Laser-Radar (LIDAR) Remote Sensing:

**Coordinating unit:** ETSETB - Escola Tècnica Superior d'Enginyeria de Telecomunicació de Barcelona

**Teaching unit:** 739 Department of Signal Theory and Communications

**Study programme:** Master in Telecommunications Engineering; Master in Electronic Engineering, Enginyeria de Telecomunicació (Pla 92), Enginyeria Electrònica (Pla 92), MINT y Máster en Enginyeria Telemàtica.

**ECTS credits:** 2.5;

**Work load:** 62.5 hours of work load for the student.

**Coordinator:** Francesc Rocadenbosch

**Other teaching staff:** ---

**Master competences to which the subject contributes:**

**Specific competences:**

- CE1: Ability to apply information theory methods, adaptive modulation and channel coding, as well as advanced techniques of digital signal processing to communication and audiovisual systems.
- CE13: Ability to apply advanced knowledge in photonics, optoelectronics and high-frequency electronic.
- CE14: Ability to develop electronic instrumentation, as well as transducers, actuators and sensors.
- CE2b: Ability to develop laser-radar/optical-active remote-sensing systems: telescope ("optical antenna") and opto-electronic receiver design, equipment and subsystems, channel modeling, link budget, and architecture specification.
- CE5b: Ability to design laser-radar remote sensing systems (LIDAR) for atmospheric environmental sensing (pollution) and chemical-species detection, either as ground-based or satellite-based systems.
- CE15b: Ability to integrate Telecommunication Engineering technologies and systems, as a generalist, and in broader and multidisciplinary contexts, such as remote sensing, atmospheric probing, and imaging.
- CE17: Ability to develop signal processing methods and algorithms for data retrieval and interpretation in atmospheric, environmental and industrial LIDAR remote sensing.

**Teaching methodology:**

- Lectures
- Application classes
Learning objectives and results of the subject:

The course focuses on a tutorial discussion of the main techniques, systems and subsystems, and applications related to LIDAR (laser-radar) remote sensing. The course presents the grounds of the technological, physical, and data-retrieval keys involved in relation to the applications of these remote sensing systems in the ground-based and space-borne contexts. Present-day application fields comprise atmospheric observation (pollution concentration and physical-variables monitoring), wind remote sensing (e.g., eolic farms), detection and monitoring of chemical species, and others, in the industrial field.

Learning results of the subject:

- Ability to develop LIDAR (laser-radar) remote-sensing systems for atmospheric sensing and chemical-species detection in the context of both ground-based and satellite-based systems.
- Ability to specify, analyse, and evaluate the performance of different types of LIDAR systems using end-to-end software simulation.
- Ability to model and interpret retrieved lidar data in terms of level-1 products (atmospheric reflectivity, attenuation) and level-2 products (pollution content and transport, gas-species concentration, and wind velocity).
- Ability to understand and forecast a wide range of LIDAR applications including pollution monitoring and gas detection in the environmental/regulatory field, wind retrieval in relation to eolic farms, telemetry, 3-D imaging and scanning in architecture, and bathymetry (sea surface and submarine investigation).
- Knowledge exposure to continental and world-wide network initiatives concerning both active and passive optical remote sensing instruments.

Study load:

Total learning time: 62.5h (20h with professor + 42.5h self/guided study)

- Large group/Theory classes: 20h
- Self study: 42.5h
Content:

1. BACKSCATTER LIDAR SYSTEMS
   1.1. Foundations and Architecture
      1.1.1. Basic design parameters: Elastic lidar equation
         1.1.1.1. Optical (OVF, background radiance)
      1.1.2. Signal conditioning and acquisition
         1.1.2.1. Signal conditioning: Receiving Chain
         1.1.2.2. Acquisition systems: Photon counters
   1.2. Examples of real systems

Dedication:
   - Large group/Theory classes: 4,5h
   - Self study: 10,5h

2. SYSTEM LINK BUDGET: END-TO-END SIMULATION
   2.1. Receiving chain: OE conversion and resolution (review)
   2.2. Generalised signal-to-noise ratio (noise-dominant modes)
   2.3. Example problem I
   2.4. Lidar range estimation: Simulation.
   2.5. Elastic-Raman link budget (problem proposal)

Dedication:
   - Large group/Theory classes: 0,5h
   - Medium group/Practical classes: 4h
   - Self study: 12h

3. RAMAN SYSTEMS
   3.1. Raman Lidar
      3.1.1. Basics about the Raman effect
      3.1.2. Atmospheric probing and system layout
         3.1.2.1. Temperature measurement
         3.1.2.2. Molecular species (gas) detection
         3.1.2.3. Water-vapor measurement
   3.2. Elastic-Raman systems: End-to-end-simulation (problem revision)

Dedication:
− Large group/Theory classes: 2h
− Medium group/Practical classes: 1h
− Self study: 6h

4. WIND-LIDAR SYSTEMS

4.1. Coherent Doppler Lidar

4.1.1. Architecture
4.1.2. Design considerations

4.2. Direct-detection Doppler systems

Dedication:
− Large group/Theory classes: 2h
− Self study: 4h

5. OTHER LASER-RADAR SYSTEMS

5.1. DIAL: Detection of gas species
5.2. Other laser-radar systems

Dedication:
− Large group/Theory classes: 2h
− Self study: 4h

6. EVALUATION

6.1 Oral presentation/interview (2h)
6.2 Final exam (2h)

Dedication:
− Large group/Theory classes: 4h
− Self study: 6h

Planning of activities:
The teaching and learning methodology combines expositive classes with more interactive ones, where systems and case problems are simulated and/or discussed based on literature reviews. A guided simulation mini-project (computer based) is progressively introduced during course.
Exercises:

- Description: Exercises to strengthen the theoretical knowledge and with a focus to guide the computer-based mini-project.

Oral presentation/interview*:

- Description: Presentation of the link-budget simulation mini-project (session 19).
  
(*) Depending on the total number of students enrolled.

Extended answer test (Final examination):

- Description: Final examination (multiple-answer test, session 20).

Qualification system:

Final examination: 50%
Oral presentation*: 50%

(*) Guided Link-budget program

Bibliography:

Basic:

Takashi Fujii, Tetsuo Fukuchi. LASER REMOTE SENSING. CRC, Taylor&Francis, Florida, 2005.

Complementary: