Universidad de Alcalá

TEACHING GUIDE

Waves Propagation

Degree in
Telecommunication Technologies Engineering (GITT)
Telecommunication Systems Engineering (GIST)
Telematics Engineering (GIT)
Electronic Communications Engineering (GIEC)

Universidad de Alcalá

Academic Year 2026/2027

2nd Year - 2nd Semester (GITT+GIST+GIT+GIEC)

Approved by the EPS School Board on June 15th, 2026

TEACHING GUIDE

Course Name:	**Waves Propagation**
Code:	**350022 (GITT+GIST+GIT+GIEC)**
Degree in:	**Telecommunication Technologies Engineering (GITT)** **Telecommunication Systems Engineering (GIST)** **Telematics Engineering (GIT)** **Electronic Communications Engineering (GIEC)**
Department and area:	**Teoría de la Señal y Comunicaciones** **Signal Theory and Communications**
Type:	**Compulsory (GITT+GIST+GIT+GIEC)**
ECTS Credits:	**6.0**
Year and semester:	**2nd Year - 2nd Semester (GITT+GIST+GIT+GIEC)**
Teachers:	To be defined
Tutoring schedule:	To be published at the beginning of the term
Language:	English

1. COURSE SUMMARY

Telecommunication systems aim at transmitting signals between two sites located several metres or kilometres apart. In order to achieve that, a guided or unguided transmission medium to propagate the signals is needed. Design, optimization and maintenance of these systems depends strongly both on the properties of the specific medium and the propagation laws that rules over them.

Wave propagation introduces the basic concepts to characterize guided (transmission lines and waveguides) and unguided media (radiopropagation). In addition, wave propagation through the different media is characterized. Finally, all the elements in the system and its influence are described.

This subject covers the fundamentals for all subjects related to microwave techniques, radio links, both wired and wireless networks and mobile systems.

Preconditions and Recommendations:

For the successful completion of the course Wave Propagation, it is essential to have a solid command of the concepts and computational tools learned in previous courses, such as those listed below:

- Physics Fundamentals I: Reference systems and vector operations; gradient, divergence, and curl operators; characterization and properties of conductors and dielectrics.
- Physics Fundamentals II: Maxwell's equations; Poynting theorem; wave equation for the electromagnetic field; plane wave propagation; phase and group velocities; energy transported by electromagnetic waves; reflection, transmission, and polarization of waves.
- Calculus I: Differentiation and integration; differential equations.
- Calculus II: Partial derivatives; line and surface integrals of vector fields; vector analysis.
- Circuit Theory: Analysis of circuits under steady-state sinusoidal conditions, as well as the use of phasors and complex exponentials.
- Circuit Analysis: Two-port networks; image parameters.

2. SKILLS

Basic, Generic and Cross Curricular Skills.

This course contributes to acquire the following generic skills, which are defined in the Section 3 of the Annex to the Orden CIN/352/2009:

en_TR2 - Knowledge of basic subjects and technologies that enables to learn new methods and technologies, as well as to provide versatility that allows adaptation to new situations.

en_TR3 - Aptitude to solve problems with initiative, decision making, creativity, and to communicate and to transmit knowledge, skills and workmanship, comprising the ethical and professional responsibility of the activity of the Technical Engineer of Telecommunication.

en_TR5 - Easy to handle specifications, regulations and mandatory standards.

en_TR8 - Capacity of working in a multidisciplinary and multilingual team and of communicating, both in spoken and written language, knowledge, procedures, results and ideas related to telecommunications and electronics.

en_TRU1 - Capacity of analysis and synthesis.

en_TRU2 - Oral and written competencies.

Professional Skills

This course contributes to acquire the following professional skills, which are defined in the Section 5 of the Annex to the Orden CIN/352/2009:

en_CT1 - Skills for autonomous learning of new concepts and techniques suitable for the conception, development or commissioning of telecommunication systems and services.

en_CT2 - Ability to use telecommunications and computing aplications (ofimatics, data bases, advanced calculus, project management, visualization, etc) in order to support the exploration and development of nets, services and aplications of telecomunications and electronic.

en_CT3 - Ability to use computer tools to search bibliographic resources or information relating to telecommunications and electronics.

en_CT4 - Skills for analyze and specify the fundamental parameters of a communications systems.

en_CT8 - Ability to understand the physical mechanisms in the propagation and transmission of electromagnetic and acoustic waves, as well as their corresponding transmitting and receiving devices.

en_CT15 - Knowledge of the telecommunication regulations in the national, European and international contexts.

Learning Outcomes

After succeeding in this subject the students will be able to:

RA1. Distinguish the behavior between the different guided transmission media.

RA2. Use those methods better suited for the analysis of the propagation of waves in guided media and for the specification of their fundamental parameters

RA3. Distinguish the fundamental parameters that characterize antennas and wave propagation, and their integration in radio communication systems.

RA4. Use methods well suited to different models describing the propagation of radio waves.

RA5. Properly handle measurement equipment and computer simulators.

RA6. Adequate analysis of results of measurements and computer simulations.

3. CONTENTS

Theoretical content blocks corresponding to the lectures in large student groups and problem solving sessions in smaller groups	Lecture hours (Including problem sessions)
BLOCK 1: GUIDED PROPAGATION MEDIA	
Unit 1. Introduction to transmission media. Introduction. Transmission media: definition, classification, frequency band use. Wave propagation in transmission media: propagation modes. Logarithmic units.	• 3 hours (Theory) • 2 hours (Problems)
Unit 2. Transmission Lines. Electromagnetic analysis of a transmission line. Circuit model. Primary and secondary parameters. Types of TX lines. High and low frequency TX lines. Physical lines: coaxial cable and microstrip lines. Voltage and power waves. Voltage reflection coefficient. Input impedance of a TX line. Standing waves and VSWR. Incidence of voltage and power waves inside a line. Transmitted power. Power delivered to a load. Power dissipated in a TX line. Smith chart.	• 12 hours (Theory) • 8 hours (Problems)
Unit 3. Waveguides. Rectangular waveguides. TE and TM Propagation modes. Characteristics of the modes: cut-off frequencies, dispersion diagrams, fields, power transmitted through the TE and TM modes, attenuation. Dominant mode TE10. Non-rectangular waveguides.	• 5 hours (Theory) • 3 hours (Problems)

Theoretical content blocks corresponding to the lectures in large student groups and problem solving sessions in smaller groups	Lecture hours (Including problem sessions)
BLOCK 2: RADIO WAVE PROPAGATION	
Unit 4. Antennas in radiocommunication systems. Model of the radioelectric system. TX and RX antennas. Radiation mechanisms. Fundamental characteristics and parameter of antennas. Basic antennas: isotropic, dipoles (elemental, short and half-wavelength), short vertical monopole. EIRP, ERP, EMRP.	• 6 hours (Theory) • 3 hours (Problems)
Unit 5. Radio wave propagation. Free-space propagation. Friis formula. Radiolinks. Excess attenuation. Propagation mechanisms.	• 2 hours (Theory) • 2 hours (Problems)

Laboratory blocks	Lecture hours
I. Introduction to computer simulation. • An introduction to a computer simulation software.	• 2 hours
II. Guided Transmission Media • Simulation of guided TX media. • Measurement of coaxial line parameters with a network analyzer. • Measurement of frequencies in waveguides	• 4 hours
III. Radiopropagation. • Antenna simulation. • Circuit parameter characterization of an antenna with a network analyzer. • Propagation in the free space. Simulation of propagation in the presence of obstacles.	• 4 hours

4. TEACHING - LEARNING METHODOLOGIES. FORMATIVE ACTIVITIES.

4.1. Credits Distribution

Number of on-site hours:	28 hours large group 18 hours small groups for problem solving sessions 10 hours small groups in the lab 2 hours for exams
Number of hours of student work:	92
Total hours	150

4.2. Methodological strategies, teaching materials and resources

Three learning strategies are developed throughout the semester to pursue the outcomes described before: theoretical learning in the classroom, learning through problem solving sessions, learning experience in the lab.

Theoretical learning in the classroom:

Sessions in large groups consist of going through the basic fundamental concepts of the subject. The aim goal is introducing the student to the basic theoretical concepts regarding wave propagation in a guided way. The students will apply these concepts both in the problem solving sessions and in the lab.

The concepts will be introduced in an increased order of complexity. In this way, retention of students is improved. It is also very convenient to stablish relations between this subject and other related ones in the curriculum.

Learning through problem solving sessions:

Problem solving sessions are devoted to create a proper atmosphere in order for the students to learn

how to apply the theoretical concepts to solve practical exercises. This is the necessary complement to the theoretical learning. In this way, the student learn how to apply the different tools available in different situations.

In each session, a series of exercises will be solved. Each student will have the exercises in advance in order to try them before the session. All doubts that may arise throughout the previous personal working will be addressed during the session.

Two objective tests will be scheduled at the beginning of the semester to properly assess the evolution of the student throughout the semester. Usually, the first objective tests take place in the middle of the semester and the second one by the end. The learning strategies in these sessions will have the aim to help the student to master effective problem solving strategies and produce certain good practices as the following ones: initial study, choosing of the best strategy to solve the specific problem, critical assessment of the final outcomes.

TIC's will support the achievement of learning outcomes. Blackboard virtual classroom will be used for this purpose.

Learning experience in the lab:

Lab exercises are a key component to the learning experience. Students will work in small groups of two or three people. Team effort is an important issue here. Each student has access to a lab manual in which all lab exercises are described step by step. Before each session, the students will go through the lab exercise guide included in the manual and will check the theoretical concepts needed for the specific exercise. These previous questions serve as a preparation of the theoretical concepts needed throughout the lab exercise. These previous questions will be carried out by a self-evaluation test in the virtual class.

Inside the lab, students will carry out a simulation or measurement exercise. Throughout the session, each group of students will elaborate a report of the exercise in order to prepare by themself the lab exam. The specific schedule will be provided to the students at the beginning of the semester.

The equipment used in this lab sessions is composed of PC's equiped with an RF and microwave design software as well as Vector network analyzers, waveguide work benches and other ancillary material needed for the exercises.

5. ASSESSMENT: procedures, evaluation and grading criteria

Preferably, students will be offered a continuous assessment model that has characteristics of formative assessment in a way that serves as feedback in the teaching-learning process.

5.1. PROCEDURES

The evaluation must be inspired by the criteria of continuous evaluation (Learning Assesment Guidelines, LAG, art 3). However, in compliance with the regulations of the University of Alcalá, an alternative process of final evaluation is made available to the student in accordance with the Learning Assesment Guidelines as indicated in Article 10, students will have a period of fifteen days from the start of the course to request in writing to the Director of the Polytechnic School their intention to take the non-continuous evaluation model adducing the reasons that they deem convenient. The evaluation of the learning process of all students who do not apply for it or are denied it will be done, by default, according to the continuous assessment model. The student has two calls to pass the subject, one ordinary and one extraordinary.

The teaching-learning methodology and the assessment process will be adapted as needed, in accordance with the guidelines of the Diversity Support Unit, to implement curricular adaptations for students with specific needs.

1. Ordinary call

Continuous evaluation option:

The continuous option should guarantee that the student has acquired all the knowledge and skills that are necessary to solve problems and situations concerning the topics of the course.

It will be based on a self-evaluation tests about the previous questions of the practical sessions, a written test about the laboratory work and two partial exams that will be taken during the semester. Continuous assessment of the laboratory work will be also carried out.

Non-continuous evaluation option:

As well as the final exam with all the contents of the course, another specific test will be done regarding those subjects involving the lab techniques and practical tasks performed by the student that attended the lab sessions.

2. Extraordinary call

Two situations are possible:

i. If the student has passed the laboratory test together with the self-evaluation tests, his or her grade in those assignments will be used to compute the final grade, together with the grade of the final examination.
ii. If the student has not passed the the laboratory test together with the self-evaluation tests a final test will be done regarding those subjects involving the lab techniques and practical tasks performed during the course by the student that attended the lab sessions.

5.2. EVALUATION

EVALUATION CRITERIA

CE1. The student should know the key components of a transmission system.

CE2. The student should be able to caracterize the different transmission media: TX lines, waveguides and the atmosphere.

CE3. The student should be able to use and interpret properly the relevant, fundamental parameters of transmission media.

CE4. The student should be able to solve practical problems with a sound understanding of the principles involved and creativity.

CE5. The student should be able to caracterize the most relevant parameters of radiating systems.

CE6. The student must be able to differentiate between the basic phenomena in free space and in the atmosphere, as well as ground wave vs space wave.

CE7. The student will show ability and self-initiative to solve problems related to wave propagation in guided media.

CE8. The student should be able to relate lab measurements and simulation results to the corresponding theoretical transmission media descriptors.

GRADING TOOLS

To analyze the success of the learning objectives, these are the grading tools:

1. **Partial Examinations (PEI)**: The student will individually solve a test with a number of theoretical and practical questions. The first test will be about Block 1 and the second will be about Block 2. This PEI2 will coincide with PEF. Those who have passed PEI1 will only take PEI2, whereas those who have not will take PEF, which will include the subjects of PEI2 as well as PEI1. PEI1 can also be recovered during the day of PEF.
2. **Self-evaluation test (ST)**: In each lab session, the student will do a self-evaluation test using the virtual class. The grade will be an average mark of all the test. If not handed over, the corresponding test will be marked with null points.
3. **Laboratory test (PL)**: There will be an extra written test that the student must pass this part of the course. It will cover all the issues that are related to the computation of parameters from measurements, their interpretation and the simulation with software. This test will be held the same day of the final exam but as a separate part.

It is compulsory to pass the ST+PL part as a whole to pass the course since this part represents the practical part according to article 6.4. of the general norms. The mark corresponding to the evaluation of the laboratory, if passed, may exempt the student from carrying out the laboratory in the extraordinary call.

4. **Final examination (PEF)**: The student will solve a full test with theoretical and practical questions clearly differentiated between Block 1 and Block 2. If the student has passed PEI1, PEF will be substituted by PEI2. Therefore, PEF will be taken if Block 1 has not been passed.

In all exams, the possibility of conducting additional oral tests is contemplated to contrast the students' knowledge reflected in the written exams, if necessary.

GRADING CRITERIA

This section below quantifies the grading criteria to be applied in this course.

Ordinary Call, Continuous Option

As a general criterion, a student who does not perform any of the evaluable tests will be considered as "Dropped out" (No presentado); as an exception to this criterion, a student who has performed all or part of the Self-Assessment Tests and the PEI1 but does not perform the rest of the evaluable tests of the subject (PL, PEI2 and PEF) will also be considered as Dropped out. Grading criteria and tools are organized in the following table:

Skill	Learning Outcomes	Grading criteria	Grading Tool	Percentage
TR2-TR3, TR5-TR8, TRU1-TRU2, CT1-CT2, CT3-CT4,CT8-CT15	RA1-RA2	CE1-CE2, CE3-CE4	PEI1	40%
	RA3-RA4	CE1-CE5, CE6-CE7	PEI2	35%
TR2-TR8, TRU1, CT1-CT2, CT3-CT8	RA1-RA2, RA3-RA4, RA5-RA6	CE1-CE2, CE3-CE5, CE6-CE8	ST PL	10% 15%

Ordinary Call, Non-continuous Option

The PEF will gather a 40% weighting from Block 1 and 35% from Block 2. Grading criteria and tools are organized in the following table:

Skill	Learning Outcomes	Grading criteria	Grading Tool	Percentage
TR2-TR3, TR5-TR8, TRU1-TRU2, CT1-CT2, CT3-CT4,CT8-CT15	RA1-RA2, RA3-RA4	CE1-CE2, CE3-CE4,CE5-CE6, CE7	PEF	75%
TR2-TR8, TRU1, CT1-CT2, CT3-CT8	RA1-RA2, RA3-RA4, RA5-RA6	CE1-CE2, CE3-CE5, CE6-CE8	PL	25%

Extraordinary Call

The PEF will gather a 40% weighting from Block 1 and 35% from Block 2. Grading criteria and tools are organized in the following table:

Competence/Skill	Learning Outcomes	Grading criteria	Grading Tool	Percentage
TR2-TR3, TR5-TR8, TRU1-TRU2, CT1-CT2, CT3-CT4,CT8-CT15	RA1-RA2, RA3-RA4	CE1-CE2, CE3-CE4, CE5-CE6, CE7	PEF	75%
TR2-TR8, TRU1, CT1-CT2, CT3-CT8	RA1-RA2, RA3-RA4, RA5-RA6	CE1-CE2, CE3-CE5, CE6-CE8	PL	25%

The PL shall not be necessary for those students having passed the ST+PL part in the ordinary, continuous option or the PL in the ordinary, non-continuous option.

6. BIBLIOGRAPHY

6.1. Basic Bibliography

- Lecture notes, provided in the Blackboard
- ULABY, Fawwaz T., et al. Fundamentals of Applied Electromagnetics, ISBN: 978-0-13-213931-1. Instructor, 2014, vol. 201409. .
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6.2. Additional Bibliography

- BAKSHI U.A. and BAKSHI, A.V. Transmission Lines and Waveguides. Technical Publication Pune, 2006.
- BALANIS, Constantine A. Antenna theory: analysis and design. John Wiley & Sons, 2016.
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- DOLUKHANOV, M. Propagation of Radio Waves. YPCC, 1995.
- ELLIOT, R.S. An Introduction to Guided Waves and Microwave Circuits. Prentice-Hall Inc., 1993.

Disclosure Note

During the evaluation tests, the guidelines set out in the Regulations establishing the Rules of Coexistence of the University of Alcalá must be followed, as well as the possible implications of the irregularities committed during said tests, including the consequences for committing academic fraud according to the Regulation of Disciplinary Regime of the Students of the University of Alcalá.