# 300227 - RL - Radiolocation

| Coordinating unit: | 300 - EETAC - Castelldefels School of Telecommunications and Aerospace Engineering |
| Teaching unit: | 739 - TSC - Department of Signal Theory and Communications |
| Academic year: | 2017 |
| Degree: | BACHELOR’S DEGREE IN AIR NAVIGATION ENGINEERING (Syllabus 2010). (Teaching unit Compulsory) |
| | BACHELOR’S DEGREE IN TELECOMMUNICATIONS SYSTEMS ENGINEERING (Syllabus 2009). (Teaching unit Optional) |
| | BACHELOR’S DEGREE IN NETWORK ENGINEERING (Syllabus 2009). (Teaching unit Optional) |
| | BACHELOR’S DEGREE IN AEROSPACE SYSTEMS ENGINEERING (Syllabus 2015). (Teaching unit Optional) |
| | BACHELOR’S DEGREE IN AEROSPACE SYSTEMS ENGINEERING/BACHELOR’S DEGREE IN TELECOMMUNICATIONS SYSTEMS ENGINEERING (Syllabus 2015). (Teaching unit Optional) |
| ECTS credits: | 6 |
| Teaching languages: | Catalan, Spanish, English |

## Teaching staff

**Coordinator:** Definit a la infoweb de l'assignatura.

**Others:** Definit a la infoweb de l'assignatura.

## Prior skills

Operability with complex numbers. Product and sum of complex numbers, rationalization, calculation of module and phase of a complex number.

Operability in linear and logarithmic scale

Operability with trigonometric functions.

Operability with signals and systems in the frequency domain by means of Fourier series and transforms, and apply the main properties of these.

Knowledge of analog communication systems and digital

## Requirements

Fundamentals of communications

## Degree competences to which the subject contributes

### Specific:

5. CE 24 AERON. Conocimiento adecuado y aplicado a la Ingeniería de: Los métodos de cálculo y de desarrollo de la navegación aérea; el cálculo de los sistemas específicos de la aeronavegación y sus infraestructuras; las actuaciones, maniobras y control de las aeronaves; la normativa aplicable; el funcionamiento y la gestión del transporte aéreo; los sistemas de navegación y circulación aérea; los sistemas de comunicación y vigilancia aérea. (CIN/308/2009, BOE 18.2.2009)

6. CE 25 AERON. Conocimiento aplicado de: Transmisores y receptores; Líneas de transmisión y sistemas radiantes de señales para la navegación aérea; Sistemas de navegación; Instalaciones eléctricas en el sector tierra y sector aire; Mecánica del Vuelo; Cartografía; Cosmografía; Meteorología; Distribución, gestión y economía del transporte aéreo. (CIN/308/2009, BOE 18.2.2009)

### Transversal:

1. SELF-DIRECTED LEARNING - Level 3. Applying the knowledge gained in completing a task according to its relevance and importance. Deciding how to carry out a task, the amount of time to be devoted to it and the most suitable information sources.
The overall objective of the course is to provide knowledge of aeronautical surveillance systems within the CNS/ATM concept defined by ICAO. Students will learn the techniques used in primary and secondary surveillance radar for air traffic control, deepening the theory of pulsed Radar to explain the primary and the secondary Radar. The course is completed with new trends Dependent Surveillance ADS (Automatic Dependent Surveillance) and Mode S interrogation techniques and other aeronautical radar based Applications such radio altimeters, dead reckoning navigation, weather radar, and anti-collision warning Systems.

In more detail, the completion of the course will enable students to:
- Identify the principal air navigation systems
- Analyse the different subsystems of a Radar system.
- Design some parameters of a Radar system to meet specifications.
- Analyse specific regulations defined surveillance equipment ICAO.
- Calculate Time and frequency-domain signals involved in surveillance systems.
- Check with computer simulations the theoretical results.

**Teaching methodology**

It is a subject with great theoretical content, which means that often the show and extracting mathematical expressions, so the lectures are held on board with the necessary support transparencies. Classes and laboratory problems should consolidate the concepts presented in lectures by conducting drills and exercises, on paper or by using simulation tools, MATLAB. In classes of problems and laboratory students work in groups of two people.

**Learning objectives of the subject**

The overall objective of the course is to provide knowledge of aeronautical surveillance systems within the CNS/ATM concept defined by ICAO. Students will learn the techniques used in primary and secondary surveillance radar for air traffic control, deepening the theory of pulsed Radar to explain the primary and the secondary Radar. The course is completed with new trends Dependent Surveillance ADS (Automatic Dependent Surveillance) and Mode S interrogation techniques and other aeronautical radar based Applications such radio altimeters, dead reckoning navigation, weather radar, and anti-collision warning Systems.

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**Study load**

<table>
<thead>
<tr>
<th>Total learning time: 150h</th>
<th>Hours large group:</th>
<th>36h</th>
<th>24.00%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hours small group:</td>
<td>24h</td>
<td>16.00%</td>
<td></td>
</tr>
<tr>
<td>Guided activities:</td>
<td>6h</td>
<td>4.00%</td>
<td></td>
</tr>
<tr>
<td>Self study:</td>
<td>84h</td>
<td>56.00%</td>
<td></td>
</tr>
</tbody>
</table>
## Content

<table>
<thead>
<tr>
<th>1.- Introduction to Air Navigation</th>
<th><strong>Learning time:</strong> 7h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 1h</td>
</tr>
<tr>
<td></td>
<td>Laboratory classes: 2h</td>
</tr>
<tr>
<td></td>
<td>Guided activities: 1h</td>
</tr>
<tr>
<td></td>
<td>Self study: 3h</td>
</tr>
</tbody>
</table>

### Description:


### Related activities:

Lab Session no. 0.- Introduction to MATLAB.

### Specific objectives:

To know the different surveillance systems and to evaluate their restrictions and performances.
2.- Pulsed Radar

**Learning time:** 92h 20m
- Theory classes: 17h
- Laboratory classes: 20h
- Guided activities: 2h
- Self study: 53h 20m

**Description:**

Radar Equation. Minimum detectable signal.


False alarm probability and time of false alarms. Probability of Detection.


Matched filter.


**Related activities:**
First exercises's short test.
First lab's short test.
Second lab's short test.
Midterm exam.
Final exam.
Lab Session no. 1.- Pulsed Radar.
Lab Session no. 2.- The Radar equation.
Lab Session no. 3.- The matched filter.
Lab Session no. 4.- The Radar antennas.
Lab Session no. 5.- The Radar Cross Section
Lab Session no. 6.- CFAR

Specific objectives:

Radar Equation. Minimum detectable signal.


False alarm probability and time of false alarms. Probability of Detection.


Matched filter.


### 3.- Radar Clutter

<table>
<thead>
<tr>
<th><strong>Description:</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Analysis of the unwanted signal inside my range, which can mask the wanted target.</td>
</tr>
<tr>
<td>Typologies: surface, volume, and angel.</td>
</tr>
<tr>
<td>Typical radar cross sections.</td>
</tr>
<tr>
<td>Signal to Clutter ratio (S/C).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Related activities:</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Second exercises's short test.</td>
</tr>
<tr>
<td>Final exam.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Specific objectives:</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>To know the unwanted echoes which can mask the targets of interest.</td>
</tr>
<tr>
<td>To analyse the effect of the clutter power on the desired signal power.</td>
</tr>
</tbody>
</table>

**Learning time:** 2h 55m  
- Theory classes: 1h 20m  
- Guided activities: 0h 15m  
- Self study: 1h 20m
4.- Doppler based Radars

**Learning time:** 23h 50m
- Theory classes: 7h
- Laboratory classes: 2h
- Guided activities: 1h
- Self study: 13h 50m

**Description:**
The Doppler Effect. Continuous-wave radar (CW): principle of operation; homodyne and heterodyne structures. Pulsed Doppler Radar. Speed’s measurement system.

MTI (Moving Target Indicator) Radar: block diagram; Canceller circuits for static targets; Transfer function of cancellers; Blind speeds; Staggered PRF; Clutter attenuation; two stages canceller; Improvement Factor; N pulses canceller; Transversal filter; Doppler filter banks; MTI Digital processing; Blind phases; I/Q channel.

Pulsed Doppler Radar: AWACS System (Airborne Warning and Control System).

FM-CW Radar: Principles of operation; range and speed measurements; application as a radio altimeter; modulation types; techniques for improving isolation.

Other Radar applications in aerospace engineering: Radar Doppler Navigation (dead reckoning); Surface Movement Radar (SMR); Radio altimeter (pulsed).

Radar Ambiguity function. Properties. Ambiguity functions of several radar waveforms.

**Related activities:**
- Session Lab 7.- MTI
- Second exercises’s short test.
- Second lab’s short test.
- Final exam.

**Specific objectives:**
- Know and apply the Doppler effect to the measurement of the speed of moving targets.
- Understand the fundamentals, characteristics and performance of the MTI radars.
- To know the applications in aeronautical engineering of the different types of continuous wave radars.
### 5.- Tracking Radars

**Learning time:** 3h 15m  
- Theory classes: 1h 20m  
- Guided activities: 0h 15m  
- Self study: 1h 40m

**Description:**  
Fundamentals. Typologies.  
Angle-Tracking Radar: Amplitude Comparison Monopulse Radar; Phase comparison Monopulse Radar; Sequential Lobing Radar; Conical Scan Radar.  
Limitations factors to tracking accuracy: Noise angle (Glint); amplitude fluctuations.  
Low-Angle Tracking.

**Related activities:**  
Second exercises's short test.  
Final exam.

**Specific objectives:**  
To know the systems and techniques of targeting and tracking of mobile targets with Radar systems.

### 6.- Secondary Surveillance Radar

**Learning time:** 10h 20m  
- Theory classes: 4h  
- Guided activities: 0h 30m  
- Self study: 5h 50m

**Description:**  

**Related activities:**  
Second exercise's short test.  
Final exam.

**Specific objectives:**  
Know the purpose, characteristics and operation of the secondary surveillance radar.
### 7. Automatic Dependence Surveillance (ADS-B)

**Learning time:** 2h 30m  
- Theory classes: 1h 05m  
- Guided activities: 0h 15m  
- Self study: 1h 10m

**Description:**  
The ADS system: Fundamentals. ADS types: ADS-B (Broadcast); ADS-C (Contract). System block diagram. Squitter Mode S. Services and compatibility.

**Related activities:**  
Final exam.

**Specific objectives:**  
To know the operation, the benefits and the limitations of the automatic systems of dependent surveillance.

### 8. Airborne Collision Avoidance System (ACAS)

**Learning time:** 2h 30m  
- Theory classes: 1h 05m  
- Guided activities: 0h 15m  
- Self study: 1h 10m

**Description:**  

**Related activities:**  
Final exam.

**Specific objectives:**  
Know the operation of anti-collision systems and their integration with radiolocation systems.

### 9. Enhanced Ground Proximity Warning System (EGPWS)

**Learning time:** 2h 30m  
- Theory classes: 1h 05m  
- Guided activities: 0h 15m  
- Self study: 1h 10m

**Description:**  

**Related activities:**  
Final exam.

**Specific objectives:**  
To know the operation of the alarm and warning systems by collision against the ground, and its integration with the radiolocation and radionavigation systems.
### 10. Weather Radar

**Description:**

**Related activities:**
Final exam.

**Specific objectives:**
Know the theory of operation, characteristics and applications in aeronautics of weather radars.
### Planning of activities

| Lab Session no. 0.- Introduction to MATLAB. | Hours: 4h  
Laboratory classes: 2h  
Self study: 2h |
|-------------------------------------------|------------------|
| **Description:**  
This practice session will introduce the main tools of MATLAB: creating files .m, using vectors and matrices, representation of results and show common commands. | |
| **Support materials:**  
MATLAB. | |
| **Descriptions of the assignments due and their relation to the assessment:**  
No deliverable. | |
| **Specific objectives:**  
Knowledge of the software to be used during the course. | |

| Lab Session no. 1.- Pulsed Radar. | Hours: 4h  
Laboratory classes: 2h  
Self study: 2h |
|----------------------------------|------------------|
| **Description:**  
Matlab routines will be created to represent RADAR pulsed signals, identified the effect of the basic parameters: carrier frequency, pulse repetition frequency, and time repetition pulses. Displayed and represent the concepts of distance through the signal delay and the concept of maximum unambiguous distance. | |
| **Support materials:**  
MATLAB. | |
| **Descriptions of the assignments due and their relation to the assessment:**  
Report the results of the activity. | |
| **Specific objectives:**  
Consolidate and extend the concept learnt in theoretical lectures. | |

| Lab Session no. 2.- The Radar equation. | Hours: 4h  
Laboratory classes: 2h  
Self study: 2h |
|----------------------------------------|------------------|
| **Description:**  
RADAR equation will be programmed in MATLAB to represent the relationship between the different parameters involved, such as the ratio of received power and range, signal to noise ratio and range, transmitted power etc. | |
| **Support materials:**  
MATLAB. | |
| **Descriptions of the assignments due and their relation to the assessment:**  
Report the results of the activity. | |
| **Specific objectives:**  
Consolidate and extend the concept learnt in theoretical lectures. | |
Lab Session no. 3.- The matched filter.  

| Description: | 
| In this lab session will be plotted the baseband complex signal and the output of the matched filter for a given code and a given signal to noise ratio. | 
| Support materials: | MATLAB | 
| Support materials: | 
| Support materials: | 
| Specific objectives: | Consolidate and extend the concept learnt in theoretical lectures. | 

Lab Session no. 4.- The Radar antennas.  

| Description: | 
| Create MATLAB routines and represent the radiation patterns of several antennas by current distribution. It will identify the basic parameters of the antennas, such as gain, beamwidth, main lobe and secondary relationship, and relationship with Radar systemic parameters such as angular resolution volume uncertainty, observation time and number of observed pulse. | 
| Support materials: | MATLAB | 
| Support materials: | 
| Specific objectives: | Consolidate and extend the concept learnt in theoretical lectures. | 

Lab Session no. 5.- The Radar Cross Section.  

| Description: | 
| This practice will be held in two sessions. Although it is not necessary to differentiate between the two sessions, the first session is to study the radar cross section of simple objects, seeing their frequency dependence and aspect ratio, while the second session will explore the radar cross section of complex objects based on the composition of simple objects. | 
| Support materials: | MATLAB | 
| Support materials: | 
| Specific objectives: | Report the results of the activity. |
### Specific objectives:
Consolidate and extend the concept learnt in theoretical lectures.

<table>
<thead>
<tr>
<th>Lab Session no. 6.- CFAR.</th>
<th>Hours: 4h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Laboratory classes: 2h</td>
</tr>
<tr>
<td></td>
<td>Self study: 2h</td>
</tr>
</tbody>
</table>

**Description:**
In this lab session we will make a very simple analysis of a typical CFAR technique named Cell-Averaging CFAR, or CA-CFAR.

**Support materials:**
MATLAB

**Descriptions of the assignments due and their relation to the assessment:**
Report the results of the activity.

**Specific objectives:**
Consolidate and extend the concept learnt in theoretical lectures.

<table>
<thead>
<tr>
<th>Lab Session no. 7.- MTI.</th>
<th>Hours: 8h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Laboratory classes: 4h</td>
</tr>
<tr>
<td></td>
<td>Self study: 4h</td>
</tr>
</tbody>
</table>

**Description:**
In this session we will analyze in the time domain two MTI's.

**Support materials:**
MATLAB

**Descriptions of the assignments due and their relation to the assessment:**
Report the results of the activity.

**Specific objectives:**
Consolidate and extend the concept learnt in theoretical lectures.

<table>
<thead>
<tr>
<th>First exercises's short test.</th>
<th>Hours: 1h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 1h</td>
</tr>
</tbody>
</table>

**Description:**
Short test on exercises about pulsed radar

**Specific objectives:**
Verify that learning objectives are achieved.

<table>
<thead>
<tr>
<th>Second exercises's short test.</th>
<th>Hours: 1h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 1h</td>
</tr>
</tbody>
</table>
### Description:
Short test on exercises about the Doppler based Radars and the tracking Radars.

### Specific objectives:
Verify that learning objectives are achieved.

### First lab’s short test.

<table>
<thead>
<tr>
<th>Hours</th>
<th>Labatonary classes: 1h</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description:</strong></td>
<td>Lab short test about the lab sessions on Matlab exercises.</td>
</tr>
<tr>
<td><strong>Support materials:</strong></td>
<td>Matlab</td>
</tr>
<tr>
<td><strong>Specific objectives:</strong></td>
<td>Verify that successful practices have been performed.</td>
</tr>
</tbody>
</table>

### Second lab’s short test.

<table>
<thead>
<tr>
<th>Hours</th>
<th>Labatonary classes: 1h</th>
</tr>
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<tbody>
<tr>
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<td><strong>Support materials:</strong></td>
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<td><strong>Specific objectives:</strong></td>
<td>Verify that successful practices have been performed.</td>
</tr>
</tbody>
</table>

### Midterm exam.

<table>
<thead>
<tr>
<th>Hours</th>
<th>Guided activities: 1h 30m</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description:</strong></td>
<td>Exam about the theoretical and practical aspects of the Pulsed Radar.</td>
</tr>
<tr>
<td><strong>Specific objectives:</strong></td>
<td>Verify that learning objectives are achieved.</td>
</tr>
</tbody>
</table>

### Final exam.

<table>
<thead>
<tr>
<th>Hours</th>
<th>Guided activities: 1h 30m</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description:</strong></td>
<td>Synthesis course exam, with theoretical and practical content, but focused towards the contents studied in the second half of the course.</td>
</tr>
<tr>
<td><strong>Specific objectives:</strong></td>
<td>Verify that learning objectives are achieved.</td>
</tr>
</tbody>
</table>
Qualification system

The ones defined in the course infoweb.

Regulations for carrying out activities

The first and second exercises control will be done during the fifth and tenth week of the course. They will be one-hour exams that will be done in theory hours. The first and second laboratory tests will last for one hour and will be held in laboratory hours, preferably during the sixth and twelfth week of the course. The mid-term exam will be held in the middle of the semester during the week dedicated especially for them, and will evaluate all the content of the subject taught until then, without this entailing the release of material for the next examinations. At the end of the semester a final exam will be done which will evaluate all the material presented in class.

Bibliography

Basic:


Complementary:
