Національний технічний університет України «КИЇВСЬКИЙ ПОЛІТЕХНІЧНИЙ ІНСТИТУТ імені ІГОРЯ СІКОРСЬКОГО»	Radioengineering Faculty Radioengineering Department

Microwave Devices (PN-10)

Curriculum of the academic discipline (Syllabus)

Course details

Level of higher education	***First (bachelor's)***
Field of knowledge	*G - Engineering, manufacturing, and construction*
Special	*G5 Electronics, electronic communications, instrument engineering, and radio engineering*
Educational program	*Information and communication radioengineering*
Status of discipline	*Compulsory for professional training*
Form of study	*Full-time (day)* *and full-time accelerated (daytime)*
Year of training, semester	*3rd year, spring semester*
Scope of the discipline	*Total: 5 ECTS credits/150 hours* *Lectures: 44 hours* *Practical classes: 16 hours* *Laboratory classes: 16 hours.* *Self-study by students: 74 hours.*
Semester control/control measures	*Semester assessment: exam* *Ongoing assessment: modular test, defense of laboratory work, CGW*
Class schedule	*Lectures (usually at least once a week starting from the 1st week), laboratory work and practical classes according to https://schedule.kpi.ua/*
Language of instruction	*Ukrainian*
Information about the course director/teachers	*Lecturer: Ph.D., Associate Professor of the Radio Engineering Department* ***Dmytro Vasylenko*** (dmytro.vasylenko@lll.kpi.ua*),* *Laboratory work: Ph.D., Associate Professor of the Radio Engineering Department* ***Dmytro Vasilenko*** *Practical classes: Ph.D., Associate Professor of the Radio Engineering Department* ***Dmytro Vasylenko***
Course location	*The course is available on the Sikorsky distance learning platform: https://do.ipo.kpi.ua/course/view.php?id=764*

Curriculum

1. Description of the course, its purpose, subject matter, and learning outcomes

Modern systems (cars, unmanned aerial vehicles, aircraft, etc.) contain up to 10-20 different antennas with corresponding transmission paths. Each transmission path requires the selection of a transmission line and the construction of the necessary components based on the selected transmission line. Each antenna requires matching devices.

After completing the course, students should demonstrate the following learning outcomes:

1) Knowledge:
- the principles of construction, design, and operation of ultra-high frequency (UHF) devices and antennas and the physical processes that occur in them;
- the basic properties of UHF devices and antennas;
- methods for calculating the parameters of UHF devices and antennas;
- methods of experimental research of the characteristics of functional elements of the antenna-feeder path.

2) Skills:
- calculate the parameters of microwave devices;
- select the most effective microwave devices for radio engineering systems operating in different frequency ranges;
- perform engineering calculations of the main characteristics of microwave devices;
- conduct experimental research on the characteristics and parameters of microwave devices.

3) Experience:
- performing calculations of narrowband and broadband matching devices of coaxial and microstrip design;
- experimental study of the characteristics of microwave devices;
- working with microwave range equipment.

In accordance with the professional educational programs (PEP) of the first "bachelor's" level of higher education, after mastering the academic discipline, students should acquire **the** following program **competencies**:

General competencies (GC)

GC 02 - Ability to apply knowledge in practical situations.

Professional competencies (PC)

PC 15 - Ability to perform calculations in the process of designing structures and means of information and telecommunication networks, telecommunication and radio engineering systems, in accordance with technical specifications using both standard and independently created methods, techniques, and software tools for design automation.

PC 16 - Ability to calculate the basic parameters of various types of antennas and microwave devices, select the most effective antennas and microwave devices for radio engineering systems with **specified** operating modes and functional characteristics, experimentally study the characteristics and devices of microwave antennas of various designs and frequency ranges**.**

PC 17 - Ability to apply modern CAD systems for the design, structural synthesis, and highly efficient multi-parameter optimization of antennas, active and passive microwave devices.

Program learning results (PLR)

According to the first "bachelor's" level of higher education, as a result of mastering the academic discipline, students must demonstrate the following **program learning results**:

PLR01 - Analyze, argue, and make decisions when solving specialized tasks and practical problems in telecommunications and radio engineering, which are characterized by complexity and incomplete certainty of conditions.

PLR18 - Find, evaluate, and use information from various sources necessary for solving professional tasks, including reproducing information through electronic search.

PLR29 - Measure the basic parameters of antennas, microwave devices, and active microwave receiving systems.

2. Prerequisites and postrequisites of the discipline (place in the structural-logical scheme of training under the relevant educational program)

In the structural and logical scheme of the professional educational program for training specialists of the first (bachelor's) level of higher education, the academic discipline "Microwave Devices" is included in the list of normative disciplines aimed at forming the professional competencies of a specialist.

Prerequisites – the academic discipline is specialized and is taught in the 5th semester of the 3rd year of study. To master this discipline, knowledge of the following disciplines is required: "Higher Mathematics," "General Physics," "Fundamentals of Metrology," "Electrodynamics and Radio Wave Propagation," "Circuit Engineering," and "Fundamentals of Circuit Theory."

Post-requisites: – knowledge gained in this discipline will enable mastery of the following disciplines: Automated Design of Antennas and Microwave Devices, Antennas, Electromagnetic Compatibility.

3. Course content

LECTURES

Section 1. Introduction.

Topic 1.1. Ultra-high frequency devices: basic definitions, classification, characteristics and parameters, areas of application. Basic engineering approaches to the design of microwave devices. Brief description of programs for numerical calculation of antenna-feeder path (AFP) elements.

Section 2. Transmission lines in radio systems and UHF devices.

Topic 2.1. Basic characteristics and parameters of transmission lines in the design of microwave devices.

Topic 2.2. Main types of transmission lines and their characteristics: two-wire, multi-wire, coaxial, waveguide, strip and microstrip, dielectric, fiber optic.

Topic 2.3. Mathematical model of a regular transmission line. The effect of the wave mode in the transmission line on the efficiency and transmission power. Transformation of impedances in transmission lines.

Section 3. Elements of antenna-feeder lines (AFL).

Topic 3.1. AFT elements: functional purpose, operating principles, characteristics.

Topic 3.2. Inhomogeneities in transmission lines and their equivalent circuits.

Section 4. Microwave multipoles and their characteristics

Topic 4.1. Wave scattering and transmission matrices, resistance and conductance matrices. Physical meaning of their elements.

Topic 4.2. Mutual, non-dissipative, reactive, symmetrical multipoles, their properties.

Topic 4.3. Operating parameters of a mismatched four-pole network.

Topic 4.4. The method of in-phase and anti-phase excitation and its application in determining the elements of scattering matrices of symmetric octapoles.

Section 5. Broadband matching.

Topic 5.1. Synthesis of step transitions with Chebyshev and maximum flat characteristics of working attenuation.

Section 6. Directional couplers and dividers.

Topic 6.1. Directional couplers (HB): principles of operation, general characteristics.

Topic 6.2. Waveguide HB with coupling through holes in the wide and narrow walls of a waveguide with a rectangular cross-section.

Topic 6.3. Waveguide-slit bridge.

Topic 6.4. Strip HB: Wilkinson divider; ring directional coupler with a length of 3/2 λ***;*** directional couplers on coupled lines; HB-Lange. Their topologies and characteristics.

Topic 6.5. Six-pole, matched divider into two (resistive) – topology, characteristics.

Section 7. Microwave filters.

Topic 7.1. Classification of filters and examples of implementation. Approximation of filter characteristics. Prototype filter.

Topic 7.2. Synthesis of microwave filters. Synthesis of a low-pass filter on a microstrip line with stepwise resistance change.

Topic 7.3. Synthesis of microwave filters based on coupled microstrip resonators.

Section 8. Microwave range control devices.

Topic 8.1. Classification, definition, design principles, characteristics. P-i-n diode as a control element of microwave devices and its characteristics.

Topic 8.2. Semiconductor phase shifters of reflective, pass-through types and on switchable lines.

Topic 8.3. Semiconductor attenuators.

Topic 8.4. Anisotropic media

Topic 8.5. Controllable devices based on the Faraday effect

Topic 8.6. Controllable devices with transverse magnetization

Topic 8.7. Ferrite and semiconductor phase shifters

PRACTICAL CLASSES

The purpose of practical classes is to master the methods of solving the main tasks of matching the elements of antenna-feeder paths with each other. Practical classes are planned on the following topics:

- characteristics and parameters of transmission lines, transformation of impedances in transmission lines;
- circular diagram of total impedances and its application for solving matching problems and finding unknown load impedance in a line.
- narrowband matching using discrete elements and transmission line segments;

- broadband matching of coaxial, microstrip, and waveguide transmission lines with different characteristic impedances

LABORATORY WORK

The main purpose of laboratory work is for students to gain experience and skills in practical work with microwave range equipment, the ability to conduct experimental studies of the characteristics and parameters of antennas and microwave devices. To process the results of research and draw conclusions. In addition, laboratory work allows the teacher to monitor the self-study of students throughout the semester.

Educational research is planned on the following topics:

1. Research on ultra-high frequency phase shifters.
2. Transmission line matching.
3. Research on bandpass filters based on a pass-through resonator in a waveguide design.
4. Research on a multi-port waveguide directional coupler.
5. Research on non-reciprocal ferrite devices.
6. Research on double waveguide tees.
7. Investigation of a waveguide-slot directional coupler.
8. Investigation of a microstrip power divider.

Modular test
Exam

4. Teaching materials and resources

Basic and additional literature (hereinafter referred to as literature) is used to prepare for lectures, laboratory classes, modular test, self-study, etc. The literature required for mastering the discipline is studied by students independently using Internet resources, on the Sikorsky distance learning platform using the Moodle platform. In the context of distance learning, students can use literature available in electronic form on university and external media.

Basic literature

1. Vasilenko, D. O. Ultra-high frequency devices. Lecture notes [Electronic resource]: textbook for bachelor's degree students in the educational program "Information and Communication Radio Engineering" in the specialty 172 "Electronic Communications and Radio Engineering" / D. O. Vasilenko; Igor Sikorsky Kyiv Polytechnic Institute. – Electronic text data (1 file: 5.67 MB). – Kyiv: Igor Sikorsky Kyiv Polytechnic Institute, 2023. – 182 p. – Title from screen. – Access: https://ela.kpi.ua/handle/123456789/57059
2. Vasilenko, D. O. Ultra-high frequency devices. Practical Guide [Electronic resource]: textbook for bachelor's degree students in the educational program "Information and Communication Radio Engineering" in the specialty 172 "Electronic Communications and Radio Engineering" / D. O. Vasilenko; Igor Sikorsky Kyiv Polytechnic Institute. – Electronic text data (1 file: 1.37 MB). – Kyiv: Igor Sikorsky Kyiv Polytechnic Institute, 2023. – 51 p. – Title from the screen. – Access: https://ela.kpi.ua/handle/123456789/57060
3. Ultra-high frequency devices. Laboratory practical [Electronic resource]: textbook for bachelor's degree students majoring in 172 "Telecommunications and Radio Engineering" / Igor Sikorsky Kyiv Polytechnic Institute; compiled by: V. S. Vuntesmeri, O. M. Kupriy,

A. F. Levina, S. E. Martynyuk, F. M. Repa. – Electronic text data (1 file: 2.03 MB). – Kyiv: Igor Sikorsky Kyiv Polytechnic Institute, 2021. – 88 p. – Title from screen. – Access: https://ela.kpi.ua/handle/123456789/52763

4. Vasilenko, D. O. Ultra-high frequency devices: Coursework (Part 1. Narrowband matching of complex loads) [Electronic resource]: textbook for students majoring in 172 "Telecommunications and Radio Engineering" / D. O. Vasilenko; Igor Sikorsky Kyiv Polytechnic Institute. – Electronic text data (1 file: 7.76 MB). – Kyiv: Igor Sikorsky Kyiv Polytechnic Institute, 2021. – 79 p. – Title from the screen. – Access: https://ela.kpi.ua/handle/123456789/45719
5. Vasilenko, D. O. Ultra-high frequency devices. Coursework (Part 2. Broadband load matching) [Electronic resource]: textbook for bachelor's degree students majoring in 172 "Telecommunications and Radio Engineering" / D. O. Vasilenko; Igor Sikorsky Kyiv Polytechnic Institute. – Electronic text data (1 file: 2.18 MB). – Kyiv: Igor Sikorsky Kyiv Polytechnic Institute, 2022. – 63 p. – Title from the screen. – Access: https://ela.kpi.ua/handle/123456789/50549
6. Modern methods of analysis, synthesis, and optimization of ultra-high frequency devices and antennas: methodological recommendations for students majoring in 6.050901 "Radio Engineering" [Electronic resource]/ D. O. Vasilenko. – Kyiv: NTUU "KPI", REF, 2015. – 58 p. A4 format. - Access: http://ela.kpi.ua/handle/123456789/16419

Additional literature

1. David M. Pozar. Microwave Engineering / David M. Pozar. – USA: John Wiley & Sons, 2005. – 700 p.

Information resources

1. https://www.youtube.com/@AWRCorporation – instructional videos on using the AWR Design Environment program.

Educational content

5. Methodology for mastering the academic discipline (educational component)

To study the academic discipline, 22 lectures, 8 practical classes, and 6 laboratory classes are planned, during which students must complete a modular test and defend their laboratory work after completion.

Lectures

No	Lecture topic and list of main questions
1	Lecture Topic 1.1. Ultra-high frequency devices: basic definitions, classification, characteristics and parameters, areas of application. Basic engineering approaches to the design of microwave devices. Brief description of programs for numerical calculation of antenna-feeder path (AFP) elements.

2	Lecture 2. Topic 2.1. The most significant characteristics and parameters of transmission lines in the design of microwave devices. Topic 2.2. Basic types of transmission lines and their characteristics: two-wire, multi-wire, coaxial. Assignment for independent study: Calculate the parameters of the RK75-4-11 cable.
3	Lecture 3. Topic 2.2. Main types of transmission lines and their characteristics: waveguide, strip and microstrip, slot. Assignment for independent study: Calculate the parameters of a microstrip line at eps=9.8, h=0.5, Z=50 Ohm, f=2.5 GHz. Calculate the parameters of a rectangular waveguide at axb=23x10 mm, f=10 GHz, wave type H10. Calculate the parameters of a circular waveguide for 2a=20 mm, wave type H11, f=10 GHz.
4	Lecture 4. Topic 2.2. Main types of transmission lines and their characteristics: dielectric, fiber optic. Topic 2.3. Mathematical model of a regular transmission line. Influence of the wave mode in the transmission line on the efficiency and transmission power. Transformation of impedances in transmission lines.
5	Lecture 5. Topic 2.4. Narrowband matching in transmission lines. Circular diagram of total impedances and its application for solving matching problems and finding unknown load impedance in a line. Topic 3.1. AFT elements: functional purpose, operating principles, characteristics. Matched loads, reactive loads.
6	Lecture 6. Topic 3.1. AFS elements: insulators, connectors, rotary joints, transitions between transmission lines, wave type conversion, transmission line turns. Topic 3.2. Inhomogeneities in transmission lines and their equivalent circuits.
7	Lecture 7. Topic 3.2. Inhomogeneities in transmission lines and their equivalent circuits Topic 4.1. Wave scattering and transmission matrices, resistance and conductance matrices. Physical meaning of their elements.
8	Lecture 8. Topic 4.2. Mutual, non-dissipative, reactive, symmetric multipoles, their properties. Assignment for self-study: Write down the scattering matrix for a section of a transmission line, resistance, connected in series and in parallel to the line. Derive the formula for the transition from the Z and Y matrices to the S matrix.
9	Lecture 9. Topic 4.3. Operating parameters of a mismatched four-pole network.
10	Lecture 10. Topic 4.4. The method of in-phase and anti-phase excitation and its application in determining the elements of scattering matrices of symmetric octapoles. Assignment for independent study: Record the S-parameters and study the operation of a double waveguide tee.
11	Lecture 11.

	Topic 5.1. Synthesis of step transitions with Chebyshev characteristic of working attenuation.
12	Lecture 12. Topic 5.1. Synthesis of step transitions with maximum flat operating attenuation characteristics.
13	Lecture 13. Topic 6.1. Directional couplers (DC): principles of operation, general characteristics. Topic 6.2. Waveguide DBs with coupling through holes in the wide and narrow walls of a waveguide with a rectangular cross-section. Topic 6.3. Waveguide-slit bridge.
14	Lecture 14. Topic 6.4. Strip HB: Wilkinson divider; 3/2λ long ring directional coupler; directional couplers on coupled lines; HB-Lange. Their topologies and characteristics. Topic 6.5. Six-pole matched divider into two (resistive) – topology, characteristics.
15	Lecture 15. Topic 7.1. Classification of filters and examples of implementation. Approximation of filter characteristics. Prototype filter.
16	Lecture 16. Topic 7.2. Synthesis of microwave filters. Synthesis of low-pass filters on a microstrip line with stepwise resistance change.
17	Lecture 17. Topic 7.3. Synthesis of microwave filters based on coupled microstrip resonators.
18	Lecture 18. Topic 8.1. Classification, definition, design principles, characteristics. P-i-n diode as a control element of microwave devices and its characteristics. Topic 8.2. Semiconductor phase shifters of reflective, pass-through types and on switchable lines.
19	Lecture 19. Topic 8.2. Semiconductor phase shifters of reflective, transmission types and on switched lines. Topic 8.3. Semiconductor attenuators.
20	Lecture 20. Topic 8.4. Anisotropic media
21	Lecture 21. Topic 8.4. Anisotropic media Topic 8.5. Controllable devices based on the Faraday effect
22	Lecture 22. Topic 8.6. Controllable devices with transverse magnetization Topic 8.7. Ferrite and semiconductor phase shifters Summing up

Lectures are methodically supported by methodological guidelines [1].

Practical

The purpose of practical classes is to master the methods of solving the main tasks of matching the elements of antenna-feeder paths with each other.

No.	**Lecture topic and list of main questions**
1	Mathematical model of transmission lines, characteristics and parameters of transmission lines and their calculation, transformation of resistances in transmission lines
2	Circular diagram of total resistances and its application for solving matching problems and finding unknown load resistance in a line.
3	Narrowband matching using discrete elements. Assignment of task 1 of the calculation and graphical work
4	Narrowband matching using transmission line segments. Matching using a loop.
5	Narrowband matching using transmission line segments. Matching using a quarter-wave transformer.
6	Broadband matching of coaxial, microstrip, and waveguide transmission lines with different characteristic impedances. Assignment of task 2 of the calculation and graphic work. Classical method.
7	Broadband matching of coaxial, microstrip, and waveguide transmission lines with different characteristic impedances. Assignment of tasks for the completion of section 2 of the calculation and graphical work. Classical method.
8	Broadband matching of coaxial, microstrip, and waveguide transmission lines with different characteristic impedances. Assignment of tasks for completing section 2 of the calculation and graphic work. Theory of low reflection coefficient.

Practical classes are methodically supported by methodological guidelines [2].

Laboratory classes

The main goal of laboratory work is for students to gain experience and skills in practical work with microwave range equipment, the ability to conduct experimental research on the characteristics and parameters of microwave devices. Process the research results and draw conclusions. In addition, laboratory work allows the teacher to monitor the self-study of students throughout the semester. In order to improve skills in working with microwave measuring instruments, it is possible to conduct 6 out of 8 laboratory works, with students independently studying the theoretical material for the other two.

No.	**Lecture topic and list of key questions**
1	Study of ultra-high frequency phase shifters. Introduction to the principles of construction and design of ultra-high frequency phase shifters and experimental study of the phase characteristics of polarization and ferrite phase shifters.
2	Transmission line matching. Introduction to methods of narrowband and broadband matching of devices and transmission lines. Experimental study of matching different transmission line loads using a dielectric transformer.

3	Study of the characteristics of a through resonator based on two reactive inhomogeneities Introduction to the principles of construction, operation, and design of pass-through resonators and the wave processes that occur in them. Experimental study of the characteristics of a pass-through resonator in a waveguide design.
4	Study of a multi-port waveguide directional coupler Familiarization with the principles of operation and construction, designs, characteristics of multi-port waveguide directional couplers (DC) and methods for their calculation. Experimental study of the characteristics and parameters of DC.
5	Study of non-reciprocal ferrite devices. Familiarization with the application, designs, and operating principles of non-reciprocal waveguide ferrite devices in the microwave range. Experimental study of the main characteristics of ferrite valves and ferrite circulators.
6	Study of a double waveguide tee. Measurement of the values of the elements of the scattering matrix of a double waveguide tee.
7	Study of a waveguide-slot directional coupler. Familiarization with the principle of operation, design, characteristics, and parameters of a waveguide-slot directional coupler (WSC). Measurement of the elements of the scattering matrix of a matched directional coupler (DC).
8	Study of a microstrip power divider. Measurement of the frequency characteristics of the transmission and reflection coefficients of a microstrip resistive power divider.

Laboratory work is methodically supported by methodological guidelines [3].

Distance learning platform

For better assimilation of the material of the academic discipline during the period of remote work, e-mail, the Sikorsky distance learning platform using the Moodle platform, and the Google Meets and ZOOM platforms for online meetings are used, with the help of which:

- simplify the placement of methodological recommendations, teaching materials, literature, etc.;
- provide feedback to students on learning tasks and the content of the academic discipline;
- completed assignments are checked and evaluated;
- keeping track of students' progress in the course, adherence to the schedule for submitting educational/individual assignments and their assessment;
- conducting modular tests.

6. Self-study of students (SS)

Self-study includes: preparation for lectures, practical and laboratory classes; completion of CGW; self-assessment of acquired knowledge; study of recommended sources and literature; preparation for modular tests; completion of assignments to reinforce the material covered in practical classes, preparation for exams, etc.

Preparation for lectures

To prepare for lectures, students must study the planned basic and supplementary literature and recommended sources. Before lectures, students must review the theoretical material that was presented in previous lectures or assigned in advance. Students are allocated approximately 1 hour for each topic of the discipline.

Preparation for laboratory classes

Students must prepare for laboratory classes in advance. Homework assignments for laboratory classes are listed in the corresponding methodological guide. Assignments must be completed before the start of the corresponding laboratory class.

Modular test (MT)

Up to 2 hours are allocated for preparation for the MT.

Calculation and graphic work (CGW)

Individual assignments for calculation work are given by the practical class instructor, who also sets deadlines for their completion.

The content of the CGW assignment is given below.

Part 1. Match the complex load Zn with a microstrip line with characteristic impedance Z0 at frequency f0. The relative dielectric permeability and height are specified for the microstrip line substrate.

Perform the matching in three ways:

- using discrete capacitances and inductances;
- using transmission line segments and parallel loops with characteristic impedance Z0;
- using a quarter-wave transformer (the student chooses how to compensate for the reactive resistance of the load).

For method 1, it is necessary to determine which matching circuit will be used and why, depict all necessary transformations on the Volpert-Smith diagram, calculate the nominal values of capacitances and inductances at frequency f0, and plot them on the matching circuit. For methods 2 and 3, it is necessary to depict all the necessary transformations on the Volpert-Smith diagram (transition along the line and/or determination of the loop length), calculate the values of the length and width of all microstrip lines, and draw the matching circuit (draw the width and length of the lines to scale).

For all matching methods, it is necessary to calculate the frequency dependence of the reflection coefficient of the resulting matching circuit in the frequency range 0.1f0 - 2f0. In the conclusions, it is necessary to compare the obtained frequency dependencies of the reflection coefficient for all matching methods.

All three types of matching must be implemented in AWR Design Environment CAD using ideal discrete elements and analytical models of microstrip elements. Compare the width of the operating frequency band and the resonance frequency of matching obtained as a result of calculation and modeling in AWR Design Environment CAD. For matching using discrete elements, replace the ideal components with their S-parameters from the AWR Design Environment CAD database and evaluate the effect of real components on the quality of narrowband matching. For matching using a loop, perform a matching analysis using the AXIEM EM simulator. Evaluate the differences in the quality of narrowband matching when modeling with analytical blocks and when simulating with an EM simulator.

Part 2. Synthesize a step transition with Chebyshev characteristics from a line with characteristic impedance Rn to a line with characteristic impedance Z0 for the frequency band f1-f2. The maximum reflection coefficient in the frequency band is Γ0.

Perform the synthesis using the method of undetermined coefficients. Calculate the dimensions of the input and output transmission lines and the step transition for a microstrip line on a material with a dielectric constant of 2.2 and a substrate height of 1.524 mm. Draw a diagram of the step transition and mark the dimensions of the transmission lines on it.

Exam

The exam is held according to the exam session schedule. At least 2 days are allocated for exam preparation. A list of questions for exam preparation is included in the information package provided to students at the beginning of the semester. During the distance learning period, the exam can be conducted according to the schedule using Moodle and the Google Meets and ZOOM online meeting platforms.

Policy and control

7. Academic discipline policy (educational component)

Class attendance

Attendance at lectures and laboratory classes is in accordance with the Regulations on the Organization of the Educational Process at Igor Sikorsky KPI. At least once every two weeks, the instructor conducts consultations on various issues related to the credit module. During consultations, the instructor can provide assistance in studying the material of classes that students have missed for various reasons and must master on their own.

In any case, students are encouraged to attend all types of classes, as they cover theoretical material and develop the skills necessary to complete coursework, laboratory work, and modular tests.

Rules for completing assignments

When studying the material of the course "Microwave Devices," students:

1) during lectures:

- complete small tasks for independent study, which help to better understand the lecture topics;
- complete a modular test using the Sikorsky platform;

2) in laboratory classes:

- prepare homework assignments based on their own tasks using sources and literature;
- complete mandatory tasks in accordance with the methodological guide;
- save the results obtained for further preparation of reports on the results of laboratory work.

Assignments are formulated by the instructor based on the course material and submitted on the Sikorsky platform (Moodle, Google Classroom) or in another form.

Rules for defending the CGW

Questions related to narrowband coordination are submitted for the defense of the CGW. In particular, the following questions are considered:

1. What is the mathematical basis for constructing the Volpert-Smith diagram?

2. For a given value of Z_H on the Volpert-Smith diagram, determine:

- the conductivity value Y_H ;

- the modulus and phase of the reflection coefficient;

- the voltage standing wave ratio (VSWR);

- at what distance from the load will the first minimum and first maximum voltage occur in mixed wave mode.

3. Write down the formula for calculating the input impedance of a transmission line with a length of l loaded with Z_H .

4. Calculate the required length of the parallel loop (with open circuit or short circuit at the end of the line) for a given value of the loop input impedance.

5. Explain why there is a range of load resistances that cannot be matched using a two-element matching circuit consisting of parallel and series reactance. Be able to draw the forbidden zone for all two-element matching circuits.

6. How is the complex load matched to the transmission line using a parallel reactive loop? Where is the loop connected to the line? How to determine the length of the loop? What is the characteristic impedance of the loop line?

7. How is the complex load matched to the transmission line using a quarter-wave transformer? What are the methods for compensating the reactive part of the load before using a quarter-wave transformer ? How to determine the characteristic impedance of the transformer line?

Additional clarifying questions may be asked about the CGW option that the student performed.

Rules of conduct in class

When studying the material of the academic discipline "Microwave Devices," students listen attentively to the lecturer during lectures and, if necessary, write down important information. Dialogue between students and the teacher in the form of questions and answers is allowed.

During laboratory classes, students complete the tasks assigned to them. The student's work involves participation in interactive forms of class organization (answering questions asked by the teacher or students). Each student is expected to be prepared for all questions in the laboratory class, supplement the reports of other students, and express their own opinion during discussions of issues that arise during the completion of tasks. Students are allowed to use their own written notes and summaries. The use of laptops, tablets, and phones for educational purposes is permitted. At the same time, students should try to express their own opinions rather than read out other people's texts. The teacher critically analyzes the presentations, comments on mistakes, and moderates discussions between students.

The topics of lectures and laboratory classes are covered in the course syllabus, which is available on the Electronic Campus, the website of the Radio Engineering Department, and the Sikorsky platform (Moodle, Google Classroom).

Missed tests

The result for a student who did not attend an assessment is zero. If a student misses an assessment for a valid reason, they are given the opportunity to make it up (complete the laboratory work) in the presence of the teacher. If the absence was without a valid reason, the issue of making it up is decided with the teacher in consultation with the department management. A missed exam is not counted regardless of the reason for the absence; in this case, the student receives a "did not show up" mark, and if they are eligible to take the exam, they must take it during an additional session.

Announcement of test results

The results of the MT are announced to each student in their presence or remotely. When communicating in person, at the student's request, they can receive an explanation showing their grade according to specific assessment criteria.

The results for the completed laboratory work are posted after its completion and defense.

Academic integrity

The policy and principles of academic integrity are defined in Section 3 of the Code of Honor of the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute." For more details, see: https://kpi.ua/code.

Ethical standards

The standards of ethical conduct for students and employees are defined in Section 2 of the Code of Honor of the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute." For more information, visit: https://kpi.ua/code.

8. Types of control and rating system for assessing learning outcomes (RSA)

The rating system for assessing academic performance is communicated to students during the first lecture of the semester. The progress of obtaining rating points is communicated to the student by the teacher who performs the rating assessment of academic performance.

Ongoing assessment

Ongoing assessment is carried out during classes and aims to check the level of students' preparation for classes. During laboratory classes, students are surveyed on topics related to the subject. Modular assessment is carried out in the form of four tests lasting 20-25 minutes each to check residual knowledge of the most important sections of the academic discipline.

Calendar control

Calendar control is carried out twice per semester to monitor the current status of the syllabus requirements. There are two possible results of calendar control: certified (c) and not certified (n/c). The result depends on the number of points scored at the time of calendar control in accordance with the requirements of Igor Sikorsky KPI.

To receive a "pass" on the first interim assessment (week 8), the student must receive at least 60% of the points for the control measures that took place before the assessment.

To receive a "pass" on the second interim assessment (week 16), students must receive at least 60% of the points for the control measures that took place before the assessment.

Semester assessment

An exam is considered a semester assessment.

Assessment and control measures

A student's grade in a subject (RD) is calculated as the sum of the current academic performance points - the starting grade (RS) and exam points (RE):

RD = RS + RE.

The starting scale RS = 60 points.

The size of the examination scale RE = 40 points.

The size of the rating scale for the discipline RD = 100 points.

The student's starting rating for the discipline consists of points awarded for:

1) work in 6 laboratory classes;
2) a modular test in the form of 4 tests;
3) CGW.

Information on the above points is summarized in the table

No.	Assessment	Maximum score	**Quantity**	**Total**
	Work in laboratory classes	4	6	24
.	Test within the scope of the modular test	3	4	12
	CGW	24	1	24
	Exam	40	1	40
	Total			100

The table shows the maximum scores for each task.

For laboratory work, the student receives a number of points proportional to the grade: 100% of the maximum number of points corresponds to an excellent grade, 60% of the maximum number of points corresponds to a satisfactory grade. The conditions for receiving the maximum grade for laboratory work are: completion of homework prior to the laboratory work, answers to all questions on the measurement methodology and the basics of the device being measured, performance of measurements, preparation of a report in accordance with the requirements, including conclusions based on the results obtained, and answers during the defense of the work.

The points earned for the test within the MT are scaled to a maximum score of 3 points.

Completion and defense of the calculation and graphic work (CGW) provides the following points:

Narrowband matching	
- error-free solution of the problem	9
- solution with minor errors	6.5
- solution with errors	4.5
- unsatisfactory or untimely performance	0
- error-free answer during the defense of the CGW	9
- answer during CGW defense with minor errors	6.5
- answer during the defense of the CGW with errors	4.5
- less than 50% of answers to questions	0
Broadband matching	
- error-free solution to the task	6
- solution with insignificant errors	4.5

- solution with errors	3
- unsatisfactory or untimely performance	0

In order to receive the highest rating, students must actively participate in laboratory classes, actively supplement the answers of other students, clearly and logically express their own position on discussion issues, and complete the MT in a timely manner. Students are given a one-time opportunity to complete the MT.

The following factors lead to a lower rating for the student: failure to complete the MT; inadequate preparation for laboratory classes; inaccuracies, incompleteness, errors in answers, or reliance on unreliable sources.

The instructor evaluates the student's work at each laboratory class and enters the grades for the work and results of the completed assignments into the "Current Control" module of the Electronic Campus. The results of the first and second calendar controls depend on the student's current rating and are entered by the teacher into the "Calendar Control" module of the Electronic Campus in the eighth and sixteenth weeks of study, respectively.

The student may appeal the teacher's grade by submitting a complaint to the teacher no later than the day after the student has been informed of the grade given by the teacher. The complaint will be considered in accordance with the procedures established by the university.

Conditions for admission to semester control

A minimum of 30 points, defense of all laboratory work, completed and defended CGW.

The exam consists of two questions from the list provided in the information package for the credit module.

Each question is worth a maximum of 20 points.

The answer to each theoretical question is awarded the following points:

- complete answer (at least 90% of the required information)	20
- sufficiently complete answer (at least 75% of the required information or minor inaccuracies)	15
- incomplete answer (at least 50% of the required information and some errors)	10
- unsatisfactory answer	0

The maximum score for the exam is 40 points.

Table of correspondence between rating points and university scale grades:

Number of points	Grade
100-95	Excellent
94	Very good
84	Good
74-65	Satisfactory
64-60	Sufficient
Less than 60	Unsatisfactory
Admission requirements not met	Not admitted

9. Additional information on the discipline (educational component)

Recommendations for students

During lectures, students should write down key terms and concepts, note the main events of the topic, and summarize the generalizations and conclusions made by the instructor. This material will be useful when preparing for laboratory classes and self-study.

When preparing for a laboratory class, students must study the lecture material on a specific topic and, preferably, familiarize themselves with additional resources on the Internet. If questions arise or unclear points are identified, they should be discussed with the lecturer. During the lab session, each student should try to master the practical skills that can be mastered on their own. Students should not refuse to answer the teacher's questions. Even if a student does not know the answer, it is advisable to try to answer, express their opinion based on their own knowledge, experience, logic of the question, etc. However, it is important to remember that not knowing the subject matter is a significant shortcoming in a student's work and will negatively affect their overall grade. A responsible attitude toward preparing for each lab session allows students not only to properly master the material, but also to save effort when taking semester exams.

Students may be credited for a course topic if they have certificates of completion of distance or online courses on the relevant subject.

Distance learning

Synchronous and asynchronous distance learning is possible using video conferencing platforms (Google Meets, Zoom, etc.) and the Sikorsky distance learning educational platform (Moodle).

Inclusive learning

Inclusive learning is permitted.

Work program for the academic discipline (syllabus):

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Approved by: Radio Engineering Department (Minutes No. 06/2025 dated 06/17/2025).

Approved by: REF Methodological Council (Minutes No. 06/2025 dated 26.06.2025).