# COURSE SYLLABUS

## Academic Year: 2024/2025

| Identification and characteristics of the course | | | | |
|---|---|---|---|---|
| Code | 401091 | | ECTS credits | 6 |
| Course title (English) | Devices for Radiofrequency and Optical Communications | | | |
| Course title (Spanish) | Dispositivos de Radiofrecuencia y de Comunicaciones Ópticas | | | |
| Degree program | Master in Telecommunication Engineering | | | |
| Faculty/School | Escuela Politécnica | | | |
| Semester | 2º | Course type (compulsory/optional) | Compulsory | |
| Module | Telecommunication Technologies | | | |
| Subject matter | Communication Systems and Technologies | | | |
| Lecturer/s | | | | |
| Name | | Room | E-mail | Web page |
| Yolanda Campos Roca | | 27 (Telecommunication Building) | ycampos@unex.es | Virtual campus |
| Rafael Gómez Alcalá | | 7 (Telecommunication Building) | rgomezal@unex.es | Virtual campus |
| Subject Area | Signal Theory and Communications | | | |
| Department | Computer and Communication Technologies | | | |
| Coordinator (Only if there is more than one lecturer) | Yolanda Campos Roca | | | |

## Competencies

### Basic competencies

CB6. Knowledge and understanding that provide a basis or opportunity for originality in developing and / or applying ideas, often in a research context.

CB7. Ability to apply the acquired knowledge and their ability to solve problems in new or unfamiliar environments within broader (or multidisciplinary) contexts related to their area of study.

CB8. Ability to integrate knowledge and face the complexity of making judgments based on information that, being incomplete or limited, includes reflections on social and ethical responsibilities linked to the application of their knowledge and judgments.

CB9. Skills to communicate conclusions, and the knowledge and rationale underpinning these, to specialized and non-specialized audiences in a clear and unambiguous way.

CB10. Learning skills that enable to continue studying in a way that will be largely self-directed or autonomous.

### General competencies

CG1. Ability to plan, calculate and design products, processes and facilities in all areas of telecommunication engineering.

CG4. Capacity for mathematical modelling, calculation and simulation in technology centres and engineering companies, particularly in research, development and innovation in all areas related to the Telecommunications Engineering and related multidisciplinary fields.

CG8. Ability to apply the acquired knowledge and solve problems in new or unfamiliar environments in broader and multidisciplinary contexts, being able to integrate this knowledge.

CG9. Ability to understand and apply the ethical responsibility, the legislation and the professional ethics of the telecommunication engineer.

CG11. Ability to learn to communicate (oral and written) findings, and the knowledge and rationale underpinning these, to public-skilled and unskilled in a clear and unambiguous way.

CG12. Possess skills for self-directed and autonomous lifelong learning.

## Transverse competencies

CT01: Innovative and entrepreneurial spirit.
CT04: Skills to communicate conclusions, along with the knowledge and the reasons behind them, to specialized and non-specialized audiences, both orally and in writing, in Spanish and English.
CT05: Ability to work as a team member.
CT07: Critical thinking skills and creativity as a means to have the opportunity to be original in the generation, development and / or application of ideas in a research or professional context.
CT8: Responsibility and ethical commitment in the performance of professional and research activity.
CT9: Respect for and promotion of human rights, democratic principles, the principles of equality between women and men, solidarity, universal accessibility and design for all, prevention of occupational risks, protection of the environment and promotion of the culture of peace.
CT10: Focus on quality and continuous improvement.
CT11: Autonomous learning capacity.
CT12: Ability to solve problems in new or unfamiliar environments within broader (or multidisciplinary) contexts.
CT13: Ability to integrate knowledge and face the complexity of formulating opinions from incomplete or limited information.

## Specific competencies

CETT10. Ability to design and manufacture integrated circuits.

CETT13. Ability to design communication components such as routers, switches, hubs, transmitters and receivers in different bands.

CETT14. Ability to apply advanced knowledge of photonics and optoelectronics, and high frequency electronics.

## Contents

Course outline

Applications of radio frequency (RF) and microwave integrated circuits. Available technologies. Two-terminal devices. Three-terminal devices. Experimental characterization and modeling. Introduction to the design of RF and microwave circuits: design methodology, passive circuits,

active circuits. Computer-aided design. Introduction to the manufacturing process of integrated RF and microwave circuits. Introduction to optical communication devices. Manufacturing, wiring and joining of optical fibers. Passive optical devices. Optical amplifiers. Anisotropic and nonlinear effects in dielectrics and optical fibers. Integrated devices for optical communications. Measurement and instrumentation for optical communications.

Course contents

Block 1: Analysis and design of RF circuits.
Block 2: Optical communication devices.

## Block 1. Analysis and Design of RF Circuits

Title of Theme 1: Course overview.

Title of Theme 2: Analysis and characterization of microwave networks.

Contents of Theme 2:

1. Introduction
2. S-parameter matrix
3. Network analyzer

Description of practical activities for Theme 2:

Assignment 1. Introduction to circuit simulation software and S-parameter simulation.
Assignment 2. Simulation of ideal transmission lines.

Title of Theme 3: Planar transmission lines

Contents of Theme 3:

1. Types of planar transmission lines.
2. Microstrip.
3. Coplanar waveguides and grounded coplanar waveguides.

Description of practical activities for Theme 3:

Assignment 3. Design and simulation of microstrip transmission lines. Parameter optimization
Assignment 4. Electromagnetic simulation

Title of Theme 4: Microwave semiconductor devices

Contents of Theme 4:

1. Materials
2. High-frequency semiconductor devices.
3. Bipolar and field-effect transistors.
4. Transistor models.

Description of practical activities for Theme 4: no activities.

Title of Theme 5: Introduction to the design of RF and microwave circuits.

Contents of Theme 5:

1. Introduction to the design of passive and active circuits.
2. Types of microwave circuits.
3. Design methodology.
4. Design example: low-noise amplifier.

Description of practical activities for Theme 5:
Assignment 5. Active circuit design.
Assignment 6. Design of a passive circuit from its specifications.
Assignment 7. Prototype construction of the passive design in printed circuit board (PCB) technology, and experimental characterization

Title of Theme 6: Activities related to the design and manufacturing of RF circuits in Extremadura, Spain and the European Union

Contents of Theme 6:
1. Professional activities
2. Research activities

Description of practical activities for Theme 6: no activities.

**BLOCK 2. Optical Communication Devices.**

Title of Theme 7: Optical passive devices
Contents of Theme 7:
1. Introduction and classification
2. Matrix characterization
3. Propagation in optical fiber
4. Attenuators

Description of practical activities for Theme 7:
Assignment 8. Optical fiber communication.

Title of Theme 8: Devices for polarization control

Contents of Theme 8:
1. Optical polarizers
2. Wave retarders
3. Polarization rotators
4. Polarization dividers and combiners

Description of practical activities for Theme 8: no activities.

Title of Theme 9: Devices for lightwave guidance control

Contents of Theme 9:

1. Optical isolators
2. Optical circulators
3. Integrated waveguides
4. Mode coupling

Description of practical activities for Theme 9:
Assignment 9. Integrated waveguides.

Title of Theme 10: Optical filters

Contents of Theme 10:

1. Fabry-Perot filter
2. Mach-Zehnder interferometer
3. Sagnac interferometer

4. Optical fiber resonant rings
5. Optical bulk filters

Description of practical activities for Theme 10:
Assignment 10. Optical filters.

Title of Theme 11: Introduction to optical amplifiers

Contents of Theme 11:

1. Operating principle
2. Gain saturation
3. Equations for the four-level optical amplifier
4. Equations for the three-level optical amplifier
5. Dynamic response and signal distortion
6. Optical amplifier noise

Description of practical activities for Theme 11: no activities.

Title of Theme 12: Semiconductor laser amplifiers

Contents of Theme 12:

1. Amplifier structure and design
2. A model for the semiconductor laser amplifier
3. Dynamic behaviour of the semiconductor laser amplifier
4. Considerations about noise in SLA amplifiers
5. Semiconductor laser.

Description of practical activities for Theme 12: no activities.

Title of Theme 13: Doped fiber amplifiers

Contents of Theme 13:
1. General principles

Description of practical activities for Theme 13:
Assignment 11. Doped fiber amplifier

## Educational activities

| Student workload (hours per lesson) | | Lectures | Practical sessions | | | | Monitoring activity | Homework |
|---|---|---|---|---|---|---|---|---|
| Lesson | Total | L | HI | LAB | COM | SEM | SGT | PS |
| Block 1: Analysis and design of RF circuits | | | | | | | | |
| 1 | 1 | 1 | | | | | | |
| 2 | 7 | 2 | | | 1 | | | 4 |
| 3 | 9.5 | 3 | | | 2 | | | 4.5 |
| 4 | 7 | 3 | | | | | | 4 |
| 5 | 44 | 9 | | | 5 | | | 30 |
| 6 | 3 | 2 | | | | | | 1 |
| Block 2: Devices for optical communications | | | | | | | | |
| 7 | 7 | 2 | | | 2 | | | 3 |
| 8 | 2.5 | 1 | | | | | | 1.5 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 9 | 7 | 2 | | | 2 | | | 3 |
| 10 | 7 | 2 | | | 2 | | | 3 |
| 11 | 14 | 4 | | | | | | 10 |
| 12 | 13 | 4 | | | | | | 9 |
| 13 | 13 | 4 | | | 1 | | | 8 |
| **Evaluation** | 15 | 3+3 | | | | | | 9 |
| **TOTAL** | 150 | 45 | | | 15 | | | 90 |

L: Lectures (100 students).
HI: Hospital internships (7 students)
LAB: Lab sessions or field practice (15 students)
COM: Computer room or language laboratory practice (20 students).
SEM: Problem-solving classes, seminars or case studies (40 students)
SGT: Scheduled group tutorials (educational monitoring, ECTS-type tutorials)
PS: Personal study, individual or group work and reading of bibliography

## Teaching methodology

1. **Expositive and participatory lectures (LG).** Activities for the entire group. The methodology used in these activities will combine presentation and discussion of theoretical and practical contents using video-projector and, occasionally, the board. Slides will be available to the students prior to the explanation of each topic.

2. **Lab assignments.** Regarding Block 1 (about RF and microwave devices), practical assignments will be conducted, aimed at familiarizing students with ADS software. These assignments will offer the students a preparation to be able to address the design project described in point 3. In relation to Block 2 (on optical communication devices), the students will use a demo version of the comercial software Optiwave and other open-source software packages.

3. **Prototype project.** The students will carry on a project consisting in the design, construction and experimental characterization of one or several microwave circuits. In the realization of this project, the methodology known as Project Based Collaborative Learning (PBCL) will be used. This project involves several phases of development, some of which will be addressed in the classroom and others as non-classroom activities: theoretical design, simulation, manufacturing and measurement. Unlike the lab assignments described in point 2, for the realization of this project the student must work autonomously (thus guaranteeing the development of CT11 and CT12 competencies).

4. **Non-classroom work**. This block includes all the activities undertaken by students in non-classroom time. In relation to the lectures, the student should review the concepts and techniques presented. Regarding the lab assignments, the student should read the written statements before the realization. With respect to the design project, students should look for information related to the type of circuit proposed and perform the calculations corresponding to the theoretical design. In addition, once the circuit is manufactured and experimentally characterized, they should write a report about it. Regarding the lab assignments on optical communication devices, students should write the report during non-classroom time.

## Learning outcomes

1. Ability to plan, calculate and design products, processes and facilities in all areas of telecommunication engineering. The specific competencies of this subject and the following transverse competencies contribute to the achievement of this learning result: CT01, CT07, CT10-CT13.

2. Ability to lead, plan and supervise multidisciplinary teams. The development of competencies CT05, CT07, CT10-CT13 contributes to achieving this goal.

3. Capacity for mathematical modeling, calculation and simulation in technology centres and engineering companies, particularly in research, development and innovation in all areas related to the Telecommunications Engineering and related multidisciplinary fields. The specific competencies of this subject and the following transverse competencies contribute to the achievement of this learning result: CT01, CT07,CT10-CT13

4. Capacity for the development, strategic planning, direction, coordination and technical and financial management of projects in all areas of the Telecommunications Engineering, following environmental and quality criteria.

5. Capacity for the overall direction, technical direction and project management research, development and innovation, in companies and technology centers.

6. Capacity for implementation, and management of manufacturing processes of electronic and telecommunications, with a guarantee of safety for people and goods, the final quality of the products and their approval. All the competencies associated to this course contribute to this learning outcome.

7. Ability to apply the acquired knowledge and solve problems in new or unfamiliar environments in broader and multidisciplinary contexts, being able to integrate this knowledge. The following transverse competencies contribute to the achievement of this goal: CT01, CT07, CT11, CT13.

8. Ability to apply principles of economics and human resource management and projects as well as legislation, regulation and standardization of telecommunications. All the competencies associated to this course contribute to this learning outcome.

9. Ability to learn to communicate (oral and written) findings, and the knowledge and rationale underpinning these, to public-skilled and unskilled in a clear and unambiguous way. This learning outcome is associated to CT4 competency.

10. Possess skills for self-directed and autonomous lifelong learning. This learning outcome is associated to CT11 competency.

11. Knowledge, understanding and ability to implement the necessary legislation in the exercise of the profession of Telecommunication Engineer. All the competencies associated to this course contribute to this learning outcome.

## Assessment methods

During the first three semester weeks, the student can choose between two different evaluation types: continuous assessment or final exams. To do this, a query will be available in the virtual classroom.

1. Continuous assessment modality. It will consist of:
    - **Written exams (60%).** Recoverable activities in June, July and January of the next year. There will be two multiple-choice exams (one approximately in the middle

of the semester, at the end of the first block, and another one on the last days of the teaching period). The minimum grades are 4 out of 10 points in each multiple-choice exam and an average grade of 5 out of 10 points. These exams are multiple choice tests and will include some questions in English related to the videos provided (see competence CT04). These exams may also include some questions regarding the practical sessions.

- **Experimental design project of a microwave circuit (25%).** The assessment of this project will be based on the prototype, the report and, when appropriate, the defense of the project. The minimum grade for this project is 3 out of 10 points. This activity is non-recoverable in May-June and recoverable in July and January of the next year through a specific practical exam, as the one described in the global assessment modality.

- **Practical work about simulation of optical communication devices (15%).** Assessment of this practical work will be based on a report on a concrete aspect of the simulations. The originality of the report will be taken into account. It is compulsory that the report includes all the practical work covered in this part. The minimum grade for this project is 3 out of 10 points. This activity is non-recoverable in May-June and recoverable in July and January of the next year through a specific practical exam, as the one described in the global assessment modality.

The grades of all the activities that have reached the minimum grade will be kept until January of the following academic year, but not later. If a student had already reached the minimum grade and tries to improve it, the final grade will be calculated by considering the last grade, not the best one.

2. Global assessment modality. They will consist of:
   - **Written exams (60%).** These are the same type of partial exams used in the continuous assessment (multiple choice tests). The minimum grades are also equal.
   - **Specific practical test on RF circuits (25%).** Written exam about the laboratory work. The minimum grade is 3 out of 10 points**.**
   - **Specific practical test about simulation of optical communication devices (15%).** Written exam about the laboratory work.

To pass the course under both assessment modalities it is required that the following two conditions are fulfilled:

1) The student should reach the minimum grades established.
2) The student should obtain a minimum grade of 5 by applying the following expression:

$$\text{Grade} = 0.60*(P1 + P2)/2 + 0.25*\text{PractRF} + 0.15*\text{PractOpticalCom}$$

where P1 and P2 are the grades of the multiple choice tests, PractRF is the grade of the RF project or the specific practical exam about RF circuits and PractOpticalCom is the grade of the practical work (or the specific exam that substitutes it) about simulation of optical communication devices.

If the student does not reach the minimum grades required, the final grade will be calculated as the minimum value between the one obtained by applying one of the previous expressions and 4.

**Particular needs:**

- Students with any disability: The Student Service Unit in cooperation with the lecturers will establish an adaptation to the particular circumstances.
- Foreign students: Possibility to take the exam in English. Contact the lecturers.

## Bibliography (basic and complementary)


Bibliography on radiofrequency devices:

[1] Michael Steer, Microwave and RF Design. Open Textbook Library (https://open.umn.edu/opentextbooks/). 2019. **Creative Commons license**.

[2] David Pozar. Microwave Engineering. John Wiley & Sons, 3rd Edition, 2004.

[3] I. A. Glover, S. R. Pennock, P. R. Shepherd. Microwave devices, circuits and subsystems for communications engineering, John Wiley & Sons, 2005.

[4] Inder Bahl, Prakash Bhartia. Microwave Solid State Circuit Design, Wiley, 2003.

[5] S. Maas. Nonlinear Microwave and RF Circuits. 2nd Edition, Artech House, 2003

[6] Rowan Gilmore, Les Besser. Practical RF Circuit Design for Modern Wireless Systems. Vol I: Passive Circuits and systems, Artech House, 2003.

[7] E. Sánchez, Introducción a los dispositivos y circuitos semiconductores de microondas", Pearson Educación, 2012.

Bibliography on devices for optical communications:

[8] J. Capmany, F.J. Fraile Peláez, J. Martí. Dispositivos de Comunicaciones Ópticas, Editorial Síntesis, 1999.

[9] Binh, Le Nguyen. Optical fiber communications systems: theory and practice with MATLAB and Simulink models, CRC Press, 2010.

[10] G. P. Agrawal, Lightwave Technology: Components and Devices, Wiley. 2004.


## Other resources and complementary materials

Virtual classroom (download slides, lab assignments, resources for Project Based Learning work, forums, etc.): http://campusvirtual.unex.es/

Web pages about radiofrequency circuits:

[11] https://www.qsl.net/va3iul/ Wide collection of RF resources.

[12] S. J. Orfanidis. Electromagnetic Waves and Antennas, http://eceweb1.rutgers.edu/~orfanidi/ewa/ewa-1up.pdf Free electronic book.

[13] http://www.amanogawa.com/archive/transmissionB.html *Applets* about transmission line theory.

[14] http://sss-mag.com/smith.html#tutor Resources about the Smith Chart.

[15] John Bushie and Anaya Vardya. 2018. BR Publishing, Inc. https://www.ieee.li/pdf/essay/rf-microwave_pcb_fundamentals.pdf

[16] Dr. Raymond Rumpf. Microwave Engineering. https://empossible.net/academics/emp4301_5302/

[17] https://rickettslab.org/radio-system-design/lectures/lecture/ Collection of video lectures from Prof. David S. Ricketts.