Course guide
300031 - ERF - RF Engineering

Last modified: 22/01/2024

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

Degree: BACHELOR'S DEGREE IN TELECOMMUNICATIONS SYSTEMS ENGINEERING (Syllabus 2009). (Compulsory subject).

Academic year: 2023 **ECTS Credits:** 10.5 **Languages:** Catalan, Spanish, English

LECTURER

Coordinating lecturer: Definit a la infoweb de l'assignatura.

Others: Definido en la infoweb de la asignatura.

PRIOR SKILLS

Good capability to operate complex numbers

REQUIREMENTS

Prerequisite:
- Electromagnetic Waves in Communications Systems

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
1. CE 23 SIS. Capacidad de análisis de componentes y sus especificaciones para sistemas de comunicaciones guiadas y no guiadas. (CIN/352/2009, BOE 20.2.2009.)
2. CE 24 SIS. Capacidad para la selección de circuitos, subsistemas y sistemas de radiofrecuencia, microondas, radiodifusión, radioenlaces y radiodeterminación. (CIN/352/2009, BOE 20.2.2009.)

Generical:
7. EFFICIENT USE OF EQUIPMENT AND INSTRUMENTATION - Level 3: Design experiments, measurements, subsystems and systems, equipment and tools most appropriate laboratory. Knowing not only benefits but also the limitations of the equipment and resources. Conduct assessments and evaluations critically, making decisions according to the overall system specifications or service.

Transversal:
3. SELF-DIRECTED LEARNING - Level 1. Completing set tasks within established deadlines. Working with recommended information sources according to the guidelines set by lecturers.
4. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.
5. TEAMWORK - Level 1. Working in a team and making positive contributions once the aims and group and individual responsibilities have been defined. Reaching joint decisions on the strategy to be followed.
6. EFFECTIVE USE OF INFORMATI0N RESOURCES - Level 1. Identifying information needs. Using collections, premises and services that are available for designing and executing simple searches that are suited to the topic.

TEACHING METHODOLOGY

This course introduces common design techniques of high frequency networks, different manufacturing technologies, and the terminology used in the industry to define the performance of the networks.
With this goal in mind, the methodology includes lectures supported by problems and laboratory simulations. Both, at the classroom and at the lab a professional CAD tool is used for the analysis and design of radiofrequency networks. Lab sessions mainly consider the design and simulation of radiofrequency networks using the knowledge provided during the lectures and the application notes provided by manufacturers. During the lab sessions, the students report their work in order to review the documents when self-studying.

LEARNING OBJECTIVES OF THE SUBJECT

By the end of the term, the student is able to:
• Understand the operating principle of electrically small devices and the main networks that can be designed with them.
• Obtain the equations of voltage and current in an ideal transmission line from an infinitesimal section. Also the student is able to calculate the voltage and current distribution (phasors and time domain) in a transmission line given a source and load.
• Match the impedance of a transmission line using lumped elements, quarter wave impedance transformers, and short-circuited and open-circuited transmission line sections, and to be able to explain the procedures.
• Calculate the attenuation of a transmission line or cable from its primary parameters, and to calculate the attenuation and losses of systems having transmission lines.
• Operate with the scattering parameters (S parameters): to know their definition, how are they measured, and how to shift the reference planes. From these parameters, to infer whether a device is active or passive, and whether it is lossy or lossless.
• Calculate the scattering matrix of a simple two port (made with transmission line sections and/or lumped elements, in series or shunt).
• Regarding two-port, three-port and four-port networks: to explain their mission in a system, to know their scattering matrices, and to solve simple problems involving networks (to compute return losses, insertion losses or gain, coupling, directivity, isolation).
• Identify different manufacturing technologies of high frequency networks (hybrid planar networks, monolithic networks, guided wave networks, MEMS ...) and to know their potential.
• Design microstrip networks from given technical specifications: filters, multiplexors, splitters/combiners, directional couplers, hybrids, switches, mixers, amplifiers, and oscillators.
• Know the main characteristics and manage to use a professional software tool for the design of radiofrequency networks and devices.
• Know the characteristics of common instrumentation in a radiofrequency laboratory: spectrum analyzer, vector network analyzer, signal generator, etc.
• Understand the block diagram of a common RF transceptor and to know some common techniques for subsystem design.

STUDY LOAD

Type	Hours	Percentage
Self study	151,5	57.71
Hours small group	48,0	18.29
Hours large group	63,0	24.00

Total learning time: 262.5 h

CONTENTS

Introduction to distributed circuit design

Description:
The topics in this lesson are:
• Transmission lines
o Reflection coefficient and Smith chart
o Power and losses
• Transmission line design
o Homogeneous and non-homogeneous lines
o Balanced and unbalanced lines
o Coupled lines
• Impedance matching with lumped elements and transmission lines

Related activities:
Activity 1
Activity 2
Activity 3
Activity 4

Full-or-part-time: 72h
Theory classes: 15h
Laboratory classes: 16h
Self study : 41h

Microwave circuits characterization

Description:
The topics in this lesson are:
• Parameters used to characterize, masure and simulate microwave networks: Z, Y, ABCD, and S
• Properties and measurement of scattering parameters S
• Calculation of the scattering parameters S of two-port networks
• Interconnection of two-port networks
• Common two-port networks: attenuators, amplifiers, isolators, and filters
• Thre or more than three ports networks: power splitters/combiners, directional couplers, 90º hybrid, 180º hybrids, circulators

Related activities:
Activity 1
Activity 5

Full-or-part-time: 55h 30m
Theory classes: 13h 30m
Laboratory classes: 8h
Self study : 34h

Fabrication technologies, instrumentation, and CAD for RF applications

Description:
The topics in this lesson are:
• Fabrication technologies of radiofrequency devices
o Planar
o Waveguides and dielectrics
o Electro-acoustics
o Electro-optics
• Components. Encapsulation, tolerances, models, etc
• Instrumentation: spectrum analyzer, vector networ analyzer, noise figure analyzer, synthesizer/signal generator, oscilloscope, power detectors
• Instrumentation control software and protocols
• CAD software for the design and analysis of radiofrequency networks and devices
o Lumped elements simulator
o 2.5D simulators (method of moments)
o 3D simulators (frequency and time)
o Multiphysics

Related activities:
Activity 1

Full-or-part-time: 18h
Theory classes: 8h
Self study : 10h

Passive devices

Description:
The topics in this lesson are:
• Reactive elements design using transmission lines
• Discontinuities
• Two-port passive components design
o Resonatora
o Filters and multiplexers
o Splitters/Combiners
o Directional couplers and hybrids
o Switches
o Phase shifters
o Mixers
o Circulators and isolators
• Waveguide networks

Related activities:
Activity 1
Activity 5

Full-or-part-time: 57h
Theory classes: 15h
Laboratory classes: 8h
Self study : 34h

Active devices

Description:
The topics in this lesson are:
• Amplifying devices
o Low noise amplifiers
o Power amplifiers
• Oscillators
o RF oscillators
o Microwave oscillators

Related activities:
Activity 1
Activity 6

Full-or-part-time: 60h
Theory classes: 11h 30m
Laboratory classes: 16h
Self study : 32h 30m

ACTIVITIES

Classroom activities

Description:
Activities to be developed in the classroom during the lectures. They are simple problems that help the students to understand the explanations provided by the lecturer. Some of these problems are solved as a team and some others individually.

Material:
Problems' statements are provided by the instructor.

Delivery:
Evaluation during the problems control.

Full-or-part-time: 42h
Theory classes: 13h 30m
Self study: 28h 30m

Introduction to the CAD of radiofrequency circuits

Description:
Introduction to the computer aided design and characterization of radiofrequency circuits and devices.

Specific objectives:
• To know the main characteristics of and being familiar with a professional tool used for the design and analysis of radiofrequency circuits
• To know the diferent kinds of solvers
o Linear: DC, AC, S parameters
o Non linealr: Transient, Harmonic Balance, Circuit Envelope
o Estatistic

Material:
Guide for the use of the software in the lab

Delivery:
Evaluation during the laboratory control.

Full-or-part-time: 8h
Laboratory classes: 4h
Self study: 4h

Transmission line modeling using radiofrequency CAD

Description:
Modeling, characterization and equivalent performance of transmission lines in terms of their electrical length using professional radiofrequency CAD software.

Specific objectives:
• Transmission line characterization by means of its voltage and current phasors.
• Input impedance of a short-circuited/open-circuited tranmission line in terms of its electrical length.

Material:
Statements of the laboratory activities.

Delivery:
Evaluation during the laboratory control.

Full-or-part-time: 8h
Laboratory classes: 4h
Self study: 4h

Impedance matching

Description:
Design of impedance matching networks with lumped elements and with transmission lines using professional radiofrequency CAD.

Specific objectives:
• To match an antenna to a transceiver using an impedance matching network realizable in microstrip technology with SMD lumped elements.
• To design the impedance matching network using stubs.

Material:
Statements of the laboratory activities.

Delivery:
Evaluation during the laboratory control.

Full-or-part-time: 16h
Laboratory classes: 8h
Self study: 8h

Passive devices design

Description:
Design of passive devices in microstrip technology using professional radiofrequency CAD.

Specific objectives:
• To dessign passive hybrid microstrip networks given their specifications: power splitter, directional coupler, ressonator, and filter.
• To understand the constraints during the practical implementation of a network.

Material:
Statements of the laboratory activities.

Delivery:
Evaluation during the laboratory control.

Full-or-part-time: 32h
Laboratory classes: 16h
Self study: 16h

Active devices dessign

Description:
Design of active devices in microstrip technology using professional radiofrequency CAD.

Specific objectives:
• Design and characterization of a Low Noise Amplifier.
• Characterization of a mixer using Harmonic Balance analysis.

Material:
Statements of the laboratory activities.

Delivery:
Evaluation during the laboratory control.

Full-or-part-time: 16h
Laboratory classes: 8h
Self study: 8h

Integration and review

Description:
Integration of previous designs into a transceptor. Review of concepts.

Specific objectives:
• Integration of previously designed devices into a transceptor.
• Performance assessment of the integrated system.

Material:
Statements of the laboratory activities.

Delivery:
Evaluation during the laboratory control.

Full-or-part-time: 16h
Laboratory classes: 8h
Self study: 8h

GRADING SYSTEM

Defined at the course infoweb.

EXAMINATION RULES.

A scientific calculator operating with complex numbers is required.
The use of mobile phones is forbidden in any assessment.

BIBLIOGRAPHY

Basic:
- Pozar, David M. Microwave engineering [on line]. 3rd ed. New York [etc.]: John Wiley & Sons, 2005 [Consultation: 05/12/2022]. Available on: https://ebookcentral-proquest-com.recursos.biblioteca.upc.edu/lib/upcatalunya-ebooks/detail.action?pq-origsite=primo&docID=2064708. ISBN 0471448788.
- Bará Temes, Javier. Circuits de microones amb línies de transmissió [on line]. Barcelona: Edicions UPC, 1993 [Consultation: 15/04/2020]. Available on: http://hdl.handle.net/2099.3/36162. ISBN 8476533381.
- Collin, Robert E. Foundations for microwave engineering. 2nd student ed. New York: IEEE : Wiley-Interscience, [2012]. ISBN 9788126515288.

Complementary:
- González, Guillermo. Microwave transistor amplifiers : analysis and design. 2nd. Englewood Cliffs, N.J.: Prentice Hall, 1997. ISBN 0132543354.
- Hong, Jia-Shen G.; Lancaster, M. J. Microstrip filters for RF/Microwave applications. New York [etc.]: John Wiley & Sons, 2001. ISBN 047138877.
- Ramo, Simon; Whinnery, John R.; Van Duzer, Theodore. Fields and waves in communication electronics. 3rd ed. New York: John Wiley & Sons, 1994. ISBN 0471305782.
- Pozar, David M. Microwave and RF wireless systems. New York [etc.]: John Wiley & Sons, 2001. ISBN 0471322822.

RESOURCES

Other resources:
Application notes
Manuals