COURSE UNIT (MODULE) DESCRIPTION

Course unit (module) title	Code
Antenna engineering	

Lecturer(s)	Department(s) where the course unit (module) is delivered
Coordinator: assoc. prof. dr. Rimvydas Aleksiejūnas **Other(s):** assoc. prof. dr. Edvardas Kazakevičius, assoc. prof. dr. Saulius Rudys	Faculty of Physics, Vilnius University

Study cycle	Type of the course unit (module)
Master (graduate)	Elective

Mode of delivery	Period when the course unit (module) is delivered	Language(s) of instruction
Classroom training	1 semester	English

Requirements for students	
Prerequisites: linear algebra, electromagnetism, microwave engineering, basic knowledge of computer programming	**Additional requirements (if any):**

Course (module) volume in credits	Total student's workload	Contact hours	Self-study hours
5	140	64	76

Purpose of the course unit (module): programme competences to be developed		
Students will get familiar with antenna fundamentals, such as radiation patterns, impedance matching and frequency characteristics. They will get understanding of radiation principles of dipole antennas as well as common antennas types such as wire, aperture and planar microstrip antennas, antenna arrays, satellite antennas, antenna materials and they electromagnetic properties. The students will get introduction to antenna measurements and testing.		
Learning outcomes of the course unit (module)	**Teaching and learning methods**	**Assessment methods**
- Will be able to solve electromagnetic radiation problems of dipole and wire antennas analytically, and use numerical electromagnetic solvers to model more complex antennas such as planar and aperture antennas. - Will get understanding about antenna design, various antenna implementations, including planar and integrated antennas, will get familiar with electromagnetic characteristics of antenna materials. - Will acquire knowledge about antenna parameters, antenna design and measurement principles.	Laboratory exercises, studying literature, discussions.	Evaluation tests of laboratory exercises.
- Gain knowledge in antenna design principles, main characteristics and measurement procedures.	Teaching problem-solving skills, demonstrations, discussion.	Written exam, closed-ended questions.

Content: breakdown of the topics	Contact hours							Self-study work: time and assignments	
	Lectures	Tutorials	Seminars	Exercises	Laboratory work	Internship/work	**Contact hours**	**Self-study hours**	**Assignments**
1. Introduction to EM and antenna basics: Review of electromagnetism and Maxwell's equations. Dipole radiation, Huygens source, crossed dipole antennas. Near and far zones, antenna impedances, S-parameters, frequency characteristics. Antenna radiation pattern, directivity, radiation efficiency. Wire antennas. Directional antennas, Yagi and log-periodic antennas. Modeling and analysis of wire antennas (MATLAB).	4				4		**8**	**6**	Literature reading, completion of lab assignments and self-study tasks.
2. Aperture antennas: Huygens' and Babinet's principles. Waveguide, horn antennas, parabolic reflectors, slot antennas. Aperture efficiency. Slot antenna design, estimation of the impedance.	4				4		**8**	**6**	Literature reading, completion of lab assignments and self-study tasks, improvement of Python programming skills.
3. Antenna arrays: Linear, planar circular and conformal arrays, feeding networks, phased arrays, beamforming, MIMO antennas. Practical exercises: array factor calculations using Python or Matlab, beamforming in linear and planar arrays.	4				4		**8**	**6**	Literature reading, completion of lab assignments and self-study tasks.
4. Satellite and GNSS antennas: Helical antennas, multipath mitigation, phase center variation, antenna noise temperature, satellite link budget analysis.	4				4		**8**	**6**	Literature reading, completion of lab assignments and self-study tasks.
5. Planar and integrated antenna technologies: Planar antennas. Integrated antennas, antennas in a package and on chip, embedded antennas. Ceramic chip antennas. Millimeter wave and terahertz antennas.	4				4		**8**	**6**	Literature reading, completion of lab assignments and self-study tasks.
6. Antenna materials: Conductors, thin films and conductive coatings. dielectric materials (Teflon, Rogers, FR4, etc.), dielectric constant and loss tangent. Ceramic materials. Frequency selective surfaces (FSS). Electromagnetic bandgap (EBG) structures. Metamaterials and metasurfaces.	4				4		**8**	**6**	Literature reading, completion of lab assignments and self-study tasks.
7. Antenna simulation and testing: Antenna modeling and simulation tools, HFSS. Antenna measurement principles. Performance testing in anechoic chambers.	8				8		**16**	**32**	Literature reading, completion of lab assignments and self-study tasks.
Preparation for the exam								**8**	
Total	**32**				**32**		**64**	**76**	

Assessment strategy	Weight, %	Deadline	Assessment criteria
Laboratory work: performing	40	During the	Evaluation of the acquired knowledge and analytical skills, the

practical exercises		semester	ability to apply knowledge to solve practical antenna modeling tasks. Each laboratory work consists of practical assignment with instructions. **5-9 points:** Estimated proportionally to the number of tests completed correctly: 50% - 5 points, 60% - 6 points, etc. **10 points:** More than 90% of tests completed and at least one self-study task performed.
Two control tests	(15+15)	During the semester	Each test presents questions in the form of a closed-form test (20 questions). Each question is worth 0.5 point.
Written exam	30	During the session	Evaluation of knowledge from antenna theory and modeling, covered during the lectures. The exam consists of 20 closed-ended questions with possible several correct answers. Each answer is scored on a scale of 0 to 0.5, and the result is summed up: **0 points:** At least one wrong answer is selected or not all the correct answers are selected; **0.5 point:** One or all available correct answer options are selected.

Author	**Year of publication**	**Title**	**Issue of a periodical or volume of a publication**	**Publishing place and house or web link**
Compulsory reading				
C. A. Balanis	2016	Antenna theory: analysis and design	4th edition	Hoboken, New Jersey: Wiley
J. D. Kraus	2003	Antennas for all applications	3rd edition	McGraw-Hill
D. G. Fang	2010	Antenna theory and microstrip antennas		Boca Raton, FL: CRC Press/Taylor & Francis
Optional reading				
R. C. Hansen	2009	Phased array antennas	2nd edition	Hoboken, N.J: Wiley
P.-S. Kildal	2015	Foundations of antenna engineering		Pixbo: Kildal Antenn, https://www.kildal.se/downloads/
S. J. Orfanidis	2016	Electromagnetic waves and antennas		Rutgers University, https://eceweb1.rutgers.edu/~orfanidi/ewa/
H. Asplund *et al.*	2020	Advanced Antenna Systems for 5G Network Deployments: Bridging the Gap Between Theory and Practice		Amsterdam: Academic Press
K. Fujimoto and H. Morishita	2014	Modern Small Antennas		Cambridge University Press