COURSE DESCRIPTION

1. Program identification information

1.1 Higher education institution	**National University of Science and Technology Politehnica Bucharest**
1.2 Faculty	**Electronics, Telecommunications and Information Technology**
1.3 Department	**Telecommunications**
1.4 Domain of studies	Electronic Engineering, Telecommunications and Information Technology
1.5 Cycle of studies	Bachelor/Undergraduate
1.6 Programme of studies	Technologies and Telecommunications Systems

2. Date despre disciplină

2.1 Course name (ro) (en)				Antennas and Propagation			
2.2 Course Lecturer				Prof. Dr. Alina Badescu			
2.3 Instructor for practical activities				Prof. Dr. Alina Badescu			
2.4 Year of studies	4	2.5 Semester	I	2.6. Evaluation type	E	2.7 Course regime	Ob
2.8 Course type	S		2.9 Course code	04.S.07.O.605		2.10 Tipul de notare	Nota

3. Total estimated time (hours per semester for academic activities)

3.1 Number of hours per week	3	Out of which: 3.2 course	2.00	3.3 seminary/laboratory	1
3.4 Total hours in the curricula	42.00	Out of which: 3.5 course	28	3.6 seminary/laboratory	14
Distribution of time:					hours
Study according to the manual, course support, bibliography and hand notes Supplemental documentation (library, electronic access resources, in the field, etc) Preparation for practical activities, homework, essays, portfolios, etc.					25
Tutoring					5
Examinations					3
Other activities (if any):					0

3.7 Total hours of individual study	33.00
3.8 Total hours per semester	75
3.9 Number of ECTS credit points	3

4. Prerequisites (if applicable) (where applicable)

4.1 Curriculum	Microwaves Calculus

4.2 Results of learning	Knowledge of propagation modes, vectorial calculus, coordinate systems.

5. Necessary conditions for the optimal development of teaching activities (where applicable)

5.1 Course	-
5.2 Seminary/ Laboratory/Project	Compulsory lab activities (according to the internal regulations of POLITEHNICA University of Bucharest)

6. General objective *(Reffering to the teachers' intentions for students and to what the students will be thought during the course. It offers an idea on the position of course in the scientific domain, as well as the role it has for the study programme. The course topics, the justification of including the course in the currcula of the study programme, etc. will be described in a general manner)*

Discipline provides students a thorough grounding in antennas and radio wave propagation as well as basic knowledge of the principles and methods used to analyze antennas.

7. Competences *(Proven capacity to use knowledge, aptitudes and personal, social and/or methodological abilities in work or study situations and for personal and proffesional growth. They refflect the empolyers requirements.)*

Specific Competences	General knowledge and specific application of the theory of antennas in various projects. The possibility of determining the feasibility of a solution based on its performance. Understanding the specifics of various types of concrete applications and operating conditions impact on the performance of antennas.
Transversal (General) Competences	Methodical analysis of the problems encountered in work, identifying the items for which solutions are established.

8. Learning outcomes *(Synthetic descriptions for what a student will be capable of doing or showing at the completion of a course. The learning outcomes reflect the student's acomplishments and to a lesser extent the teachers' intentions. The learning outcomes inform the students of what is expected from them with respect to performance and to obtain the desired grades and ECTS points. They are defined in concise terms, using verbs similar to the examples below and indicate what will be required for evaluation. The learning outcomes will be formulated so that the correlation with the competences defined in section 7 is highlighted.)*

Knowledge	*The result of knowledge aquisition through learning. The knowledge represents the totality of facts, priciples, theories and practices for a given work or study field. They can be theoretical and/or factual.* The learning outcomes of the "Antennas and Propagation" course, in terms of Knowledge, include: 1. **Fundamental principles of antennas** – types of antennas, characteristic parameters (gain, directivity, impedance, polarization, efficiency, etc.). 2. **Electromagnetic wave propagation** – propagation models, environmental effects on propagation (reflection, diffraction, attenuation, dispersion, etc.). 3. **Electromagnetic radiation theory** – Maxwell's equations applied to antenna and propagation analysis. 4. **Characteristics and performance of various antenna types** – dipole antennas, Yagi-Uda, patch, parabolic, log-periodic antennas, etc. 5. **Antenna analysis and design methods** – techniques for modeling and simulating antenna radiation. 6. **Antenna systems** – antenna arrays, phased arrays, and interference effects. 7. **Interaction of antennas with the environment** – effects of terrain, buildings, atmospheric conditions, and the ionosphere on propagation. 8. **Practical applications of antennas** – terrestrial and satellite communications, radar, IoT, 5G, etc.
Skills	*The capacity to apply the knowledge and use the know-how for completing tasks and solving problems. The skills are described as being cognitive (requiring the use of logical, intuitive and creative thinking) or practical (implying manual dexterity and the use of methods, materials, tools and intrumentation).* The learning outcomes of the **"Antennas and Propagation"** course, in terms of **Skills**, include: 1. **Analyzing and interpreting antenna parameters** – calculating and interpreting gain, impedance, directivity, bandwidth, etc. 2. **Selecting and designing antennas** – choosing the appropriate antenna type for various communication applications. 3. **Simulating and modeling antennas** – using simulation software (e.g., HFSS, CST, MATLAB) to analyze antenna performance. 4. **Antenna measurement and testing** – utilizing equipment such as a network analyzer, anechoic chamber, and frequency spectrum analyzer. 5. **Evaluating electromagnetic wave propagation** – applying propagation models to estimate the performance of a radio link. 6. **Diagnosing and optimizing antenna performance** – identifying issues and adjusting characteristics to maximize efficiency. 7. **Implementing antenna systems** – integrating antennas into communication, radar, satellite, or IoT systems. 8. **Interpreting environmental effects on propagation** – analyzing the impact of obstacles, atmospheric conditions, and the ionosphere on radio transmissions.

Responsability and autonomy	*The student's capacity to autonomously and responsably apply their knowledge and skills.* The learning outcomes of the **"Antennas and Propagation"** course, in terms of **Responsibility and Autonomy**, include: 1. **Ability to make informed decisions** in selecting, designing, and implementing antennas and communication systems, considering technical requirements and environmental constraints. 2. **Taking responsibility for antenna system performance** by evaluating and optimizing them to comply with technical standards and regulations. 3. **Autonomy in using and configuring measurement and testing equipment**, such as network analyzers, frequency spectrum analyzers, and anechoic chambers. 4. **Ability to identify and solve technical issues** related to signal propagation and antenna efficiency, proposing appropriate solutions. 5. **Independent work in research and innovation**, focusing on the development of new antenna models and improvements in propagation techniques. 6. **Teamwork and interdisciplinary collaboration**, contributing to the design and implementation of advanced communication technologies.

9. Teaching techniques *(Student centric techniques will be considered. The means for students to participate in defining their own study path, the identification of eventual fallbacks and the remedial measures that will be adopted in those cases will be described.)*

Teaching (definitions, demonstrations, properties) of the main theoretical concepts is carried out using the classical method (the board). To facilitate the understanding of physical phenomena, some properties / characteristics are presented using the projector, covering communication function demo.

Oral communication methods used are expository method and problem-method.

On-site course materials are available electronically.

10. Contents

COURSE		
Chapter	**Content**	**No. hours**
1	1. Introduction 1.1. Types of antennas 1.2. Radiation mechanism 1.3. Current distribution in a wire antenna	2

2	2. Fundamental parameters of antennas 2.1. Characteristic radiation, types of radiation characteristics and diagrams 2.2. The lobes of the radiation characteristic 2.3. Field regions 2.4. The radiation intensity 2.5. Antenna directivity 2.6. Antenna gain 2.7. Efficiency. The efficiency of the antenna 2.7.2. Efficiency lobe 2.7.3. Polarization efficiency 2.7.4. Radiation efficiency 2.7.5. Aperture efficiency 2.8. Lobe opening angle 2.9. Polarization of antenna 2.10. The input impedance of the antenna 2.11. Vector effective length of the antenna 2.12. Effective area 2.12.1. Scattering surface 2.12.2. Loss surface 2.12.3. Catch surface 2.13. The connection between the maximum directivity and effective area 2.14. Antenna temperature	4
3	3. Radiation vector potential functions and integrals 3.1. Magnetic vector potential function 3.2. Electric vector potential function	2
4	4. Wire antennas 4.1. Radiated electric field for an infinitesimal dipole 4.1.1. Radiation Resistance 4.1.2. directivity 4.1.3. Determination of field regions 4.2 . Dipole of finite length 4.2.1. Current distribution along the antenna 4.2.2. Radiated field 4.2.3. The radiation intensity 4.2.4 . Radiation resistance 4.2.5 . Input resistance 4.2.6 . Effect of non-zero distance between terminals 4.3. Parameters of the half wavelength dipole 4.4 . Infinitesimal dipole above an infinite perfect conductor plane 4.4.1. image theory 4.4.2. vertical electric dipole 4.4.2.1. Far field 4.4.2.2. Radiated power, radiation intensity, directivity and radiation resistance 4.4.3. Horizontal electric dipole 4.4.3.1 . Far field 4.4.3.2 . Radiated power, radiation intensity , directivity and radiation resistance 4.5. Ground effect on the radiation characteristic of the antenna 4.5.1. Vertical dipole 4.5.2. Horizontal dipole	6

5	5. Loop antennas 5.1. Circular infinitesimal loop. Radiated field 5.1.1. Radiation Resistance 5.1.2. Directivity 5.2. Square loop 1 hours	1
6	6. Broadband antennas & antenna miniaturization 6.1. Biconical antenna 6.2. Cylindrical dipole 6.3. Log-periodic antennas	2
7	7. Antenna systems 7.1. A two element system. Uniform system of N linear antennas 7.2. Planar antenna system 7.3. Uniform circular N-antenna system	2
8	8. Printed antennas 8.1. Microstrip rectangular patch. Transmission line model 8.2. Planar inverted-F antenna (PIFA) 8.3. Ceramic chip antennas	2
9	9. Phased arrays for 5G, Radar and Satellite 9.1 Phase fronts and beamsteering; array configurations 9.2. Digital Beamforming 9.3. RF/Analog Beamforming 9.4. Hybrid Beamforming 9.5. Near/far field and weighting (tapers) 9.5.1. Effect of element spacing 9.5.2. Effect of scan angle	2
10	10. Aperture antennas 10.1. Horn antennas 10.2. Reflector Antennas	2
11	11. Propagation of radio waves 11.1. Propagation in free space attenuation. Budget link 11.2. Propagation through ionosphere 11.2.1. Refraction index 11.3. Antennas for satellite navigation 11.4. Antennas for satellite communications	3
	Total:	28

Bibliography:

u- Antennas and propagation (electronic version), in press
2. J. Kraus, Antennas for all applications, McGraw-Hill, 2015
3. C. Balanis, “AntennaTheory – analysis and design”, John Wiley&Sons, 1997

LABORATORY

Crt. no.	Content	No. hours
1	Lab 1 Matlab: basic parameters characteristic radiation	2
2	Lab 2 Matlab: half wavelength dipole	2

3	Lab 3 Matlab: Infinitesimal electric dipole above a perfect conducting plane	2
4	Lab 4 Matlab: Liniar uniform string of N isotrope antennas	2
5	Lab 5 NEC: antenna simulator environment –part I	2
6	Lab 6 NEC: antenna simulator environment –part II	2
7	Final test	2
	Total:	14

Bibliography:

anu,- Îndrumar laborator Antene și propagare.
- Îndrumar laborator Antene și propagare.

11. Evaluation

Activity type	11.1 Evaluation criteria	11.2 Evaluation methods	11.3 Percentage of final grade
11.4 Course	- Knowledge of basic theoretical concepts - Knowledge of the application of theory to specific problems - Critical analysis and comparison of techniques and theoretical models	Exam scheduled session. Topics cover all the syllabus of the subject, making a synthesis of comparative theoretical completion of the course and explaining patterns of application exercises.	40

11.5 Seminary/laboratory/project	- Knowledge of the fundamental parameters of antennas - Analysis of simple pie - Study of antenna systems - Understanding the features of different types of applications and the impact of operating conditions on the performance of concrete antennas	Oral laboratory examination comprises a theoretical and practical component. Theoretical component consists of each student response to a separate set of questions; the practical component is to determine the fundamental parameters of antennas.	30
	Theoretical Foundation and Documentation Clarity of explanations regarding antenna principles Correct references to scientific literature and relevant standards. Justification of the chosen antenna type. Antenna Design and Analysis Correctness of calculations for antenna parameters (gain, directivity, impedance, polarization, etc.). Use of simulation software for analyzing antenna radiation. Optimization of the design based on the application.	Evaluation through Technical Report Students are required to prepare a written report that includes theoretical foundations, calculations, simulations, and conclusions. The evaluation focuses on the clarity of explanations, correctness of calculations, and analysis of results. Evaluation through Simulation and Numerical Modeling Specialized software is used for the design and analysis of antennas. The professor evaluates the accuracy of the modeling and the correct interpretation of results.	30
11.6 Passing conditions			
Minimum 50 points.			

12. Corroborate the content of the course with the expectations of representatives of employers and representative professional associations in the field of the program, as well as with the current state of knowledge in the scientific field approached and practices in higher education institutions in the European Higher Education Area (EHEA)

The unprecedented development of radio communication systems, wireless sensors and detection systems and the electromagnetic tracking has made radio equipment to be ubiquitous. The structure of any radio system includes at least one antenna. The trend of miniaturization of the equipment or spectral efficiency requires the development of new types and variants of antennas. The industry has a demand for qualified engineers with radio specializations and a solid foundation in the field of antennas and radio channel modeling, able to develop new products and services.

The course syllabus meets the present requirements for development and progress, subscribed services of the European economy services in Electronics and Telecommunications Engineering, the studying program of Technology and telecommunications systems (TST). In the context of current technological advancement, equipment radiofrequency fields concerned are virtually endless, such as applications and consumer goods (mobile terminal "smart -phone"), medical (treatment , imaging), the military (special communications systems integrated radar systems and radio waveguides), the security (surveillance systems), the current highly professional communications and others.

This provides the bachelor graduates skills in line with current needs, a technical and scientific training, enabling rapid employment after graduation. This policy is in accordance with the Polytechnic University of Bucharest, both in terms of content and structure and in terms of skills and international openness offered to graduates.

Date	Course lecturer	Instructor(s) for practical activities
	Prof. Dr. Alina Badescu	Prof. Dr. Alina Badescu
Date of department approval	Head of department	
	Serban Obreja	
Date of approval in the Faculty Council	Dean	
	Mihnea Udrea	