Course guide
230705 - OSEN - Optical Fiber Sensor Technologies

Last modified: 25/05/2023

Unit in charge: Barcelona School of Telecommunications Engineering
Teaching unit: 739 - TSC - Department of Signal Theory and Communications.

Degree: MASTER'S DEGREE IN TELECOMMUNICATIONS ENGINEERING (Syllabus 2013). (Optional subject).
MASTER'S DEGREE IN ADVANCED TELECOMMUNICATION TECHNOLOGIES (Syllabus 2019). (Optional subject).

Academic year: 2023 **ECTS Credits:** 5.0 **Languages:** English

LECTURER

Coordinating lecturer: Consultar aquí / See here:
https://telecos.upc.edu/ca/estudis/curs-actual/professorat-responsables-coordinadors/responsables-assignatura

Others: Consultar aquí / See here:
https://telecos.upc.edu/ca/estudis/curs-actual/professorat-responsables-coordinadors/professorat-assignat-idioma

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 (work-technical report on a subject related to Optical fiber Sensors)
Presentations of Technical Reports.
Final Exam: Extended answer test

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, the importance of fiber optic sensors, their main technologies, and key devices, components and subsystems that allow the implementation of fiber sensor systems. The next chapter is dedicated to the analysis and design of the OTDR subsystem that will allow to know the exact distance in the fiber optic segment where the distributed fiber sensors perform the measurements (temperature, strain, vibration, etc.). Then the main distributed optical fiber sensors (Rayleigh, Raman and Brillouin) will be analyzed. 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 only 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, 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, strain-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

Type	Hours	Percentage
Hours large group	39,0	31.20
Self study	86,0	68.80

Total learning time: 125 h

CONTENTS

I. Introduction

Description:
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-distibuted sensing networks
Distributed fiber optic sensing
Fiber Bragg Grating sensors
Interferometric sensing

Full-or-part-time: 10h
Theory classes: 4h
Self study : 6h

II. Optical Time Domain Reflectometry (OTDR)

Description:
II.1.- OTDR: Applications for Distributed Optical Fiber Sensors
II.2.- OTDR: Operating Principles
II.3.- OTDR: Limitations
II.4.- OTDR: Alternatives for High-Performance Long-Haul
II.5.- OTDR: Signal Averaging
II.6.- OTDR: Correlation Techniques
II.7.- OTDR: Complementary Codes
II.8.- OTDR: Correlation Gain
II.9.- Phase-OTDR

Full-or-part-time: 19h 30m
Theory classes: 8h 30m
Self study : 11h

III. Raman-Distributed Temperature Sensors (Raman-DTS)

Description:
III.1.- Raman-DTS
III.2.- Raman scattering
III.3.- Raman-DTS: Temperature measurements
III.4.- Raman-DTS System
III.5.- Raman-DTS Performances
III.6.- Raman-DTS with Loop Configuration
III.7.- Raman-DTS: Long-Range (LR) with Hybrid Configuration
III.8.- Raman-DTS: LR with Coded-OTDR and Discrete Raman Amplification
III.9.- Raman-DTS: Anti-Stokes Raman with Rayleigh Loss Correction
III.10.- Raman-DTS: Dual Sources separated by Stokes Shifts
III.11.- Raman-DTS: Applications

Full-or-part-time: 14h
Theory classes: 6h 30m
Self study : 7h 30m

IV. Brillouin-Distributed Fiber Sensors (Brillouin-DFS)

Description:
IV.1- Brillouin Scattering
IV.2- Brillouin-DFS
IV.3- Brillouin-DFS: Interrogation Techniques
IV.4- Brillouin-DFS System Performances
IV.5- Brillouin-DFS: Applications

Full-or-part-time: 13h
Theory classes: 6h
Self study : 7h

V. Fiber Bragg Grating (FBG) Sensors

Description:
V.1- Bragg Grating in Optical Fiber
V.2- Fiber Bragg Grating: Temperature and Strain Sensor
V.3- FBG Interrogator System
V.4- High Capacity FBG-WDM Sensing System
V.5- FBG Sensor with High Birefringent Optical Fiber
V.6- FBG Sensor: Benefits and Applications
V.7- FBGs in multicore fiber for 3D sensing
V.8- Appendix: Strain definitions

Full-or-part-time: 22h
Theory classes: 9h
Self study : 13h

VI. Distributed Acoustic Sensing (DAS)

Description:
VI.1- DAS: Introduction
VI.2- DAS: Interrogation Techniques
VI.3- DAS: Signal Processing
VI.4- DAS: Applications

Full-or-part-time: 12h 40m
Theory classes: 7h
Self study : 5h 40m

VII. Applications of Fiber Optic Sensors

Description:
VII.1.- Applications of Distributed Temperature Sensors (DTS)
VII.2.- Distributed Strain Sensors (DSS): practical issues, solutions and applications
VII.3.- Applications of Distributed Acoustic Sensors (DAS)
VII.4.- Applications of Distributed Vibration Sensors (DVS)
VII.5.- Applications of Fiber Bragg Grating Sensors (FBG-Sensors)
VII.6.- Applications of Plastic Fiber-Optic Sensors (PFOS)
VII.7.- Applications to IoT and Smart Cities
VII.8.- Applications of New Optical Fibers (SDM and FMF) to sensing technologies

Full-or-part-time: 9h
Theory classes: 5h
Self study : 4h

ACTIVITIES

Technical Report

Description:
Technical Report: This activity involves the preparation of a Technical Work, in groups of 1 or 2 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)

Specific objectives:
Evaluate technical research done individually or in group on a subject related to the course.

Material:
For this course ATENEA will be the virtual teaching support tool. From ATENEA the students will be able to download all the documents (slides, reports, articles, etc.) related to the course-Technical Report.

Delivery:
Technical Report:1 week before the end of course

Full-or-part-time: 29h
Self study: 29h

Oral Presentation: Technical Report

Description:
Technical Report Presentation

Specific objectives:
To evaluate the ability to present oral in group and individually results of the technical report

Material:
Power Point presentation

Full-or-part-time: 0h 45m
Laboratory classes: 0h 45m

FINAL EXAM

Description:
Final Exam

Full-or-part-time: 1h 30m
Theory classes: 1h 30m

GRADING SYSTEM

Final examination: 40%
Individual assessment: 10%
Technical Report: 50%

EXAMINATION RULES.

On the final exam students will be able to bring all kinds of technical information (slides, books, related papers of the course, etc.)

BIBLIOGRAPHY

Basic:
- Hartog, Arthur H.. An Introduction to distributed optical fibre sensors [on line]. CRC Press, 2017 [Consultation: 22/04/2020]. Available on: https://ebookcentral.proquest.com/lib/upcatalunya-ebooks/detail.action?docID=4865550. ISBN 9781351645300.
- Patil, Supriya; Shjaligram, Arvind. Fiber optic sensors : design to prototype. Lap Lambert Academic Publishing, 2016. ISBN 9783659887666.

Complementary:
- Rao, Yun-Jiang ; Ran, Zeng-Ling; Gong, Yuan. Fiber-Optic Fabry-Perot Sensors: An Introduction [on line]. CRC Press, 2017 [Consultation: 22/04/2020]. Available on: https://ebookcentral.proquest.com/lib/upcatalunya-ebooks/detail.action?docID=4850461. ISBN 9781498736947.
- Mulualem, Yelkal. FPGA Architecture design for distributed optical fiber sensors. Lap Lambert Academic Publishing, 2016. ISBN 9783659892233.

RESOURCES

Hyperlink:
- Nom recurs. 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.