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

Department of Applied
Radio Electronics

[RE-343] MICROWAVE DEVICES AND ANTENNAS

Curriculum of the academic discipline (Syllabus)

Course details

Level of higher education	First (bachelor's)
Field of knowledge	17 - Electronics, Automation, and Electronic Communications
Specialization	172 - Electronic Communications and Radio Engineering
Educational program	Intelligent technologies of radio electronics
status	Regulatory
Form of higher education	Full-time
Year of training, semester	3rd year, fall semester
Scope of the discipline	5 credits (Lectures: 36 hours, Practical classes: 36 hours, Laboratory classes: 18 hours, Independent work: 60 hours)
Semester control/control measures	Exam
Class schedule	https://schedule.kpi.ua
Language of instruction	Ukrainian
Information about the course leader/teachers	Lectures: Peregudov S. M., Practical classes: Peregudov S. M., Laboratory classes: Peregudov S. M., Independent work: Peregudov S. M.

Course placement https://classroom.google.com/c/NzI1OTQzMjYwNjE1?cjc=w4brxw5

Curriculum

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

The rapid development of telecommunications systems and their intellectualization has led to the convergence of many areas of research that previously developed separately. The propagation of electromagnetic waves, digital technology, powerful microwave generators, antenna devices, solid-state ultra-high-frequency devices — all these areas of technology can be grouped under the general heading of generation and conversion of electromagnetic signals for high-speed information transmission. The development of such equipment requires radio engineers to be able to solve complex problems involving the use of various microwave devices and antenna devices.
The discipline "Microwave Devices and Antennas" belongs to the cycle of professional and practical training of first-level (bachelor's) students in the specialty "Electronic Communications and Radio Engineering."
The aim of teaching this discipline is to develop knowledge about microwave devices and antennas used in wireless communication systems, understanding of methods of generating, transmitting, and converting radio signals by such devices, and basic technological operations of the production process.
The subject of the discipline is the most important components and devices of microwave technology, their main technical characteristics, operating conditions, and field of application.
As a result of the course, students will develop:

General competencies
GC 01 Ability to think abstractly, analyze, and synthesize.
GC 02 Ability to apply knowledge in practical situations.
GC 04 Knowledge and understanding of the subject area and understanding of professional activity.
GC 07 Ability to learn and master modern knowledge.
GC 08 Ability to identify, pose, and solve problems

Professional competencies
PC 01 Ability to understand the essence and significance of information in the development of a modern information society.
PC 03 Ability to use basic methods, techniques, and tools for obtaining, transmitting, processing, and storing information.
PC 04 Ability to perform computer modeling of devices, systems, and processes using application software packages.
PC 08 Willingness to promote the implementation of promising technologies and standards.
PC 10 Ability to install, debug, configure, adjust, test, and commission telecommunications and radio engineering structures, facilities, and equipment.
PC12 Ability to perform work related to managing traffic flows in information and telecommunications networks.
PC16 Ability to apply standard calculation methods in the design of telecommunications and radio engineering devices and systems.
PC18 Ability to assess the place and advantages of introducing elements of intelligent technologies and intelligent radio electronics into various fields of human activity.
PC20 Ability to select methods and means of information processing using intelligent technologies.
PC22 Ability to select, critically evaluate, and choose technical solutions at all stages of the development and design of radio-electronic equipment using intelligent technologies.
PC23 Ability to select and apply specialized software tools for simulation modeling and design of radio-electronic equipment.
PC25 Ability to reasonably select CAD for analysis, calculation, optimization of the output characteristics of mathematical and circuit models of analog and digital devices depending on the frequency range, taking into account external factors, use Internet information resources to obtain mathematical and design models of radio components from manufacturers based on an assessment of the characteristics of information transmission in radio networks.

The study of the discipline "Microwave Devices and Antennas" contributes to the achievement of the following program learning outcomes
PLO 01 Analyze and make informed decisions when solving specialized tasks and practical problems in telecommunications and radio engineering, which are characterized by complexity and incomplete

certainty of conditions.
PLO 02 Apply the results of personal search and analysis of information to solve qualitative and quantitative problems of a similar nature in information and communication networks, telecommunications and radio engineering systems;
PLO 04 Explain the results obtained from measurements in terms of their significance and relate them to the relevant theory.
PLO 07 Competently apply terminology in the field of telecommunications and radio engineering. PLO 13 Apply fundamental and applied sciences to analyze and develop processes occurring in telecommunications and radio engineering systems.
PLO 22 Monitor the technical condition of information and communication networks, telecommunications and radio engineering systems during their technical operation in order to identify deterioration in performance or failures, and systematically record this by means of documentation.
PLO 26 Design and implement elements of intelligent technologies using software-configurable equipment.
PLO27 Apply basic methods and techniques for obtaining information.
PLO28 Apply methods and means of influencing the parameters of the physical environment. PLO29 Select the configuration, structure, main components, and elements of radio- electronic equipment depending on its purpose.
PLO30 Apply a comprehensive approach to the design of telecommunications and radio-electronic equipment.

Within the framework of the above-mentioned general and professional competencies and program learning outcomes, students should:
know the physical principles of operation and technical characteristics of microwave range devices and antennas; the basic methods of their modeling and development stages; be able to use the acquired knowledge in the design, development, and operation telecommunications equipment, which includes microwave devices; analyze signal conversion in such devices.
Students gain experience working with individual components of telecommunications equipment and their application in the creation of intelligent systems for various functional purposes.

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

Interdisciplinary connections are determined by the place of the discipline "Microwave Devices and Antennas" in the training program for specialists in the field of electronics and telecommunications. It is based on the general training of students in physics and mathematics. The professional discipline that precedes its study is "Electrodynamics and Radio Wave Propagation."
The discipline "Microwave Devices and Antennas" provides for the study of the first (bachelor's) level of higher education in the degree "Communication Methods in Intelligent Radio-Electronic Systems."

3. *Contents of the academic discipline*

Names of sections and topics	Number of hours				
	Total	including			
		Lectures	Practical	Laboratory work	SRC
Introduction. Content and structure of the discipline. Microwave radio systems, their structure and application	1	1			
Section 1 Passive microwave devices					
Topic 1.1 Microwave transmission lines	4	1	2		1
Topic 1.2 Fundamentals of long line theory	11	2	2	3	4
Topic 1.3 Narrowband matching of ultra-high frequency equipment path nodes	5.5	2	2		1.5
Topic 1.4 Methods and means of broadband matching of microwave devices	11	2	2	3	4
Topic 1.5 Microwave resonators and filters	8.5	2	4		2.5
Topic 1.6 Bridges and power dividers for microwave signals	5.5	2	2		1
Total for Section 1	46.5	12	14	6	14.5
Section 2 Active microwave devices					
Topic 2.1 Component base of active microwave devices range	8	2		3	3
Topic 2.2 Diode devices for amplitude and phase control and frequency conversion of microwave signals	11	2	2	3	4
Topic 2.3 Diode microwave generators	5.5	2	2		1.5
Topic 2.4 Low-noise transistor amplifiers in the microwave range	8.5	2	4		2.5
Topic 2.5 Microwave power amplifiers based on transistors	5.5	2	2		1
Topic 2.6 Active microwave devices based on microcircuits	5.5	2	2		1
Topic 2.7 Devices and elements of wireless communication microsystems	3	2			1
Total for Section 2	47	14	12	6	15
Section 3 Microwave Band Antennas					
Topic 3.1 Basic principles of antenna theory	5.5	2	2		1.5
Topic 3.2 Decimeter-wave antennas	11	2	2	3	4
Topic 3.3 Aperture antennas and their applications	8	2		3	3
Topic 3.4 Types of printed antennas. Mobile communication antennas	8.5	2	4		2.5
Topic 3.5 Principle of operation and main components of phased antenna arrays	5.5	2	2		1
Total for Section 3	38.5	10	10	6	12.5
Modular test	2				2
Exam	2				2
Calculation and graphic work	14				14
Total hours	150	36	36	18	60

4. Learning materials and resources

Basic

1. Wireless technologies of intelligent radio equipment: Radio receiving and transmitting devices: Lecture course. [Electronic resource]: textbook for students majoring in 172 "Electronic Communications and Radio Engineering" / Igor Sikorsky Kyiv Polytechnic Institute; compiled by: V.A. Druzhinin, M.M. Stepanov. – Kyiv: Igor Sikorsky Kyiv Polytechnic Institute, 2023. – 599 p.
2. Ilnytskyi L.Ya. Ultra-high frequency devices and antennas: Textbook / Ilnytskyi L.Ya., Sibruk L.V., Shcherbina O.A. – Kyiv: NAU, 2013. – 188 p.
3. Wireless technologies of intelligent radio-electronic equipment. Part 1: Laboratory workshop

[Electronic resource]: textbook for students majoring in 172.
"Electronic Communications and Radio Engineering" / Igor Sikorsky Kyiv Polytechnic Institute; compiled by: S. M. Peregudov. – Electronic text data (1 file: 4.23 MB). – Kyiv: Igor Sikorsky Kyiv Polytechnic Institute, 2023. – 70 p.Access: https://ela.kpi.ua/handle/123456789/57245.

4. Wireless technologies of intelligent radio equipment. Part 1: Home assignment [Electronic resource]: textbook for students majoring in 172 "Electronic Communications and Radio Engineering" / Igor Sikorsky Kyiv Polytechnic Institute; compiled by S. M. Peregudov. – Electronic text data (1 file: 3.21 MB). – Kyiv: Igor Sikorsky Kyiv Polytechnic Institute, 2023. – 31 p. Access: https://ela.kpi.ua/handle/123456789/57246. Supplementary

5. Telecommunication Transmission Systems: Textbook / V. M. Kychak, O. M. Shynkaruk, H. H. Bortnyk, I. I. Chesanovskyi, O. V. Stalchenko. – Khmelnytskyi: NADPSU Publishing House, 2016. – 424 p.

6. Pozar, D.M. Microwave Engineering / David M. Pozar – 4th ed. – John Wiley & Sons, 2012. – 752 p.

7. Steer, Michael. Fundamentals of Microwave and RF Design. (Third Edition), NC State University, 2019. doi: https//doi.org/10.5149/ 9781469656892 Steer.

8. Hong Jia-Sheng. Microstrip filters for RF/microwave applications / Jia-Sheng Hong : 2nd ed. – Hoboken: John Wiley & Sons, Inc., 2011. – 655 p.

Information resources

1. Microwaves101.com (Microwave Encyclopedia) [Electronic resource] – Access mode: https://www.microwaves101.com.

2. Microwave Journal [Electronic resource] – Access mode: http://www.microwavejournal.com.

3. Microwave engineering and antennas [Electronic resource] – Access mode: https://www.coursera.org/learn/microwave-antenna?

4. RF and millimeter-Wave Circuit Design [Electronic resource] – Access mode: https://www.coursera.org/learn/rf-mmwave-circuit-design

Educational content

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

No Lectures	Lecture topic, list of main questions, References to literature and assignments for independent study
1 Part 1	**Introduction. Content and structure of the discipline** Scope and design features of radio engineering devices and systems in the microwave range. The concept of a microwave path in a radio engineering system. Its main elements and devices, their classification and graphical representation. Independent work assignment: review the lecture material, pay attention to the topics of the classes, types of assignments, and the student assessment system.
	Chapter 1 Passive Devices in the Microwave Range
1, Part 2	**Topic 1.1 Microwave transmission lines** Basic principles of electromagnetic wave propagation in free space and in guided structures (waveguides). Overview of the main microwave transmission lines. Closed transmission lines (waveguides). Types of oscillations (modes), their properties, and relationship to the type of line. Two-wire lines for high-speed data transmission in computer networks (shielded and unshielded twisted pair). Planar transmission lines as the basis for ultra-high frequency microcircuits. Formulas for calculating the main parameters. Microstrip transmission line (MTP), its main parameters and characteristics. Independent work assignment: review lecture material and study literary sources; compare the parameters of the main microwave transmission lines.

Lecture No.	Lecture topic, list of main questions, references to literature, and assignments for independent work
2	**Topic 1.2 Fundamentals of long line theory** The concept of a long microwave transmission line with T-, E-, and H-waves. An equivalent transmission line as an element of a microwave circuit, its diagram. Voltage and current waves, their propagation in a long line. Running wave mode. Reflection coefficient and standing wave ratio. Total reflection mode. Normalized and non-normalized voltages, currents, and resistances for equivalent and real transmission lines. Short-circuited and open-circuited lines. Lossless line loaded on active and complex resistances, their input resistance. Dependence of input impedance on frequency and segment length. Implementation of inductive and capacitive elements in microwave devices. Independent work assignment: review the lecture material and study the literature sources – analyze the characteristics of long transmission lines.
3	**Topic 1.3 Narrowband matching of ultra-high frequency equipment components** Line segment with load. Transformation of load resistance. Short-circuited and open-circuited at the end of the line segment. The concept of standing wave ratio, its relationship to the reflection coefficient. Matched and mismatched loads of a long lines. General matching issues. Matching methods (method of creating additional reflection, method of absorbing reflected waves, method of absorbing incident and reflected waves). Quarter-wave transformer, its calculation. The concept of a loop. Series and parallel loops as matching elements. Use of two and three loops in a matching circuit. Smith chart as a tool for calculating matching circuits. Procedure for calculating the parameters of matching loops using the chart. Independent work assignment: review the lecture material, master the basic methods of matching microwave path nodes, learn how to use the Smith chart.
4	**Topic 1.4 Methods and means of broadband matching of microwave devices** Broadband matching of microwave devices using a reactive four-pole network. Step and smooth transitions. Connection of devices with different active and line segments with different wave impedances. Transformation of the active component of the input and output impedance of devices. Step and smooth transformer of active impedances. The order of its calculation. Transitions for transmission lines of different types. Properties of ferrite materials in the microwave range. Faraday effect. Non-reciprocal devices of the microwave path. Classification of ferrite devices. Ferrite valves on resonant absorption and field displacement. Ferrite circulators, design features and principle of operation. Designs of microstrip non-reciprocal devices. Independent work assignment: review the lecture material, memorize the main types of transitions and non-interactive devices for transmission lines, and master the basic methods for calculating their parameters.
5	**Topic 1.5 Microwave resonators and filters** Basic characteristics of a resonator. Equivalent circuit of a volumetric resonator with one coupling element. Resonators on transmission line segments. Resonator designs and parameters. Pass-through resonator with two coupling elements. Cascade connection of resonators. Types of filters. Algorithm for synthesizing a microwave filter. Prototype for filter synthesis. Butterworth and Chebyshev approximations. Determination of filter input losses. Calculation of the equivalent circuit of a low-pass filter. Standardized low-frequency prototype filters. Determination of the number of elements in the prototype filter circuit and its main parameters. Features of microwave filter design. Determination of the design parameters of filter elements. Features of design and manufacturing technology. Requirements for the selection of materials. Experimental determination of characteristics. Features of the development of high-frequency filters and bandpass filters for microwave range systems. Independent work assignment: review the lecture material, compare the methods for calculating low-pass and high-pass filters, as well as bandpass filters.

Lecture No.	Lecture topic, list of key questions, references to literature, and assignments for independent work
6	**Topic 1.6 Bridges and power dividers for microwave signals** The concept of a microwave multipole. Matrix methods for describing microwave devices. Scattering and transmission matrices of microwave devices. Signal graphs and their application in the theory of microwave circuits. Use of six- and eight-pole networks for signal distribution in microwave paths. Design features for different types of transmission lines. Bridges and power dividers. Their main characteristics and application in microwave technology. Wilkinson bridge and square bridge, their operating principle, main parameters, and the procedure for calculating electrical and design parameters. Bridge topology for microstrip devices. Scattering matrices. Features of use. Main advantages and disadvantages of power dividers and summers. The principle of operation of ring and modified ring bridges. Methodology for calculating the parameters and topology of the device. Independent work assignment: review the lecture material, explain the principles of operation of microwave signal power division devices.
	Section 2 Active microwave devices
7	**Topic 2.1 Component base of active microwave devices** Nomenclature of modern component base for active microwave devices. Main parameters and characteristics. Principles of operation and design features of electronic devices for microwave radio equipment nodes. Types of ultra-high frequency diodes, their classification, features, and manufacturing technologies. Transistors for microwave signal amplifiers. Selection criteria and design features. High mobility transistors (HMTS), their principle of operation and main parameters. Nomenclature and functional capabilities of modern ultra-high frequency range microcircuits, specifics of application. Ensuring the operating mode of semiconductor devices and protection against electromagnetic interference. Independent work assignment: review the lecture material, paying attention to the principles of selecting components for microwave devices depending on their purpose, operating frequency range, and signal power.
8	**Topic 2.2 Diode devices for amplitude and phase control and frequency conversion of microwave signals** Means of controlling microwave signal parameters. Mechanically and electrically controlled devices. The principle of operation of a pin diode, its semiconductor structure. Cased and uncased diodes. Electrically controlled devices based on pin diodes. The principle of operation of modulators, attenuators, and phase shifters based on pin diodes. Features of the structure of diodes for these devices. The speed of switching devices and methods for increasing it. Diode detectors and signal amplitude limiters. Requirements for the parameters and characteristics of microwave detector diodes. Methods and means of increasing the sensitivity of microwave detector circuits. Diode frequency converters. Their structural diagram. Balanced and unbalanced converters, their advantages and disadvantages. Features of designs in the microwave range. Frequency converters on integrated and hybrid-integrated microcircuits. Basic principles of frequency converter design. Independent work assignment: review the lecture material, master the basic methods for calculating the operating mode of diode devices for controlling the amplitude and phase microwave signals and determine their main parameters.

Lecture No.	Lecture topic, list of main questions, references to literature, and assignments for independent work
9	**Topic 2.3 Microwave signal generation devices** The principle of operation of an avalanche breakdown diode (ABD) and its use in microwave range generator devices. IMPATT and TRAPATT operating modes. Avalanche frequency of a diode. Advantages and disadvantages of using ABD as a source of microwave signals. IMPATT noise factor. Microwave reference noise generators. The Gunn effect. The principle of operation of the Gunn diode and its use in generator devices. The use of Gunn diode generators in microwave equipment. Main parameters and characteristics of generators. Comparison of LPD and DG generators in terms of noise factor, frequency range, and operating mode. Methods of stabilizing the frequency of diode generators and their coordination with other components of the ultra-high frequency path. Independent work assignment: review the lecture material, analyze the principle of microwave signal generation using an LPD and a Gunn diode, pay attention to the differences in their main characteristics and operating modes.
10	**Topic 2.4 Low-noise transistor amplifiers of the microwave range** Transistor amplifiers of the microwave range. Basic parameters and characteristics of amplifiers (output power, gain, noise factor, dynamic range, frequency response). Classification of amplifiers by output power. Low-noise amplifiers and principles of their design. Component base. Methods for calculating electrical characteristics. Integrated microwave amplifiers. Power supply circuits for active elements. Methods for calculating the operating mode of an amplifier transistor. Designing input and output matching circuits for amplifiers. Stability of microwave amplifiers. Stability coefficient. Methods of ensuring a constant gain coefficient. Conditional and unconditional stability of the amplifier. Stability criterion. Independent work assignment: review the lecture material, consider the principles of low-noise amplifier design, their application in wireless radio equipment, and their main characteristics, pay attention to the classification of microwave amplifiers and design features.
11	**Topic 2.5. Microwave power amplifiers based on transistors** Classification of power amplifiers and their component base. Criteria for selecting active elements, taking into account the specifics of the microwave range. Design features and main characteristics. Examples of amplifiers. Determination of dynamic range. Compression point. Signal distortion and methods of its elimination. Basic principles of designing microwave power amplifiers. The problem of heat dissipation. Stabilization of the temperature regime and methods for calculating the cooling system of the active element. Calculation of the operating mode of the transistor and matching circuits with an ultra-high frequency path. Construction of power amplifiers using microwave signal summers. Independent work assignment: review the lecture material, analyze the method for calculating microwave power amplifiers and note its differences from low-power amplifiers, pay attention to the classification of microwave amplifiers and design features.
12	**Topic 2.6 Active microwave devices on microcircuits** Classification of ultra-high frequency microcircuits. Main types of microcircuits. Integrated and hybrid-integrated microcircuits. Main materials of modern integrated UHF microcircuits and means of their installation in devices. Features of hybrid-integrated microcircuits. Basic transmission lines and materials used for their construction. Microcircuits of amplifiers, mixers, microwave synthesizers band. Elements for selecting their operating mode and design. Advantages and disadvantages of their use in radio-electronic equipment. Principles of construction of devices for microwave band radio systems based on integrated and hybrid-integrated circuits. Independent work assignment: review the lecture material, examine the types of microwave range integrated circuits available on the modern semiconductor device market; pay attention to the operating frequency ranges and power.

Lecture No.	Lecture topic, list of main questions, references to literature, and assignments for independent work
13	**Topic 2.7 Devices and components of wireless communication microsystems** Analog-to-digital and digital-to-analog signal conversion. Digital signal processing (DSP). Specifics of digital radio signal processing. DSP methods and means in microwave devices, their features. Software and hardware components of modern ultra-high frequency system devices. Reasons for limiting DSP means in the microwave range. Advantages and disadvantages of software-configurable devices. Visual programming environment for software-configurable devices. Controlling their operation and configuring basic parameters and characteristics. Independent work assignment: review the lecture material, understand the meaning of the terms "software-configurable device" and "digital signal processing"; pay attention to the relationship between the sampling frequency and the operating range of a microwave device.
	Section 3 Microwave range antennas
14	**Topic 3.1 Basic principles of antenna theory** General information about antennas. Basic terms and definitions. Antenna as part of a communication channel. General antenna design. Near and far radiation zones. Features of fields and characteristic impedances in each zone. General characteristics of radiation sources. Point radiation sources, electric and magnetic dipoles. Determination of their characteristic impedance in the near and far radiation zones. The concept of an isotropic antenna. Main characteristics of antennas (directivity, gain, input impedance, noise temperature). Using antenna parameters to determine the range of wireless communication. Classification of microwave antennas and their applications. Main parameters and characteristics. Brief overview of antenna design software. Independent work assignment: review the lecture material, memorize the most common types of antennas, how their parameters and characteristics are determined.
15	**Topic 3.2 Decimeter band antennas** Basic types of antennas. Examples of resonant antennas, their design. Dipole and frame antennas, basic parameters and applications in communication equipment. Advantages and disadvantages of such antennas, their modifications. Antennas of Bluetooth and Wi-Fi devices. Antennas of satellite navigators, basic requirements for their parameters. Principle of operation and design of a spiral antenna, parameters and characteristics. Quadrifilar spiral antenna (QSA). Yagi antenna, characteristics, design, and varieties. Independent work assignment: review the lecture material, analyze the designs and operating principles of the most common decimeter-wave antennas.
16	**Topic 3.3 Aperture antennas and their applications** Features of centimeter and millimeter wave band antennas. Slit and horn antennas as radiation sources. Horn antenna directional pattern. The principle of operation of mirror and lens antennas. Satellite television antennas, basic requirements for their design and electrical parameters. Direct-focus and offset satellite television antennas, their differences, directional pattern, gain coefficient, and noise characteristics. The principle of construction of broadband antennas (traveling wave antennas). Vivaldi antenna, its frequency characteristics. Dielectric antennas in the centimeter and millimeter ranges. Requirements for the materials of their structural elements. Applicator antennas and probes for biomedical applications. Features of operation in the near field. Independent work assignment: review the lecture material, compare the operating principles and characteristics of the antennas presented for different applications, compare the operating conditions of the antennas discussed in the lecture.

Lecture No.	Lecture topic, list of key questions, references to literature, and assignments for independent work
17	**Topic 3.4 Types of printed antennas. Mobile communication antennas** Radiating elements of antennas, technological features of implementation. Printed antennas of the decimeter and centimeter ranges. Microstrip antennas, design and their application in communication technology. Patch antennas as a type of printed antennas. Calculation of the main characteristics of patch antennas. Main manufacturing processes. Selection of materials for patch antennas, integration with the microwave path of radio equipment. Printed antennas for mobile communication terminals and IoT (patch, PIFA, etc.). The need to use different types of antennas, ensure their electromagnetic compatibility, and eliminate the effect of antenna shielding by the user. Independent work assignment: review the lecture material, examine the principles of printed antennas.
18	**Topic 3.5 Principle** of **operation and main components of phased antenna arrays** Physical and technical fundamentals of phased antenna arrays (PAA). Active and passive elements of PAA. Determination of the PAA directional pattern, methods and means of its adjustment. Stationary and portable antenna systems. Areas of application of PABs. Use of PABs in military technology. Biomedical applications of antennas with controlled directional patterns. Use of PHAR in multi-beam radio communication systems. Prospects for application in 5G and 6G mobile communication technologies. Microminiaturization of phased antenna arrays for portable radio equipment. Independent work assignment: review the lecture material, explain the principle of operation of phased antenna arrays, and provide examples of their application.

Practical classes

The discipline "Microwave Devices and Antennas" belongs to the cycle of professional and practical training, therefore, special attention is paid to the practical component of the learning process.
The main objectives of the practical classes are:
– deepening and consolidating theoretical knowledge;
– mastering the principles of designing microwave devices and systems;
– learning methods for calculating the parameters of basic elements of a microwave path;
– mastering methods for determining the characteristics of microwave devices for telecommunications systems;
– acquiring skills in preparing graphic and text documentation accompanying microwave range products.

No.	Lesson topic and list of key questions (list of teaching aids, references to literature, and assignments for independent study)
	Topic 1.1 Microwave transmission lines
1	**Calculation of complex impedances of the simplest circuits** Independent work assignment: review the material from the practical class, learn how to calculate the complex resistance of RLC circuits, determine their frequency characteristics, and master the methods for calculating the transmission coefficient of a cascade connection of devices.
	Topic 1.2 Fundamentals of long line theory
2	**Determining the main parameters of a transmission line with load** Independent work assignment: review the material from the practical class, learn to calculate the main parameters of an equivalent long line with load for different modes of operation (input impedance and reflection coefficient)
	Topic 1.3 Narrowband matching of microwave devices in a microwave path
3	**Calculation of matching circuit parameters on elements with concentrated and distributed parameters** Independent work assignment: review the material from the practical class, calculate the narrowband matching circuit on concentrated elements and loops.

	Topic 1.4 Methods and means of broadband matching of microwave devices
4	**Determination of parameters and calculation of the frequency response of a coaxial step transition** Independent work assignment: review the material from the practical class; learn to calculate the electrical parameters of step transitions and their amplitude-frequency characteristics. frequency characteristics.
	Topic 1.5 Microwave resonators and filters
5	**Calculation of electrical parameters and topology of a low-frequency microstrip filter** Independent work assignment: review the material from the practical class; master the method for calculating a low-frequency filter on microstrip line segments.
6	**Calculation** of **a microwave bandpass filter on resonators** Independent work assignment: review the material from the practical class; learn how to calculate a bandpass filter in the AWR Design Environment package.
	Topic 1.6 Dividers and summers of microwave signals
7	**Analysis of balanced mixer characteristics** Independent work assignment: review the material from the practical session; analyze the main characteristics of a balanced mixer on a square bridge in the AWR Design Environment package.
	Topic 2.2 Diode devices for amplitude and phase control and frequency conversion of microwave signals
8	**Calculation of a microstrip attenuator on pin diodes** Independent work assignment: review the material from the practical class, learn how to evaluate the main parameters of an attenuator on pin diodes, and calculate the topology of power supply circuits.
	Topic 2.3 Diode microwave generators
9	**Calculation of the matching circuit and operating mode of a diode generator** Independent work assignment: review the material from the practical class, learn to evaluate the main parameters of generator diodes and master the method of calculating matching circuits for diode generators.
	Topic 2.4 Low-noise transistor amplifiers of the microwave range
10	**Calculation of the input and output circuits of a transistor amplifier** Independent work assignment: review the material from the practical class, perform calculate the input and output matching circuits of a low-noise amplifier in the AWR Design Environment package.
11	**Analysis of the main characteristics of a low-noise microwave amplifier** Independent work assignment: review the material from the practical class, analyze the main characteristics of a low-noise amplifier in the AWR Design Environment package.
	Topic 2.5 Microwave power amplifiers based on transistors
12	**Determining the stability factor of a transistor amplifier** Independent work assignment: review the material from the practical class, master the method for determining the stability coefficient of transistor amplifiers.
	Topic 2.6 Active microwave devices on microcircuits
13	**Calculation of the transmission coefficient of a cascade connection of microwave devices** Independent work assignment: review the material from the practical class, master the method for determining the transmission coefficient of a cascade connection of active devices under conditions of their mismatch.
	Basic principles of antenna theory
14	**Determination of the main characteristics of antennas in the near and far zones** Independent work assignment: review the material from the practical class, learn how to determine the boundaries of antenna radiation zones, and calculate the characteristic impedance of electric and magnetic dipoles.
	Topic 3.2 Decimeter band antennas

15	**Matching the antenna to the feeder line** Independent work assignment: review the material from the practical class, learn to calculate the matching circuit between the antenna and the feeder using a Smith chart.
	Topic 3.4 Types of printed antennas. Mobile communication antennas
16	**Calculating the topology and parameters of a patch antenna** Independent work assignment: review the material from the practical class, learn to calculate the topology and evaluate the main parameters of a patch antenna.
17	**Calculation of PIFA antenna parameters** Independent work assignment: review the material from the practical session, learn how to calculate topology and evaluate the main parameters of a PIFA antenna.
	Topic 3.5 Principle of operation and main components of phased antenna arrays
18	Evaluating the efficiency of signal transmission between antennas Independent work assignment: review the material from the practical class, learn to evaluate the efficiency of signal power transmission between antennas using the Friis equation.

Laboratory classes

The main purpose of the laboratory classes
– to test acquired theoretical knowledge in practice;
– acquiring skills in working with measuring instruments and equipment;
– to study methods for measuring parameters and experimentally determining the main characteristics of microwave devices;
– acquiring skills in evaluating experimental data and drawing conclusions.

No.	Name of laboratory work	Number of classroom hours
1	**Measuring the characteristics of microwave path irregularities using the node displacement method** Independent work assignment: prepare for the laboratory work using the material from the methodological recommendations and lectures 2 and 3; complete the experimental part of the work; prepare a report and prepare answers to the control questions.	3
2	**Measurement of frequency characteristics of microwave devices using a P2-69 panoramic analyzer** Independent work assignment: prepare for the work using the material from the methodological recommendations and lecture 5; perform the experimental part of the work; prepare a report and prepare answers to control questions.	3
3	**Study of the characteristics of a ferrite valve** Independent work assignment: prepare for work using the material from the methodological recommendations and lecture 7; complete the experimental part of the work; prepare a report and answers to the control questions.	3
4	**Investigation** of **the characteristics** of **an electrically controlled attenuator** Independent work assignment: prepare for the laboratory work using the material from the methodological recommendations and lecture 11; perform the experimental part of the work; prepare a report and prepare answers to the control questions.	3
5	**Investigation of the properties of a frame antenna** Independent work assignment: prepare for the laboratory work using the material from the methodological recommendations and lecture 14; complete the experimental part of the work; write a report and prepare answers to the control questions.	3
6	**Investigation of the characteristics of a dipole antenna** Independent work assignment: prepare for the lab work using the material from the methodological recommendations and lectures 14 and 15; complete the experimental part of the work; write a report and prepare answers to the control questions.	3

6. *Independent work*

Students complete the independent work assignments listed in section 5, as well as in the methodological recommendations for practical and laboratory classes in accordance with the academic calendar. During the semester, they must complete a calculation and graphic work (CGW). The approximate topics of the CGW assignments are listed in the appendix to section 9.

Policy and control

7. *Policy of the academic discipline (educational component)*

Rules for attending classes

Laboratory classes are mandatory for completing the assignment. If they are missed, they must be made up by prior agreement with the instructor.

If a student misses a lecture or practical class, they must complete the assigned tasks and undergo an interview with the instructor on the material covered in the missed class. Lecture and practical class materials with assignments are posted on Google Classroom, which students will have access to at the beginning of the semester.

Ongoing assessment of lecture material

Control of the lecture material covered is carried out by means of oral questioning or testing (at the discretion of the teacher). The time of testing is determined by the teacher. The total number of points is indicated in paragraph 8.

Assessment of practical assignment tasks

During the semester, students must complete assignments on the topics covered in practical classes. The number of assignments may be determined by the instructor, and the total number of points for all assignments is specified in section 8.

Admission to laboratory classes and defense of the report on the work performed

Before laboratory work, students undergo an individual interview with the teacher, answering control questions and explaining the course of work. Based on the results of the interview, a decision is made on admission to the work.

Students work in teams, compile a measurement report (one per team), and sign it with the teacher at the end of the class.

Each student prepares a report on the work performed and defends it individually. The report is defended during the next scheduled laboratory class. The grade that the student receives for the laboratory session consists of the points obtained during the admission and defense and is entered into the current record after the successful defense of the work.

The number of points is indicated in the rating system (clause 8).

If the laboratory session cannot be held due to force majeure circumstances or the student missed it for a valid reason, the work is performed at a time appointed by the dean's office or, at its discretion, is conducted online.

If a student misses a laboratory class without a valid reason, the laboratory work and its defense are performed during the exam session.

Assessment of computational and graphical work

The assessment for the RGR has two components: for the explanatory note and for the answers during the defense. The final assessment is announced during the defense.

The defense of the RGR takes place during consultations according to the schedule in the last two weeks of the semester or, by prior agreement with the teacher, at another time.

There is no provision for retaking the RGR.

Assessment of the modular control work (MCW)

The MCR is conducted in the form of a test on the material covered at the end of the semester, but no later than week 17. The time of the test is determined by the teacher. The total number of points is specified in paragraph 8.

Bonus and penalty points and academic integrity policy The most active students, in particular those who perform exemplary tasks based on the course material, can receive from 1 to 10 points towards their semester rating.
Penalty points are applied:
– if a student violates academic integrity requirements and submits someone else's work as their own. In this case, they must redo the assignment, and their overall grade for the work will be reduced by 15%;
– if a student submits an explanatory note from the RGR late (clause 8);
– if a student submits and/or defends a laboratory work report late (clause 8).

Deadline and resubmission policy

The deadline for submitting practical assignments and RGR is set by the instructor. In case of violation of the deadline without a valid reason, the grade for the assignment is reduced by 1 point, and the instructor assigns the student a deadline for resubmitting the assignment. In case of repeated violation of the deadline (without a valid reason), the grade is reduced by another 1 point.
The deadline for submitting exams and retakes is determined by the schedule approved by the dean of the faculty.

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

A student's rating consists of points (on a 100-point scale) that they receive for:

1. ongoing assessment of lecture material assimilation (an average of 7 answers per student);
2. answers during practical classes (an average of 7 answers per student);
3. completion and defense of laboratory work;
4. modular control work (MCW);
5. calculation and graphic work (CGW)
6. answers on the exam.

The number of points and assessment criteria are determined as follows.

Rating (weighted) point system and assessment criteria

1. Control of mastery of lecture material
The maximum number of points is 8.

2. Work in practical classes
The maximum number of points for all practical classes is: 14.

3. Laboratory work
The maximum number of points for all laboratory work is 15 points.

4. Modular control work (MCW) Weighted score – 8.

5. Calculation and graphic work (CGW)
Weighted score – 15.

6. Penalty points for:

– not being allowed to participate in laboratory work due to unsatisfactory initial assessmen. -1 point;

– absence from a lecture, practical or laboratory class without a valid reason .... -1 point;

– late submission of coursework and laboratory reports -2 points.

Calculation of the semester rating scale (R)

The size of the R scale is formed as the sum of the weighted scores of control measures (R_C) during the semester and the weighted score of the exam (R_E): R= R_C + R_E .
The size of the starting scale........................R_C = 60 points.
The size of the exam scale. ....R_E = 40 points.
The size of the rating scale........................... R = 100 points.

The size of the starting scale is determined by the sum of the maximum possible points for control measures (positions 1-5) carried out during the semester: RC = 8 + 14 + 15 + 8 + 15 = 60 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)

Approximate topics of RGR assignments

The load impedance of a coaxial cable at frequency is (see Table 1).
1. Determine:
1) the input resistance of the mismatched line at the node and the lumped elements;
2) the parameters of the matching circuit, which consists of the elements specified in the task option (Table 1);
3) the amplitude-frequency characteristic of the matched load.
2. Provide a sketch of the calculated matching circuit.
3. Draw conclusions based on the calculation results and offer recommendations for the manufacturing technology of the matching circuit.

When completing the assignment, use the demo version of *Smith v4.0* or other software, subject to prior agreement with the instructor.

Table 1 — RGR task options

Option	Coordination elements	Cable		f, GHz	Zo, Ohm
		Type	*d*, mm		
1	OL	RK 50-3-a90V	1.05	1	25+j25
2	SC	RK 50-3-a90B	1.0	1.5	30 – j25
3	L, C	RK 50-3-a90B	1.05	2	75+j30
4	L, C	RK 50-3-a90B	1.05	2.5	100 – j25
5	OS	RK 50-4.8-a90P	1.72	1.0	20 + j45
6	SC	RK 50-4.8-a90P	1.72	1.5	40 – j55
7	L, C	RK 50-4.8-a90P	1.72	2.0	60+ j25
8	L, C	RK 50-4.8-a90P	1.72	2.5	130 – j25
9	OL	RK 75-4.8-a60B(P)	1.12	1.0	45 + j60
10	SC	RK 75-4.8-a60B(P)	1.12	1.5	30 – j25
11	L, C	RK 75-4.8-a60B(P)	1.12	2.0	80 + j15

Notes: OL – open loop; SC – short-circuited loop; L, C – concentrated inductance and capacitance

Description of material, technical, and informational support for the discipline

Practical classes involving the use of software are held in computer classrooms (402-17, 404-17) with 18 workstations equipped with programs. Computers with the following minimum requirements: 32-bit (x86) or 64-bit (x64) processor with a clock speed of 1 GHz or faster*; 1 gigabyte (GB) of RAM (for the 32-bit version) or 2 GB (for the 64-bit version); 16 GB (for the 32-bit version) or 20 GB (for the 64-bit version) of free hard disk space; Graphics device with DirectX 9 support and WDDM 1.0 or later driver.
Software:
Smith V4.1 (shareware, demo available demo version available):
https://www.fritz.dellsperger.net/smith.html;
– Cadence AWR Design Environment (PTF license, Igor Sikorsky KPI).
Methodological recommendations for completing practical tasks have been developed and are available on Google Classroom.
Laboratory classes are held in the training laboratory (301-17) with models for performing the tasks specified in paragraph 5. Methodological recommendations for the tasks are posted on Google Classroom.

Work program for the academic discipline (syllabus):
Compiled by Peregudov S. M.;
Approved by the PRE Department (Minutes No. 06/2025 dated 06/25/2025)
Approved by the methodological commission of the faculty/research institute (protocol No. 06/2025 dated 26.06.2025)