), which may be downloaded from the e-learning platform ("Aula Virtual"), with instructions and recommendations on how to act properly, from the point of view of prevention (safety, ergonomics, etc.), when developing any type of activity at the University. You will also find recommendations on how to proceed in an emergency or if an incident occurs.

Particularly when carrying out training practices in laboratories, workshops or field work, you must follow all your teacher's instructions, because he/she is the person responsible for your safety and health during practice performance. Feel free to ask any questions you may have and do not put your safety or that of your classmates at risk.

5.4. Theory syllabus in english (teaching modules and units)

BLOCK I. RADAR SYSTEMS

Unit 1: Introduction to radar systems

- Lecture 1: Introduction and Basic Concepts
- Lecture 2: The Radar Range Equation

Unit 2: Radar Subsystems and External factors

- Lecture 3: Propagation effects
- Lecture 4: Radar Cross Section
- Lecture 5: Detection of Signals in Noise
- Lecture 6: Pulse Compression
- Lecture 7: Radar antennas
- Lecture 8: Clutter
- Lecture 9: Signal Processing - MTI and Pulse Doppler Techniques
- Lecture 10: Tracking and Parameter Estimation
- Lecture 11: Transmitters and Receivers

Unit 3: Selected Radar Applications

- Lecture 12: Air Traffic Control Radars

BLOCK 2. RADIONAVIGATION SYSTEMS

Unit 4: Introduction to radionavigation systems

Lecture 13**:** Introduction and Basic Concepts

Unit 5: Terrestrial systems

Point source systems:

Lecture 14**:** Direction Finding: Nondirectional Beacons (NDB), Automatic Direction Finding (ADF), VHF Direction Finding (VDF)

Lecture 15**:** VHF Omnidirectional Range (VOR), Distance Measuring Equipment (DME), Tactical Air Navigation (Tacan)

Aircraft Landing Systems:

Lecture 16**:** Aircraft Landing Systems: Instrument Landing System (ILS), Microwave Landing System (MLS)

Unit 6: Satellite Systems

Lecture 17**:** Satellite Systems**:** Global Navigation Satellite Systems (GNSS); fundamentals of satellite navigation; Global Positioning System (GPS); Global Orbiting Navigation Satellite System (GLONASS), Galileo, Compass

5.5. Detailed description of learning goals for every teaching module

BLOCK 1: Radar Systems

Unit 1: Introduction to Radar Systems

- **TOPIC 1 (BLOCK 1, UNIT 1): RADAR SYSTEMS: INTRODUCTION AND BASIC CONCEPTS**

The objective is to introduce the students to radar systems, outlining the basic concepts and design issues of modern radar.

- **TOPIC 2 (BLOCK 1, UNIT 1): THE RADAR RANGE EQUATION**

The objective is to teach the students to interpret and calculate Radar Range Equation (RRE) which one of the basic and most important topics in radar systems, tying together all the radar subsytems and external factors.

Unit 2: Radar Subsystems and External factors

- **TOPIC 3 (BLOCK 1, UNIT 2): PROPAGATION EFFECTS**

The objective is to teach the students the individual propagation effects affecting electromagnetic radar signals as they travel to and from the target.

- **TOPIC 4 (BLOCK 1, UNIT 2): RADAR CROSS SECTION**

The objective is to familiarize the students with the basic concepts of the The Radar Cross Section (RCS) which is a measure of power scattered in a given spatial direction when a target is illuminated by an incident wave

- **TOPIC 5 (BLOCK 1, UNIT 2): DETECTION OF SIGNALS IN NOISE**

The objective is to teach the students the basic concepts of detection of a target, a detection threshold, and the probabilities of false alarm and detection. These concepts will then be tied together in a description if the radar detection problem.

❖ **TOPIC 6 (BLOCK 1, UNIT 2): PULSE COMPRESSION**

The objective is to teach the students the basic concepts and motivation behind Pulse Compression, including a discussion on range resolution, bandwidth and pulsewidth.

❖ **TOPIC 7 (BLOCK 1, UNIT 2): RADAR ANTENNAS**

The objective is to familiarize the students with the fundamentals of radar antennas, such as field regions, radiation patterns (with a main focus on beamwith, gain and sidelobes), and polarization.

❖ **TOPIC 8 (BLOCK 1, UNIT 2): CLUTTER**

The objective is to familiarize the students with the concepts of *radar clutter*, the differences between clutter and noise, and the main measure used for clutter backscatter (called the scattering coefficient).

❖ **TOPIC 9 (BLOCK 1, UNIT 2): SIGNAL PROCESSING - MTI (MOVING TARGET INDICATOR) AND PULSE DOPPLER TECHNIQUES**

The objective is to teach the students the basics of radar signal processing, i.e. Moving Target Indicator (MTI) and Pulse Doppler Techniques, beginning with a review of clutter characteristics from the previous topic, a review of the Doppler effect, techniques for measuring Doppler shifts in pulsed waveforms, Doppler velocity ambiguity, and finally the differences between MTI and Pulse Doppler Techniques.

❖ **TOPIC 10 (BLOCK 1, UNIT 2): TRACKING AND PARAMETER ESTIMATION**

The objective is to familiarize the students with radar tracking, including Single Target Tracking and Multiple Target Tracking in Track-while-Scan (Automatic Detection and Tracking) and Phased Array Tracking radars.

❖ **TOPIC 11 (BLOCK 1, UNIT 2): TRANSMITTERS AND RECEIVERS**

The objective is to familiarize the students with aspects relating to radar transmitter and receivers and transmitter/receiver architectures used in radar systems.

Unit 3: Selected Radar Applications

❖ **TOPIC 12 (BLOCK 1, UNIT 3): AIR TRAFFIC CONTROL RADARS**

The objective is to familiarize the students with Air Traffic Control (ATC) radars such as Primary Surveillance Radars (En-route and Airport Surveillance Radars) and Secondary Surveillance Radars (SSR).

BLOCK 2: Radionavigation Systems

Unit 4: Introduction to Radionavigation Systems

❖ **TOPIC 13 (BLOCK 2, UNIT 4): INTRODUCTION AND BASIC CONCEPTS**

The objective is to give a general introduction to radionavigation systems and associated Term. Common position fixing methods will be covered, as well as overview of the main navigation system performance parameters.

Unit 5: Terrestrial Systems

❖ **TOPIC 14 (BLOCK 2, UNIT 5): POINT SOURCE SYSTEMS I (DIRECTION FINDING)**

The objective is to teach the students the basic principles of operation of point source systems based on direction finding (NDB, ADF, VDF), as well as their capabilities and limitations.

❖ **TOPIC 15 (BLOCK 2, UNIT 5): POINT SOURCE SYSTEMS II (VOR, DME, TACAN)**

The objective is to teach the students the basic principles of operation of point source systems DME, VOR, and TACAN, as well as their capabilities and limitations.

❖ **TOPIC 16 (BLOCK 2, UNIT 5): AIRCRAFT LANDING SYSTEMS**

The objective is to teach the students the basic principles of aircraft landing systems, as well as their capabilities and limitations.

Unit 6: Satellite Systems

❖ **TOPIC 17 (BLOCK 2, UNIT 6): SATELLITE SYSTEMS**

The objective is to teach the students the basic principles of satellite systems, as well as the characteristics, capabilities and limitations of different global satellite navigation systems.

6. Teaching method

6.1. Teaching method

Teaching activity	Teaching techniques	Student workload	Hours
Lectures	Presentation and explanation of the course material. Resolving doubts. Special emphasis will be made on the fundamental and more complex theoretical aspects of the course.	In-class: Active attendance and class participation. Taking notes. Questions.	**55**
Problem solving classes	Solving problems in the classroom and/or presenting case studies.	In-class: Active attendance. Questions and problem solving.	**10**
Laboratory sessions	Explaining the laboratory exercises. Supervising and leading the laboratory classes. Evaluating student knowledge and participation.	In-class: Individual and/or cooperative work in the laboratory under lecturer supervision. Active participation.	**10**
Individual and/or group consultation and tutorials	Resolving student questions and doubts related to the course	In-class: Actively participating in resolution of their questions/doubts.	**4,5**
Individual study/work	Lecture notes covering all course topics will be made available to the students to ease individual study	Self-study: Individual study. Problem solving.	**84**
Work/Report preparation	Preparation of laboratory reports.	Self-study: Personal or group work where the results of the work made in the laboratory will be described.	**20**
Realization of summative and formative course assessment activities	Preparing the individual written examinations	In-class: Attending and taking the midterms and final exam.	**4**
			187,5

6.2. Learning outcomes (4.5) / teaching activities (6.1)

	Learning outcomes (4.5)								
Teaching activities (6.1)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Lectures	x	x	x	x	x	x	x	x	x
Problem solving classes	x	x	x	x	x	x	x	x	x
Laboratory sessions	x	x	x	x	x	x			
Individual and/or group consultation and tutorials	x	x	x	x	x	x	x	x	x
Individual study/work	x	x	x	x	x	x	x	x	x
Work/Report preparation	x	x	x	x	x	x			
Realization of summative and formative course assessment activities	x	x	x	x	x	x	x	x	x

7. Assessment method

7.1 Assessment method

Actividad	Tipo		Sistema y criterios de evaluación*	Peso (%)	Resultados (4.5) evaluados
	Sumativa*	Formativa*			
Midterm Exam B1	x	x	A written exam consisting of theoretical and theoretical-practical questions and problems covering Topics 1-6	35%(*)	1-5
Midterm Exam B2	x	x	A written exam consisting of theoretical and theoretical-practical questions and problems covering Topics 7-12	35%(*)	1-5
Midterm Exam B3	x	x	A written exam consisting of theoretical and theoretical-practical questions and problems covering Topics 13-17	30%(*)	6-9
Final Exam	x		The final exam is divided in 3 parts: Part B1 of the final written exam will consist of theoretical and/or practical questions aimed at evaluating the acquired knowledge of Topics 1-6	35%(*)	1-9
			Part B2 of the final written exam will consist of theoretical and/or practical questions aimed at evaluating the acquired knowledge of Topics 7-12	35%(*)	
			Part B3 of the final written exam will consist of theoretical and/or practical questions aimed at evaluating the acquired knowledge of the material covered in Block II (Radionavigtion systems, Topics 13-17)	30%(*)	
Laboratory work	x	x	Participation and successful completion of the laboratory classes is compulsory for passing the course. Evaluation based on participation, oral questioning and/or lab reports.	PASS/FAIL	1-5

(*) There will be 3 individual written Midterm examinations during the semester: Part B1 will cover topics 1-6, Part B2 will cover topics 7-12, and Part B3 will cover topics 13-17. For each midterm, students who obtain a grade greater than or equal to 4.5 out of 10 have the option to skip that corresponding part of the final exam.

The Final examination will consist of three parts: Part B1 covering Topics 1-6, Part B2 covering Topics 7-12 and Part B3 covering Topics 13-17 (Block 2: Radionavigation Systems) each carrying a maximum of 10 points. Each part will be taken by those students who did not pass the corresponding Midterm exam (received a grade <4.5) or by students who wish to try to improve upon their Midterm grades. Note: Students who decide to try to improve upon their Midterm grade(s) in the final exam, permanently renounce the grade received

on the corresponding Midterm, irrespective of the result they obtain on the final exam.

The final grade is based on the grades received for each Part (Part B1, B2 and B3). To pass the course it is necessary to obtain a minimum score of 4.5 out of 10 for each Part an overall minimum score of 5 out of 10 for the Final Grade. The grade for Parts B1, B2 and B3 can be obtained either though the Midterms or the Final Exam as outlined above.
The final grade will then be calculated as:

Final grade= 35%(Part B1 grade) +35%(Part B2 grade)+30%(Part B3 grade)
To pass the course the student must obtain a Final grade >= 5.0,
such that Part B1 grade >= 4.5, Part B2 grade >= 4.5 and Part B3 grade >=4.5

7.2. Control and monitoring methods (optional)

Learning process monitoring will be realized through the following activities:
- Posing questions/problems and monitoring student participation in the classroom.
- Monitoring student work in the laboratory sessions.
- Individual and/or group tutorials
- Individual written midterm and final examinations

8. Bibliography and resources

8.1. Basic bibliography

- M. Skolnik, *Introduction to Radar Systems*, New York, McGraw-Hill, 3rd Edition, 2001
- M. Richards, J. Scheer, W. Holm, *Principles of Modern Radar: Basic Principles*, SciTech Publishing, 2010
- B. Forsell, *Radionavigation Systems*, Artech House, Inc., 2008

8.2. Supplementary bibliography

- *J. C. Toomay, Paul J. Hannen, Radar Principles for the Non-Specialist, 3rd Edition*, SciTech Publishing, 2004.
- G. W. Stimson, *Introduction to Airborne Radar*, 2nd *and 3rd Editions*, SciTech Publishing, 1998, 2014
- *Radio Navigation, JAA ATPL Training Edition 2*,Jeppesen Sanderson Inc, 2007
- B. Hofmann-Wellenhof, K. Legat, M. Wieser, *Navigation, Principles of Positioning and Guidance*, Springer-Verlag, 2003
- M. Kayton, W.R. Fried, *Avionics Navigation Systems*, John Willey & Sons, Inc., 1997
- L.C. Peña Morán, *Ayudas a la Navegación Aérea*, Diego Marin Librero Editor, 2000

8.3. On-line resources and others

- All material used during the development of this course will be available online in the Virtual Classroom
- O'Donnell, Robert M. *RES.LL-001 Introduction to Radar Systems, Spring 2007*. (Massachusetts Institute of Technology: MIT OpenCourseWare), http://ocw.mit.edu License: Creative Commons BY-NC-SA