Subject: Transmission Media
Code: 18502
Institution: Escuela Politécnica Superior
Degree: Telecommunication Technologies and Services Engineering
Level: Graduate
Type: Core course
ECTS: 6

1. COURSE TITLE

Transmission Media (MTX)

1.1. Course number

18502

1.2. Course area

Telecommunication Systems

1.3. Course type

Optative

1.4. Course level

Graduate

1.5. Year

3rd

1.6. Semester

1st

1.7. Credit allotment

6 ECTS

1.8. Prerequisites

Students are expected to have previous knowledge in an introductory course on electromagnetic fields and waves (as Fundamentals of Wave Transmission and Propagation).

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:

Dr. Jorge A. Ruiz Cruz (Coordinator)
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Laboratory:

(to be defined)
Departamento de Tecnología Electrónica y de las Comunicaciones
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Module-Office:
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1.11. Course objectives

Transmission Media (MTX) is a course on RF/microwave systems and techniques for communication systems. At the end of the course, the student is expected to understand the main concepts for transmitting electromagnetic waves and to be able to analyze and design circuits with transmission lines. It is also planned to implement and characterize in the laboratory some of those circuits.

The mains skills to achieve from the Module 4.1 “Telecommunication Systems” are the following:

- To analyze components and their specifications for guided and wireless communication systems.
- To be able to select circuit, subsystems, and RF/microwave systems for diverse applications.

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

SPECIFIC OBJECTIVES FOR EACH UNIT

TEMA I.- Transmission lines from the circuit point of view	
1.1	Writing the equations that define both voltage and current waves in the transmission line and their fundamental parameters
1.2	Computing in a transmission line the reflection coefficient, impedance, and standing wave diagram
1.3	Computing the incident and reflected wave in a circuit depending on the source and load impedance
1.4	Computing the delivered power in terms of the power of the incident and reflected waves
1.5	Computing the aforementioned parameters in a lossy transmission line
TEMA II.- Circuits based on transmission lines. Impedance matching.	
2.1	Computing the matrices Z, Y, T for simple cuadripoles, including the case with transmission lines. Relate the S-matrix with wave amplitudes.
2.2	Being able to generalize the concept of cuadripole and characterization matrices to N-port problems
2.3	Writing the different equivalent conditions for maximum power transfer, defining impedance matching and resonance conditions
2.4	Understanding the difference between no reflected wave and maximum power transfer
2.5	Transforming reflection coefficients and impedances by means of the Smith chart
2.6	Designing load matching circuits with the Smith Chart
TEMA III.- Transmission lines from the electromagnetic point of view. TEM, TE and TM waves guided by a transmission system	
3.1	Writing the solution of an electromagnetic field with transverse and longitudinal components in a system with translational symmetry
3.2	Using separation of variables to obtain the field equations
3.3	Writing the electromagnetic field of a TE, TM and TEM mode and describing its fundamental parameters
3.4	Analyzing the propagation constant and wave impedance based on the electromagnetic properties of the medium and the frequency
3.5	Using the concept of cutoff frequency, fundamental mode, high order mode, monomode bandwidth
3.6	Obtaining the parameters of a transmission line associated to a TEM mode from the TEM mode field
3.7	Calculate the losses in the conductors, incorporating this phenomenon to the transmission line and its parameters
TEMA IV.- Particular cases: propagation modes in the most common transmission media	
4.1.	For the coaxial cable, computing the TEM mode, characteristic impedance, and first higher order mode
4.2	For the microstrip line, understanding the difference between TEM and quasi-TEM mode; computing the characteristic impedance, and first higher order mode

4.3	For the rectangular waveguide, computing the TEmn, TMmn, (stressing the importance of the fundamental TE10), characteristic impedance, and first higher order mode
4.4	For the circular waveguide, computing the $TE^{c,s}qr$, $TM^{c,s}qr$, (stressing the importance of the fundamental TE11), characteristic impedance, and first higher order mode
4.5	For the dielectric waveguides, being able to understand the electromagnetic model associated to them, especially in an optic fiber
TEMA V.- Circuit theory in microwave systems	
5.1	Understanding that a microwave circuit is made up of several elements: describing examples with transmission media, lumped elements and radiating elements
5.2	Describing the limitations of the classic parameters to describe high frequency circuits
5.3	Describing the S-matrix in a general case and the power waves
5.4	Describing the physical meaning of the S matrix, its properties and its values in simple circuits

1.12. Course contents

I. **Transmission Lines from the circuit point of view.**

1. Transmission line equations. Fundamental parameters.
2. Definitions of reflection coefficient, impedance, and standing wave diagram
3. Ideal (non-lossy) transmission line with arbitrary source (Vg, Zg) and load (ZL). Particular cases: Zg=Zo, ZL=Zo, λ/2, λ/4, short, open, origin transformation, incident and reflected waves, incident, reflected and delivered power.
4. Lossy transmission line. Comparison with the non-lossy line for the previous particular cases

II. **Circuits based on transmission lines. Impedance matching.**

1. Circuits with transmission lines and lumped elements. Concept of cuadripole (and multi-pole) and characterization by means of Z, Y or T-matrices. Introduction to the S-matrix
2. Matching load and maximum power transfer.
3. Maximum power transfer in circuits with transmission lines and relation with the reflection coefficient.
4. Chart with reflection coefficients and impedances: the Smith chart.
5. Application to circuits with transmission lines and lumped elements.
6. Matching networks in transmission line circuits using the Smith Chart

III. **Transmission lines from the electromagnetic point of view. TEM, TE and TM waves guided by a transmission system.**
    1. Classification of the waveguiding systems. Guided waves according to the electromagnetic model.
    2. Computation of the propagation modes TEM, TE and TM.
    3. Cutoff frequency, fundamental mode, high order mode, monomode bandwidth
    4. Classification of the waveguiding systems according to the number of conductors.
    5. Connection between the electromagnetic and circuital model: transmission line as the equivalent circuit of a propagating mode. Transmission line for the TEM mode. Special cases of TE and TM.
    6. Effect of the losses in the conductors.

IV. **Particular cases: propagation modes in the most common transmission media.**
    1. Coaxial cable.
    2. Microstrip line.
    3. Rectangular waveguide.
    4. Dielectric waveguides
    5. Other transmission media.

V. **Circuit theory in microwave systems.**
    1. General theory for microwave systems with transmission media, lumped elements and radiating elements
    2. Formulation of the problem with voltages and currents. Matrices Z and Y. Limitation of this approach for general circuits
    3. Formulation of the problem with power waves. Definition of incident and scattered power waves, generalized and non-generalized.
    4. Definition of the S-matrix.
    5. Analysis of simple circuits with the S-matrix.

1.13. Course bibliography

Fundamental and covering the whole course:

- D. M. Pozar, "Microwave engineering", New York, John Wiley & Sons, 2005
- R. E. Collin, "Foundations for microwave engineering", IEEE Press, 2001

Recommended for some parts of the course:

- J.E. Page de la Vega, "Propagación de ondas guiadas", "Problemas de campos electromagnéticos" , Servicio de Publicaciones, E.T.S.I. de Telecomunicación, Universidad Politécnica de Madrid.

Advanced (related to subsequent courses, some of them very specific and just for further specialization in very particular topics):

- R. E. Collin, "Field theory of guided waves", IEEE Press, 1991
- C. Balanis, "Advanced engineering electromagnetics", John Wiley & Sons 1989.
- V.V. Nikolski, "Electrodinámica y propagación de ondas de radio", http://www.urss.ru, Editorial URSS, 1973.
- J. Uher, J. Bornemann, U. Rosenberg, "Waveguide components for antenna feed systems: theory and CAD", Artech House, 1993
- G. L. Matthaei, L. Young, E. M. T. Jones, "Microwave filters, impedance-matching networks, and coupling structures", Artech House, 1980
- R. J. Cameron, C. M. Kudsia, R. R. Mansour, "Microwave filters for communication systems: fundamentals, design, and applications", Wiley-Interscience, 2007