ANX-PR/CL/001-01

LEARNING GUIDE

SUBJECT

93000922 - Radiofrequency Technologies

DEGREE PROGRAMME

09AT - Master Universitario en Teoria de la Señal y Comunicaciones

ACADEMIC YEAR & SEMESTER

2020/21 - Semester 1

Index

Learning guide

1. Description

1.1. Subject details

Name of the subject	93000922 - Radiofrequency Technologies
No of credits	6 ECTS
Type	Optional
Academic year ot the programme	First year
Semester of tuition	Semester 1
Tuition period	September-January
Tuition languages	English
Degree programme	09AT - Master Universitario en Teoria de la Señal y Comunicaciones
Centre	09 - Escuela Tecnica Superior de Ingenieros de Telecomunicacion
Academic year	2020-21

2. Faculty

2.1. Faculty members with subject teaching role

Name and surname	Office/Room	Email	Tutoring hours *
Jose Ramon Montejo Garai	B-421I	joseramon.montejo@upm.es	Sin horario. Appointment arranged by email
Jesus Grajal De La Fuente	C-420	jesus.grajal@upm.es	Sin horario. Appointment arranged by email

Miguel Angel Gonzalez De Aza	B-421D	miguelangel.gonzalez@upm.es	Sin horario. Appointment arranged by email
Francisco Eduardo Carrasco Yepez	B-417	eduardo.carrasco@upm.es	Sin horario. Appointment arranged by email
Gerardo Perez Palomino (Subject coordinator)	B-412	gerardo.perezp@upm.es	Sin horario. Appointment arranged by email

* The tutoring schedule is indicative and subject to possible changes. Please check tutoring times with the faculty member in charge.

3. Prior knowledge recommended to take the subject

3.1. Recommended (passed) subjects

The subject - recommended (passed), are not defined.

3.2. Other recommended learning outcomes

- Foundation of microwave engineering

- Working knowledge of MATLAB

4. Skills and learning outcomes *

4.1. Skills to be learned

CB06 - Poseer y comprender conocimientos que aporten una base u oportunidad de ser originales en el desarrollo y/o aplicación de ideas, a menudo en un contexto de investigación

CB07 - Que los estudiantes sepan aplicar los conocimientos adquiridos y su capacidad de resolución de problemas en entornos nuevos o poco conocidos dentro de contextos más amplios (o multidisciplinares) relacionados con su área de estudio

CB08 - Que los estudiantes sean capaces de integrar conocimientos y enfrentarse a la complejidad de formular juicios a partir de una información que, siendo incompleta o limitada, incluya reflexiones sobre las responsabilidades sociales y éticas vinculadas a la aplicación de sus conocimientos y juicios

CB09 - Que los estudiantes sepan comunicar sus conclusiones y los conocimientos y razones últimas que las sustentan a públicos especializados y no especializados de un modo claro y sin ambigüedades

CB10 - Que los estudiantes posean las habilidades de aprendizaje que les permitan continuar estudiando de un modo que habrá de ser en gran medida autodirigido o autónomo

CE01 - Analizar y aplicar técnicas para el diseño y desarrollo avanzado de equipos y sistemas, basándose en la teoría de la señal y las comunicaciones, en un entorno internacional

CE02 - Evaluar y sintetizar los resultados de un trabajo en equipo en proyectos relacionados con la teoría de la señal y las comunicaciones, en un entorno internacional.

CE03 - Valorar y contrastar la utilización de las diferentes técnicas disponibles para la resolución de problemas reales dentro del área de teoría de la señal y comunicaciones.

CETFM - Capacidad de realizar un trabajo o proyecto integrando y relacionando las competencias adquiridas en las distintas asignaturas del máster, junto con la capacidad de defenderlo en público ante un grupo de personas expertas en el tema del trabajo

CT01 - Capacidad para comprender los contenidos de clases magistrales, conferencias y seminarios en lengua inglesa

CT03 - Capacidad para adoptar soluciones creativas que satisfagan adecuadamente las diferentes necesidades planteadas

CT04 - Capacidad para trabajar de forma efectiva como individuo, organizando y planificando su propio trabajo, de forma independiente o como miembro de un equipo

CT05 - Capacidad para gestionar la información, identificando las fuentes necesarias, los principales tipos de documentos técnicos y científicos, de una manera adecuada y eficiente

CT06 - Capacidad para emitir juicios sobre implicaciones económicas, administrativas, sociales, éticas y medioambientales ligadas a la aplicación de sus conocimientos

4.2. Learning outcomes

RA10 - Capability to design systems and equipments for multimedia generation and distribution

RA12 - Capability to construct probabilistic models from experimental data using inference tools.

RA14 - Capability to model real phenomena using probability theory.

RA1 - Capacidad para desarrollar técnicas de tratamiento de señal específicas para datos masivos y diseñar aplicaciones sobre señales como: imágenes, señales de video, voz, audio y las procedentes de sensores de diversanaturaleza

RA13 - Capability to construct parameter estimators, hypothesis tests and linear regression models.

RA15 - Capability to relate the foundations of statistical inference with standard machine learning schemes.

RA19 - Knowledge of tools to design optimal filtering and signal processing structures

RA17 - Capacidad para aplicar conocimientos de modelado estadístico, técnicas de optimización y modelos de series temporales en el análisis de datos y como base para el desarrollo de algoritmos de aprendizaje automático

RA18 - Knowledge of tools for description, analysis and modeling of discrete-time random processes

* The Learning Guides should reflect the Skills and Learning Outcomes in the same way as indicated in the Degree Verification Memory. For this reason, they have not been translated into English and appear in Spanish.

5. Brief description of the subject and syllabus

5.1. Brief description of the subject

This course is a comprehensive top-down approach to Radio Frequency (RF) systems and the technologies involved, which begins with the specifications of a system and finishes with the selection of the appropriate technology, components, and circuits to meet these specifications. An in-depth understanding of the variety of components in the market and their specifications and limitations are basic for a successful design of increasing complex RF systems.

This course presents advanced concepts related to passive and active microwave devices implemented in different technologies. Regarding to the passive devices, the technology is focused on both guided and opened structures for the implementation of the components comprising the antenna feeders. Filters, Multiplexers, polarization converters or phase-shifters will be presented, thus analysing the required specifications when used in real communication systems. In connection with active components, a huge variety of components in different technologies with various operating regimes appear. Therefore, an effort has been carried out to select the most significant ones to cover the most important applications.

Both in-house software developed in Matlab as well as a commercial software will be used to show the different strategies to analyse and design the different circuits and sub-systems presented in this course.

5.2. Syllabus

1. Circuit theory of microwave devices.
   1.1. Outline of power waves and S parameters.
   1.2. Signal flow graphs with S parameters.
   1.3. S matrix properties: reciprocity, symmetry and unitary.
   1.4. Z and Y parameters applied to microwave circuits.
   1.5. S parameters measurement: calibration.
   1.6. Reference plane shift applied to S matrix.
   1.7. Reference impedance change applied to S matrix.
   1.8. Two-port cascade connection with S parameters.
   1.9. Bartlett theorem: symmetry of passive devices.

1.10. S parameters of lumped and distributed circuits: examples.

1.11. CAD of subsystems defined by S parameters.

1.12. Example: CAD using S parameters

2. Waveguide concepts: application to passive devices.

2.1. Basic concepts of waveguides.

2.2. Rectangular waveguides: modes and symmetries.

2.3. Circular waveguide: modes and symmetries.

2.4. Waveguide engineering; industrial standards.

3. Microwave filters: design and technologies

3.1. Overview of mm-wave guided devices: filters, couplers and multiplexers

3.2. Filter synthesis approximation.

3.2.1. Maximally flat approximation: Butterworth filters.

3.2.2. Equiripple aproximation: Chebyshev filters.

3.3. Filter circuital syntheysis.

3.3.1. Circuital recursive process.

3.3.2. Frequency and impedace transfomation.

3.3.3. Inmitance inverters and coupling matrix.

3.4. Example: Practical Design of filters

4. Microwave devices using non-guided (free space) technology

4.1. Overview of mm-wave non-guided devices: filters (FSSs), polarization converters and phase-shifters

4.2. Introduction to planar open periodic structures: V and H TEM-modes and transmission line approach

4.3. Ferquency Selective Surfaces (FSSs): spatial and spectral filtering

4.4. Example: practical design of FSSs

5. Hybrid technology (HMIC).

5.1. Hybrid integrated technology. Substrates.

5.2. Characteristics of planar transmission lines.

5.3. Distributed and lumped elements in HMIC.

5.4. Directional Couplers, Dividers and Combiners.

6. MMIC technology.

6.1. Introduction to MMIC.

6.2. Component technology and foundry choice.

6.3. Active devices (Transistor types).

6.4. Packaging Integration of MMICs in HMIC.

6.5. Foundry use and economics.

7. RF and Microwave Solid State Amplifiers.

7.1. Amplifier characteristics and definitions.

7.2. Amplifier classes and analysis.

7.3. Amplifier examples.

7.4. Linearization Techniques.

7.5. Thermal design.

7.6. Power combining.

7.7. Amplifier packages.

8. RF and microwave Solid State Oscillators.

8.1. Fundamentals, Classification and Parameters.

8.2. Crystal oscillators and oscillators with stabilized resonators.

8.3. Frequency controlled oscillators.

8.4. Frequency synthesizers and direct digital synthesizers.

8.5. Noise in oscillators and system performance.

9. Control Components.

9.1. Attenuators.

9.2. Phase shifters and Time delay.

9.3. Circulators and isolators.

9.4. Switches and matrices.

10. Complementary materials.

10.1. Measurement equipments.

10.2. RF design tools.

11. Design of a selected RF system

11.1. Presentation of an RF system.

11.2. Clarification of objectives.

6. Schedule

6.1. Subject schedule*

Week	Face-to-face classroom activities	Face-to-face laboratory activities	Distant / On-line	Assessment activities
1	**Chapter 1. 1.1. Outline of power waves and S parameters.1.2. Signal flow graphs with S parameters. 1.3. S matrix properties: reciprocity, symmetry and unitary. 1.4 Z and Y parameters applied to microwave circuits.** Duration: 02:00 Lecture **Chapter 1. 1.5. S parameters measurement: calibration. 1.6. Reference plane shift applied to S matrix. 1.7. Reference impedance change applied to S matrix. 1.8. Two-port cascade connection with S parameters.** Duration: 02:00 Lecture			
2	**Chapter 1. 1.9. Bartlett theorem: symmetry of passive devices.1.10. S parameters of lumped and distributed circuits: examples. 1.11. CAD of subsystems defined by S parameters. 1.12. Example: CAD using S parameters** Duration: 02:00 Lecture **Chapter 2. 2.1. Basic concepts of waveguides. 2.2. Rectangular waveguides: modes and symmetries.** Duration: 02:00 Lecture			**Homework 1** Individual work Continuous assessment Not Presential Duration: 06:00
3	**Chapter 2. 2.3. Circular waveguide: modes and symmetries.** Duration: 02:00 Lecture **Chapter 2. 2.4. Waveguide engineering; industrial standards.** Duration: 02:00 Lecture			
4	**Chapter 3. 3.1 Overview of mm-wave guided devices: filters, couplers and multiplexers. 3.2 Filter synthesis approximation.** Duration: 02:00 Lecture **Chapter 3. 3.3 Filter circuital syntheysis.** Duration: 02:00			**Homework 2** Individual work Continuous assessment Not Presential Duration: 06:00

	Lecture			
5	**Chapter 3. 3.4 Example: Practical design of filters.** Duration: 03:00 Lecture **Chapter 4. 4.1. Overview of mm-wave non-guided devices: filters (FSSs), polarization converters and phase-shifters.** Duration: 01:00 Lecture			
6	**Chapter 4. 4.2 Introduction to planar open periodic structures: V and H TEM-modes and transmission line approach. 4.3 Ferquency Selective Surfaces (FSSs): spatial and spectral filtering.** Duration: 02:00 Lecture **Chapter 4. 4.4 Example: practical design of FSSs** Duration: 02:00 Lecture			**Homework 3** Individual work Continuous assessment Not Presential Duration: 06:00
7	**Chapter 5: Hybrid technology (HMIC) - Hybrid integrated technology. Substrates. - Planar transmission lines. - Distributed and lumped elements in HMIC** Duration: 02:00 Lecture **Chapter 5: Hybrid technology (HMIC) - Directional Couplers, Dividers and Combiners** Duration: 02:00 Lecture			
8	**Chapter 6: MMIC technology - Component technology - Active Devices - Packaging - Foundry use** Duration: 02:00 Lecture **Chapter 7: Microwave Amplifiers (4h) - Amplifier characteristics and definitions - Amplifier classes and analysis - Amplifier examples** Duration: 02:00 Lecture			**Homework 4** Individual work Continuous assessment Not Presential Duration: 06:00
9	**Chapter 7: Microwave Amplifiers - Linearization Techniques - Thermal design** Duration: 04:00 Lecture			
10	**Chapter 7: Microwave Amplifiers - Power combining - Amplifier packages** Duration: 02:00 Lecture **Chapter 8: Microwave Oscillators - Fundamentals, Classification and Parameters - Crystal oscillators and**			**Homework 5** Individual work Continuous assessment Not Presential Duration: 08:00

	oscillators with stabilized resonators - Frequency controlled oscillators Duration: 02:00 Lecture			
11	**Chapter 8: Microwave Oscillators - Frequency synthesizers and direct digital synthesizers - Noise in oscillators and system performance** Duration: 02:00 Lecture **Chapter 9: Control Components - Attenuators - Phase shifters and Time delay - Circulators and isolators** Duration: 02:00 Lecture			
12	**Chapter 9: Control Components - Switches and matrices** Duration: 02:00 Lecture **Chapter 10: Complementary Materials (3h) - Measurement equipments - RF design tools** Duration: 02:00 Lecture			
13	**Chapter 11: Design of a selected RF system** Duration: 04:00 Lecture			**Homework 6** Individual work Continuous assessment Not Presential Duration: 08:00
14				
15				
16				
17				**Final Design** Individual work Continuous assessment Not Presential Duration: 06:00 **Only final exam** Written test Final examination Presential Duration: 02:00

Depending on the programme study plan, total values will be calculated according to the ECTS credit unit as 26/27 hours of student face-to-face contact and independent study time.

* The schedule is based on an a priori planning of the subject; it might be modified during the academic year, especially considering the COVID19 evolution.

7. Activities and assessment criteria

7.1. Assessment activities

7.1.1. Continuous assessment

Week	Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
2	Homework 1	Individual work	No Presential	06:00	10%	5 / 10	CB08 CB09 CT01 CB07 CT03 CB06 CE02 CT04 CE01 CT06 CE03 CT05 CB10
4	Homework 2	Individual work	No Presential	06:00	15%	5 / 10	CB09 CB07 CT03 CB06 CE02 CE01 CT06 CE03 CT05 CB10
6	Homework 3	Individual work	No Presential	06:00	15%	5 / 10	CB09 CB07 CT03 CB06 CE02 CE01 CT06 CE03 CT05 CB10

8	Homework 4	Individual work	No Presential	06:00	10%	5 / 10	CB09 CB07 CT03 CB06 CE02 CE01 CT06 CE03 CT05 CB10
10	Homework 5	Individual work	No Presential	08:00	15%	5 / 10	CB09 CB07 CT03 CB06 CE02 CE01 CT06 CE03 CT05 CB10
13	Homework 6	Individual work	No Presential	08:00	15%	5 / 10	CB09 CB07 CT03 CB06 CE02 CE01 CT06 CE03 CT05 CB10
17	Final Design	Individual work	No Presential	06:00	20%	5 / 10	CB09 CB07 CT03 CB06 CE02 CE01 CT06 CE03 CT05 CB10

7.1.2. Final examination

Week	Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
17	Only final exam	Written test	Face-to-face	02:00	100%	5 / 10	CB08 CB09 CT01 CB07 CT03 CB06 CE02 CT04 CE01

							CT06 CE03 CT05 CB10

7.1.3. Referred (re-sit) examination

Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
Extraordinary examination will be carried out exclusively by the final examination method.	Written test	Face-to-face	03:00	100%	5 / 10	CB08 CB09 CT01 CB07 CT03 CB06 CETFM CE02 CT04 CE01 CT06 CE03 CT05 CB10

7.2. Assessment criteria

Students will be qualified through continuous evaluation by default. If the student does not deliver the first homework before the deadline, it means that renounces to the continuous evaluation. Nevertheless, it is highly advisable to be evaluated through continuous evaluation.

Evaluation will assess if students have acquired all the competences of the subject. Thus, evaluation through final assessment will be carried out considering all the evaluation techniques used in continuous evaluation (EX, ET, TG, etc.), and will be celebrated in the exam period approved by Junta de Escuela for the current academic semester and year. Evaluation activities that assess learning outcomes that cannot be evaluated through a single exam can be carried out along the semester.

Extraordinary examination will be carried out exclusively by the final examination method.

The continuous evaluation is composed of six homeworks (80%) developed individually by the student and a final design (20%). The content of these homeworks will be directly related to the concepts exposed in the course. In the final design, a radiofrequency system will be implemented, being every student the designer of a specific part. In the case of a final assessment, an exam regarding to the concepts of the course will be the evaluation (100%).

8. Teaching resources

8.1. Teaching resources for the subject

Name	Type	Notes
Microwave Engineering, David.M. Pozar, John Wiley and Sons Inc., 2012, 4th edition.	Bibliography	
Foundations for Microwave Engineering , Robert E. Collin, McGraw-Hill Inc. 1992.	Bibliography	
Microwave Engineering Passive Circuits , Peter A. Rizzi, Prentice-Hall Inc., 1998.	Bibliography	
Field and Waves in Communications Electronics, S. Ramo, J.R. Whinnery, T.V. Duzzer, 3th edition, John Wiley and Sons, 1993.	Bibliography	
An Introduction to Guided Waves and Microwaves Circuits, R.S. Elliot, Ed. Prentice-Hall, 1998	Bibliography	
Advanced Engineering Electromagnetics, C.A. Balanis. John Wiley and Sons.	Bibliography	
Microwave filters, impedance-matching networks and coupling structures, G.L. Matthaei, L. Young, E.M.T. Jones, Artech House, 1980. (Reimpresión de la edición de Mc-Graw-Hill 1960.	Bibliography	
Computer Aided Design of Microwave Circuits, K. C. Gupta, Ed. Artech House, 1981.	Bibliography	

Principles of Microwave Circuits, C. G. Montgomery, R. H. Dicke, and E. M. Purcell	Bibliography	
Waveguide Components for Antenna Feed Systems: Theory and CAD,1993 Jaroslaw Uher, Jens Bornemann.	Bibliography	
High Efficiency RF and Microwave Solis State Amplifiers. P. Colantonio, Feranco Giannini, E. Limiti. Wiley, 2009.	Bibliography	
Fundamentals of RF and Microwave TransistorAmplifiers. I.J. Bahl, Wiley, 2008.	Bibliography	
Passive RF & Microwave Integrated Circuits. L. Maloratsky, Elsevier, 1999	Bibliography	
Handbook of RF, Microwave, and Millimeter-Wave Componenets. L.A. Belov, S.M. SmolskiY, V.N. Kochemasov. Artech House, 2012.	Bibliography	
Foundations of Oscillator Circuit Design. G. Gonzalez. Artech, 2007.	Bibliography	
Frequency Synthesizers: Concept to Product. A. Chenakin. Artech, House, 2010.	Bibliography	
Advanced Phase-Lock Techniques. J. A. Crawford. Artech, House, 2007.	Bibliography	
Frequency Selective SurfacesTheory and Design. B. A. Munk,Wiley, 2000	Bibliography	

9. Other information

9.1. Other information about the subject

This subject is related with the SDG number 9: "Industry, innovation and infrastructure", as it analyzes new methodologies applicable for the industry. In particular the point 9.5: "Enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, in particular developing countries, including, by 2030, encouraging innovation and substantially increasing the number of research and developmentworkers per 1 million people and public and private research and development spending"