1. COURSE TITLE

Fundamentals of Wave Transmission and Propagation (FTPO)

1.1. Course number

18475

1.2. Course area

Transmission Systems

1.3. Course type

Core course (*Training Module Common to the Telecommunications Branch*)

1.4. Course level

Graduate

1.5. Year

2º

1.6. Semester

2º

1.7. Credit allotment

6 ECTS

1.8. Prerequisites

It is required to use complex numbers, trigonometric functions and complex exponentials. Integration and derivation is also required, including the multi-dimensional case. Students are expected to have previous knowledge in an introductory course on electromagnetic fields (electrostatic and magnetostatic regime).

1.9. Minimum attendance requirement

Attendance to lectures is especially important to achieve the course goals.

1.10. Faculty data

Please add @uam.es to all e-mail addresses below.

Theory:

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1.11. Course objectives

FTPO is an introductory course to electromagnetic fields in the context of communication systems. At the end of the course, the student is expected to understand and to be able to use the main concepts of propagation and wave transmission, which are the most basic phenomena for allowing communication between remote users.

The mains skills to achieve are those belonging to the *Training Module Common to the Telecommunications Branch*:

"CO8: To understand the phenomena of propagation and transmission of electromagnetic waves, and their corresponding transmitters and receivers …"

At the end of each unit, the student should be capable of:

SPECIFIC OBJECTIVES FOR EACH UNIT

TEMA I.- Introduction to electrodynamics. Maxwell's equations.	
1.1	Write Maxwell’s equations in both integral and differential form in the time domain, with constitutive relations for simple media
1.2	Formulate the equations of the static, quasi-static, and arbitrary-time variation regimes
1.3	Operate with vectors whose components are complex numbers
1.4	Use of vector operators in the context of Maxwell`s equations
1.5	Apply the Fourier transform to vectors and to integral and differential equations
1.6	Formulate Maxwell's equations in the frequency domain applying the Fourier transform
1.7	Write a monochromatic electromagnetic field in both time and frequency domains
TEMA II.- Media and energy transfer.	
2.1	Write constitutive relations of a medium in the frequency domain, define complex electric permittivity and complex magnetic permeability
2.2	Define when a medium has no losses, identify dielectric and conductor media
2.3	Write the boundary conditions of the electromagnetic field at the interface between two media, and also when one of them is a perfect conductor
2.4	Formulate Poynting theorem, analyzing its consequences at different simple cases
2.5	Relate Poynting theorem with the complex power balance in a circuit.
2.6	Calculate power and stored energy using electromagnetic fields
TEMA III.- Homogeneous plane waves.	
3.1	Obtain the field equations from the Maxwell equations
3.2	Write the electromagnetic field of a homogeneous plane wave, describing its parameters: propagation constant and intrinsic impedance
3.3	Calculate the power transmitted by a monochromatic homogenous plane wave and the power dissipated in the medium
3.4	Analyze the propagation constant and wave impedance based on the electromagnetic properties of the medium and the frequency
3.5	Write a monochromatic homogeneous plane wave in the time domain, analyzing its temporal variation, wavelength and phase velocity
3.6	Define the transfer function associated to a plane wave from the point of view of communication systems
3.7	Identify the polarization of a monochromatic homogeneous plane wave, defining linear and circular polarization
TEMA IV.- Incidence of plane waves on discontinuity planes	
4.1.	Analyze the incidence of an electromagnetic wave that propagates in a homogeneous medium on an obstacle
4.2	Write the boundary conditions when an homogeneous plane wave impinges perpendicularly on a plane which is a discontinuity between two media
4.3	Obtain the relation between the impinging, transmitted and reflected waves, defining the concept of reflection coefficient and impedance

4.4	Represent and analyze the standing wave diagram
4.5	Formulate the normal incidence on a good conductor, defining the skin effect
4.6	Analyze the incidence on a stratified medium, writing the conditions for maximum power transfer and matching; use for simple cases such as lambda/2 and lambda/4
4.7	Write the boundary conditions when an homogenous plane wave impinges obliquely on a plane, write Snell laws
TEMA V.- Guided waves. The transmission line.	
5.1	Analyze the form of the electromagnetic field in a general waveguiding system
5.2	Classify the different types of waveguiding systems
5.3	Write the solution of the electromagnetic field with only transverse components (TEM) in a waveguiding system
5.4	Define the voltage and current in a medium with TEM modes
5.5	Define the transmission line and its basic parameters
5.6	Establish the equivalence of several cascaded transmission lines with the propagation of a homogenous plane wave in a stratified media

1.12. Course contents

I. **The electromagnetic model based on Maxwell's equations.**

1. Definition of the macroscopic electromagnetic model: Maxwell's equations in the time domain.
2. Definition of the material media in the electromagnetic model
3. Definition of the static regime: electrostatics and magnetostatics.
4. Definition of slow temporal variation regime. Kirchhoff’s laws.
5. Definition of arbitrary temporal variation regime.
6. Fourier transform applied to Maxwell's equations. Monochromatic regime.

II. **Material media and energy transfer.**

1. Equations and constitutive relations in the frequency domain.
2. From Maxwell's equations to the equations of the energy balance. Force, work, energy and power associated to the electromagnetic field.
3. Power conservation in time and frequency domains.

III. **Homogeneous plane waves.**

1. From Maxwell's equations to plane waves. Propagation constant and intrinsic impedance.
2. Monochromatic homogeneous plane waves: propagation velocity, wavelength, transmitted and dissipated power.
3. Study of different media, including conductors.
4. Plane wave as information carrier. Transfer function from the point of view of communication systems. Delay, group velocity, amplitude and phase distortion.
5. Polarization of the electromagnetic field.

IV. **Incidence of plane waves on discontinuity planes.**

1. Introduction to the problem of incidence on obstacles.
2. From Maxwell's equations to stationary waves. Reflection coefficient and wave impedance.
3. Field spatial pattern. Standing wave diagram.
4. Normal incidence on a conductor. Skin effect.
5. Normal incidence on stratified media. Matching.
6. Oblique incidence on discontinuity planes. Snell's law.

V. **Guided waves. The transmission line.**

1. From Maxwell's equations to guided wave field solutions. Types of modes: TEM, TE, TM and hybrids.
2. Classification of the waveguiding systems. The optical fiber.
3. TEM waves in media with two or more conductors. Definition of voltage and current.
4. Transmission line concept. Use of the reflection coefficient and wave impedance concepts as in plane waves.

1.13. Course bibliography

Basic:

- D.K. Cheng, "Fundamentos de electromagnetismo para ingeniería", Addison-Wesley.
- Fraile Mora, Jesús, “Electromagnetismo y circuitos eléctricos”, Mc Graw Hill 2005
- J.E. Page de la Vega, C. Camacho Peñalosa, "Ecuaciones y relaciones energéticas de la electrodinámica", "Ondas planas", "Propagación de ondas guiadas", "Problemas de campos electromagnéticos" , Servicio de Publicaciones, E.T.S.I. de Telecomunicación, Universidad Politécnica de Madrid.
- S. Ramo, J.R. Whinnery, T. Van Duzer, "Fields and waves in communications electronics", John Wiley & Sons, Third Edition, 1994.

Intermediate:

- J.D. Kraus, "Electromagnetismo", McGraw-Hill, 1986.
- C.T.A. Johnk, "Teoría electromagnética", Limusa, 198I.

- P. Lorrain, D.R. Corson, “Campos y Ondas Electromagnéticos”, Ed. Selecciones Científicas (Madrid 1986)

Advanced (related to subsequent courses):

- D. M. Pozar, "Microwave Engineering", John Wiley and Sons.
- D. M. Pozar, "Microwave and RF wireless systems", John Wiley & Sons, 200l.
- V.V. Nikolski, "Electrodinámica y propagación de ondas de radio", http://www.urss.ru, Editorial URSS, 1973.
- R. E. Collin, "Foundations for microwave engineering", IEEE Press, 200l.
- A. Cardama y otros, “Antenas”, Edicions UPC 200ll.
- C. A. Balanis, “Antenna Theory. Analysis and Design”, John Wiley & Sons 1997.
- C. A. Balanis, “Advanced Engineering Electromagnetics”. John Wiley and Sons.