230705 - OSEN - Optical Fiber Sensor Technologies

Coordinating unit: 230 - ETSETB - Barcelona School of Telecommunications Engineering
Teaching unit: 739 - TSC - Department of Signal Theory and Communications
Academic year: 2018
Degree: MASTER'S DEGREE IN TELECOMMUNICATIONS ENGINEERING (Syllabus 2013). (Teaching unit Optional)
ECTS credits: 5

Teaching languages: English

Teaching staff
Coordinator: Junyent Giralt, Gabriel
Others: Junyent Giralt, Gabriel
         Gene Bernaus, Juan Manuel

Opening hours
Timetable: Any time is possible by appointment email-

Degree competences to which the subject contributes

Specific:
CE11. Knowledge of hardware description languages for high-complex circuits.

CE3. Ability to implement wired/wireless systems, in both fix and mobile communication environments.

CE15. Ability to integrate Telecommunication Engineering technologies and systems, as a generalist, and in broader and multidisciplinary contexts, such as bioengineering, photovoltaic conversion, nanotechnology and telemedicine.

CE6. Ability to model, design, implement, manage, operate, administrate and maintain networks, services and contents

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.

Transversal:
CT4. EFFECTIVE USE OF INFORMATION RESOURCES: Managing the acquisition, structuring, analysis and display of data and information in the chosen area of specialisation and critically assessing the results obtained.
CT5. FOREIGN LANGUAGE: Achieving a level of spoken and written proficiency in a foreign language, preferably English, that meets the needs of the profession and the labour market.
CT3. TEAMWORK: Being able to work in an interdisciplinary team, whether as a member or as a leader, with the aim of contributing to projects pragmatically and responsibly and making commitments in view of the resources that are available.

Teaching methodology
Lectures (3h/week)
Group work or Individual work (distance):Technical Report
Oral presentations
Other activities
Extended answer test (Final Exam)
Learning objectives of the subject

The objective of this course is to train students in the methods of studying, analyzing, designing and evaluating the technologies-applications of optical sensors implemented with optical fibers. First, we consider the evolution of optical sensors in general, the importance of fiber optic sensors, their main technologies, and key devices, components and subsystems that allow the implementation of fiber sensor systems. A key chapter is dedicated to the analysis and design of the OTDR subsystem that will allow to know the exact distance to the optical fiber segment where the measurement (temperature, vibration, etc.) is carried out in distributed fiber sensors. Because fiber optics can behave like a distributed sensor, the practical application of such sensors is now very relevant for sensing applications in tens of kilometers with a single interrogator at one end. For measurements at discrete points, fiber sensors with Bragg Grating (FBG) are the most widely used for their simplicity and performance. Finally, we will analyze the sensors based on interferometers with fiber optic technology, mainly a Fabry Perot cavity implemented by optical fiber. Finally, the industrial applications of these sensors will be analyzed, commenting on the applications of the low-cost sensors based on plastic fibers, and the applications of the optical sensors for the technology and the development of Smart-Cities.

Learning results of the subject:
- Ability to analyze, specify, design optical sensors (and sensor networks) implemented with optical fiber: distributed, non-distributed, quasi-distributed and discrete.
- Ability to develop solutions and applications for different types of fiber sensors: temperature, voltage-deformation, vibration, acoustic, etc.
- Ability to analyze and design the interrogation systems for different types and applications of sensors.
- Ability to analyze and design a key subsystem: Optical Time Domain Reflectometer (OTDR)
- Ability to analyze the importance of optical sensors for the development of technologies related to "Smart Cities" and Energy Efficiency.

Study load

<table>
<thead>
<tr>
<th>Total learning time: 125h</th>
<th>Hours large group: 39h</th>
<th>31.20%</th>
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<tbody>
<tr>
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<td>Hours medium group: 0h</td>
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<tr>
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<td>Hours small group: 0h</td>
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<td>Guided activities: 0h</td>
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<td>Self study: 86h</td>
<td>68.80%</td>
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## Content

### I. Introduction

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<thead>
<tr>
<th>Description:</th>
<th>Learning time: 12h</th>
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<tr>
<td></td>
<td>Theory classes: 5h</td>
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<td>Self study: 7h</td>
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- I.1.- Optical sensors: A historical perspective
- I.2.- Fiber-Optic Sensors: Fundamentals and Applications
- I.3.- Optical fibre technology:
  - Fiber optics
  - Components, Devices and Subsystems
- I.4.- Types of optical fiber sensors:
  - Quasi-distributed sensing networks
  - Distributed fiber optic sensing
  - Fiber Bragg Grating sensors
  - Interferometric sensing

### II. Optical Time Domain Reflectometry (OTDR)

<table>
<thead>
<tr>
<th>Description:</th>
<th>Learning time: 19h 30m</th>
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<tbody>
<tr>
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<td>Theory classes: 8h 30m</td>
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<td>Self study: 11h</td>
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- II.1.- Principles of optical time domain reflectometry (OTDR) for distributed sensing.
- II.2.- Types of OTDR
- II.3.- Types of lasers for OTDR
- II.4.- OTDR based Coding
- II.5.- Basic subsystems
- II.6.- Considerations for designing:
  - SNR
  - Sensing range
  - Resolutions
  - Time data acquisition and processing system
  - Etc.
### III. Distributed fiber sensing technology

**Description:**

III.1. - Raman-based distributed temperature sensors (DTS):
- Theory
- Bloc diagram
- Interrogator system
- Performances

III.2. - Brillouin based distributed temperature and strain sensors:
- Theory
- Bloc diagram
- Interrogator system
- Performances

III.3. - Rayleigh backscatter: distributed acoustic and vibration sensors
- Theory
- Bloc diagram
- Interrogation system
- Performances

III.4. - FPGA architecture desing for Distributed fiber sensors

**Learning time:** 24h 30m
- Theory classes: 11h 30m
- Self study: 13h

### IV. Fiber Bragg Grating (FBG) sensors

**Description:**

IV.1. - Bragg Gratings in Optical Fibers: Fundamentals and Applications
IV.2. - Interrogator system
IV.3. - High Capacity WDM Distributed Sensing System Using FBGs
IV.4. - Performances
IV.5. - Optical fibers with high-quality FBG arrays
IV.6. - FBGs in multicore fiber for curvature sensing

**Learning time:** 22h
- Theory classes: 9h
- Self study: 13h
# 230705 - OSEN - Optical Fiber Sensor Technologies

## V. Fiber Optic Interferometric sensing

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<tbody>
<tr>
<td>V.1.- Overview of fiber-optic Interferometric sensing</td>
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<tr>
<td>V.2.- Fiber Fabry-Perot (FFP) sensing technology</td>
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<td>V.3.- Performances of FFP</td>
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<th>Learning time:</th>
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<tr>
<td>12h 40m</td>
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<td>Theory classes: 5h 40m</td>
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<td>Self study : 7h</td>
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## VI. Applications of fiber optic sensors

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<td>VI.1.-Applications of distributed temperature sensors</td>
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<tr>
<td>VI.2.- Distributed strain sensors: practical issues, solutions and applications</td>
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<tr>
<td>VI.3.- Applications of distributed vibration sensors (DVS)</td>
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<td>VI.4.- Other types of distributed sensors and their applications</td>
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<td>VI.5.- Applications of Fiber Bragg Grating sensors</td>
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<td>VI.6.- Applications of fiber-optic Interferometric sensors</td>
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<td>VI.7.- Applications of plastic fiber-optic sensors</td>
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<td>VI.8.- Applications to Smart Cities</td>
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<tr>
<td>9h</td>
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<td>Theory classes: 4h</td>
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<td>Self study : 5h</td>
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## Planning of activities

| **TECHNICAL REPORT** | **Hours:** 29h  
Theory classes: 0h  
Self study: 29h |
|---------------------|------------------|
| **Description:**    | Technical Report: This activity involves the preparation of a Technical Work, in groups of 2 or 3 students, which must be delivered in PowerPoint format and presented to the class at the end of the course.  
Oral Presentation: Oral presentation of Technical Report (30 minutes)  
Final exam (90 minutes) |
| **Support materials:** | For this course ATENEA will be the virtual teaching support tool. From there the students will be able to download all the documents (slides, related papers, etc.) related to the course. |
| **Descriptions of the assignments due and their relation to the assessment:** | Technical Report: 3 week before the end of course |
| **Specific objectives:** | Evaluate technical research done in group on a subject related to the course. |

| **ORAL PRESENTATION** | **Hours:** 0h 45m  
Laboratory classes: 0h 45m |
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<tr>
<td><strong>Description:</strong></td>
<td>Technical Report Presentation of a work group</td>
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<tr>
<td><strong>Support materials:</strong></td>
<td>Power point presentation</td>
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<tr>
<td><strong>Specific objectives:</strong></td>
<td>To evaluate the ability to present oral in group and individually results of the technical report</td>
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| **FINAL EXAM** | **Hours:** 1h 30m  
Theory classes: 1h 30m |
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<tbody>
<tr>
<td><strong>Description:</strong></td>
<td>Final Exam</td>
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## Qualification system

Final examination: 40%  
Individual assessment: 10%  
Group assessments: 50% (*Technical Report*, group technical work)

## Regulations for carrying out activities

On the final exam students will be able to bring all kinds of technical information (slides, books, related papers of the course, etc.)
For this course ATENEA will be the virtual teaching support tool. From there the students will be able to download all the documents (slides, related papers, etc.) of the course.