Subject: Fundamentals of Wave Transmission and Propagation
Code: 18475
Institution: Escuela Politécnica Superior
Degree: Telecommunication Technologies and Services Engineering
Level: Graduate
Type: Core course
ECTS: 6

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 quasi-static and static regime, relating them to the Kirchoff's laws
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
2.2	Formulate the different types of electromagnetic material properties, identifying dielectric and conductor media
2.3	Write the boundary conditions of the electromagnetic field at the interface between two media
2.4	Write the boundary conditions of the electromagnetic field at the interface between a perfect conductor and another medium
2.5	Calculate power and stored energy using the electromagnetic fields
2.6	Formulate Poynting theorem, analyzing it at different simple cases
2.7	Relate Poynting theorem with the complex power balance in a circuit.
TEMA III.- Transverse electromagnetic waves (TEM). Homogeneous plane waves.	
3.1	Write the solution of an electromagnetic field with only transverse components (TEM) in a system with translational symmetry
3.2	Use separation of variables to obtain the field equations
3.3	Write the electromagnetic field of a homogeneous plane wave, describing its propagation parameters
3.4	Analyze the propagation constant and wave impedance based on the electromagnetic properties of the medium and the frequency
3.5	Calculate the power transmitted by a monochromatic homogenous plane wave and the power dissipated in the medium
3.6	Write a monochromatic homogeneous plane wave in the time domain, analyzing its temporal variation
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	Analyze the incidence on a stratified medium, writing the conditions for maximum power transfer and matching
4.6	Design of simple matching structures
4.7	Formulate the normal incidence on a good conductor, defining the skin effect
4.8	Write the boundary conditions when an homogenous plane wave impinges obliquely on a plane
4.9	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
5.7	Understand the equivalent cuadripole of a transmission line, using it in basic circuits
5.8	Write the conditions for maximum power transfer and matching in transmission lines
5.9	Calculate the losses in the conductors, incorporating this phenomenon to the transmission line and its parameters
TEMA VI.- Propagation and radiation from the point of view of communications systems.	
6.1	Write the transfer function of a transmission system
6.2	Define the phase and group velocity, and phase and group delay
6.3	Analyze the variation of these parameters with the frequency, defining amplitude distortion and phase distortion
6.4	Describe the phenomenon of radiation in simple terms
6.5	Define the basic parameters of an antenna, matching, gain and radiation diagram

1.12. Course contents

I. **Introduction to electrodynamics. Maxwell's equations.**

1. Maxwell's equations in the time domain.
2. Description of the media. Constitutive relations.
3. Static regime: electrostatics and magnetostatics.
4. Concept of slow temporal variation. Kirchhoff's laws.
5. Arbitrary temporal variation.
6. Fourier transform applied to Maxwell's equations. Monochromatic regime.

II. **Media and energy transfer.**

1. Equations and constitutive relations in the frequency domain.
2. Electromagnetic field boundary conditions.
3. Energy balance and Maxwell's equations.
4. Power conservation in time and frequency domains.

III. **Transverse electromagnetic waves (TEM). Homogeneous plane waves.**

1. Maxwell's equations in systems with translational symmetry.
2. Field solutions with transverse components: TEM waves.
3. Basic characteristics of TEM solutions: propagation constant and wave impedance.
4. Homogeneous plane waves as a special case of TEM modes.
5. Monochromatic homogeneous plane waves: propagation velocity, transmitted and dissipated power.
6. Temporal variation of a homogeneous plane wave.
7. Polarization of the electromagnetic field.

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

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

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

1. Guided wave field solutions.
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. Equivalent cuadripole of a transmission line.
5. Effect of the losses in the conductors.
6. Transmission line parameters and transmission line as a circuit element.

VI. **Propagation and radiation from the point of view of communications systems.**

1. Fundamental concepts in propagation: transfer function of a transmission system (guided or wireless).
2. Phase, group and signal velocities. Time delay. Attenuation.
3. Amplitude distortion and phase distortion.
4. Introduction to radiation.
5. Basic parameters of an antenna. Antenna gain.
6. Basic types of antennas.

1.13. Course bibliography

Basic:

- S. Ramo, J.R. Whinnery, T. Van Duzer, "Fields and waves in communications electronics", John Wiley & Sons, Third Edition, 199IV.
- D.K. Cheng, "Fundamentos de electromagnetismo para ingeniería", Addison-Wesley.
- J.D. Kraus, "Electromagnetismo", McGraw-Hill, 198VI.
- C.T.A. Johnk, "Teoría electromagnética", Limusa, 198I.
- 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.

Intermediate:

- P. Lorrain, D.R. Corson, "Campos y Ondas Electromagnéticos", Ed. Selecciones Científicas (Madrid 1986)
- D. M. Pozar, "Microwave and RF wireless systems", John Wiley & Sons, 200I.
- D. M. Pozar, "Microwave Engineering", John Wiley and Sons.
- V.V. Nikolski, "Electrodinámica y propagación de ondas de radio", http://www.urss.ru, Editorial URSS, 197III.

Advanced (related to subsequent courses):

- R. E. Collin, "Foundations for microwave engineering", IEEE Press, 200I.
- A. Cardama y otros, "Antenas", Edicions UPC 200II.
- C. A. Balanis, "Antenna Theory. Analysis and Design", John Wiley & Sons 1997.
- C. A. Balanis, "Advanced Engineering Electromagnetics". John Wiley and Sons.