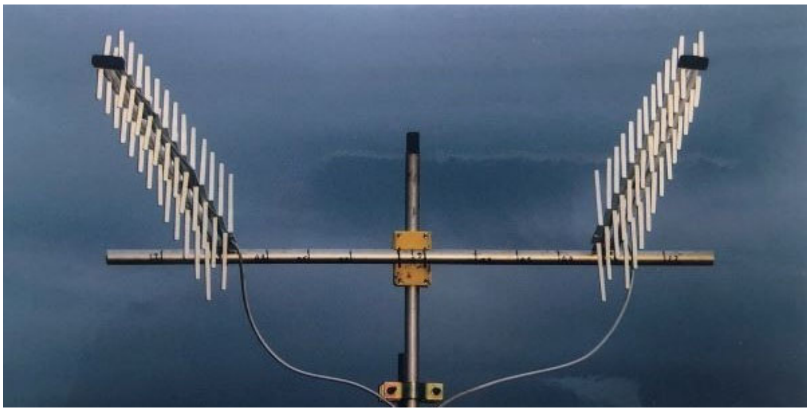
Національний технічний університет України
«КИЇВСЬКИЙ ПОЛІТЕХНІЧНИЙ ІНСТИТУТ
імені ІГОРЯ СІКОРСЬКОГО»

Radioengineering
Department



Curriculum of the academic discipline (Syllabus)

Course details

Level of higher education	First (bachelor's)
Field	17 - Electronics, Automation, and Electronic Communications
Special	172 - Electronic communications and radio engineering
Educational program	172B ROS - Radio Communications and Signal Processing (EDEBO id: 6364)172B RSI - Radio Systems Engineering (EDEBO id: 7350)172B ICR - Information and Communication Radio Engineering (EDEBO id: 49228)172B ICRI+ - Information and Communication Radio Engineering (EDEBO id: 57910)G5B ICRI - Information and Communication Radio Engineering (EDEBO id: 83618)
Discipline status	Regulatory
Form of higher education	Full-time Full-time accelerated
Year of training, semester	3rd year, 6th semester (full-time study)
Scope of the discipline	5 credits (Lectures 36 hours, Practical classes 18 hours, Laboratory classes 36 hours, Self-study 60 hours)
Semester control/control measures	Exam
Class schedule	https://schedule.kpi.ua
Language of instruction	Ukrainian
Information about course coordinator/teachers	Lecturer: Kupriy O. M., Practical classes: Kupriy O. M., Lab: Kupriy O. M., Self-study: Kupriy O. M.
Course location	*The course is available on the Sikorsky distance learning platform:* https://do.ipo.kpi.ua/course/view.php?id=8356

Curriculum

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

The subject of this discipline is antennas — their design, construction, calculation of basic characteristics and parameters, the physical content of the processes accompanying their operation, and experimental research of their parameters and characteristics.

By definition, an antenna is a radio engineering device or an entire system that emits and receives electromagnetic waves in transmission and reception modes, respectively, and is an integral part of every radio engineering system. In many cases, it is antennas that determine the maximum achievable characteristics and parameters of radio engineering systems, such as range, coordinate accuracy, resolution, bandwidth, noise immunity, and their cost. Sometimes an antenna is called the "eyes" of a radio engineering system.

It should be noted that radio engineering systems are systems that provide information exchange between two or more points separated in space. Examples of radio engineering systems include radar, radio navigation, radio communication (including mobile communication systems), television, telemetry, radio control, space radio engineering systems, radio telescopes, Earth sounding systems, medical radio engineering systems, and others.

The carrier of information in these systems is electromagnetic waves that propagate in the environment in which the transmitting and receiving antennas are located.

Mastering the academic discipline "Antennas" answers the question: What are antennas and what are their main functions in radio engineering systems? In addition, it will help you gain:

Knowledge of:

- the principles of construction, the principles of operation of antennas of different frequency ranges, especially in the VHF range, the features of their application in various radio engineering systems;
- the physical content and mathematical interpretation of the main parameters and characteristics of antennas;
- application of the Kirchhoff-Huygens principle to solve problems of radiation from a symmetrical vibrator (SV), rectangular or circular aperture antennas, straight equidistant, equal amplitude, linear phase antenna arrays (AR);
- principles of operation, design, maximum achievable characteristics and parameters of antennas discussed in the lecture notes. Connecting them to power lines in the frequency ranges of their application.

Skills:

- select from known and propose their most effective design options for antennas for radio engineering systems for various purposes in different frequency ranges that will meet the specified technical conditions for the antenna;
- Perform engineering calculations of the main parameters and characteristics of selected or proposed antennas.
- carry out the design development of these antennas;
- conduct experimental research on the main characteristics and parameters of antennas, and analyze them.

Experience:

- performing calculations, conducting experimental studies of antenna characteristics and parameters;

- working with microwave range equipment.

After completing the course, students should demonstrate the following program competencies and learning outcomes according to the educational program (see https://osvita.kpi.ua/op):

General competencies (GC)

GC 2 Ability to apply knowledge in practical situations.

GC 7 Ability to learn and acquire modern knowledge.

Professional competencies (PC)

PC 1 Ability to understand the essence and significance of information in the development of modern information society.

PC 3 Ability to use basic methods, means, and tools for obtaining, transmitting, processing, and storing information.

PC 8 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, devices, and equipment.

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 parameters of microwave devices and antennas of various designs in different 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)

PLR 1 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.

PLR 4 Explain the results obtained from measurements in terms of their significance and relate them to the relevant theory.

PLR 30 Measure the basic parameters of antennas, microwave devices, and active microwave receiving systems.

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

The study of the academic discipline "Antennas" is based on the competencies acquired during the study of the following academic disciplines: "Higher Mathematics," "General Physics" (section "Electricity and Magnetism"), "Computer Science," "Fundamentals of Metrology," "Electrodynamics and Radio Wave Propagation," "Fundamentals of Circuit Theory," "Signals and Processes in Radio Engineering," "Design."

The practical skills and theoretical knowledge acquired while studying the academic discipline "Antennas" are further used in the study of special academic disciplines: "Complex Antenna Systems," "Radio Engineering Systems for Various Purposes," "CAD Antennas," "Satellite Information Systems," and others.

3. Course content

LECTURE TOPICS

Part 1

Section 1

Introduction. Basic definitions. Types of antennas. Their main functions in radio engineering systems, classification of antennas. Main tasks of antenna theory. Comparative analysis of antennas of different frequency ranges in terms of their directivity and efficiency. Brief description of programs for numerical calculation of antennas.

Section 2

Basic characteristics and parameters of antennas:

- complex directivity function (directivity);
- directivity patterns (amplitude, phase, polarization);
- directional action, gain, and efficiency coefficients;
- polarization parameters of antennas;
- antenna matching characteristics;
- operating frequency band of the antenna;
- effective length and area of the antenna;
- antenna area utilization factor;
- antenna radiation power;
- antenna radiation resistance and input resistance;
- noise temperature of the antenna;
- the far field of the antenna and its boundary;

Section 3

Theory of a symmetrical vibrator (SV). Distribution of current and charge along the length of the SV. SV radiation field and its analysis. Directionality diagrams for different relative lengths of the symmetrical vibrator. Characteristics and parameters of the SV (radiation resistance, directivity coefficient as a function of its relative length, input resistance).

Section 4

Radiation from rectangular and circular apertures with different laws of field amplitude distribution at the aperture and different laws of field phase change at it. Mathematical and physical analysis of the radiation field. Directivity diagrams and their analysis.

Section 5

Radiation of antenna arrays. General provisions. Theorem (rule) of multiplying directional patterns (DP). Radiation field of a straight, equidistant antenna array (AA) with equal-amplitude excitation and a linear law of phase change of currents or fields of emitters in the AA. Mathematical and physical analyses of the directional patterns of this AR in normal, inclined, and axial radiation modes. AR pitch and its effect on the directional pattern. Analysis of the effect of the number of AR elements on the directional pattern. Amplitudes of the side lobes of the directional pattern.

The effect of uneven amplitude distribution of power fields (currents) and phase distortions on the AR directional pattern. The concept of a continuous linear emitter. The AR directivity coefficient.

Part 2

Antennas (designs, principles of operation, maximum achievable characteristics, calculations).

Section 6

Vibrator antennas. Design of symmetrical and asymmetrical vibrators in different frequency ranges. Symmetrizing and matching devices when powering a symmetrical vibrator with a coaxial transmission line.

Uda-Yagi antenna (wave channel). Designs, principle of operation, potential characteristics, connection of the antenna to the feed line. Calculations.

Log-periodic antennas. Designs, principle of operation, potential characteristics, antenna connection to the power line ( ). Calculations. Butterfly antenna.

Section 7

Zigzag and spiral antennas. Designs, principle of operation, potential characteristics, connecting the antenna to the feed line. Calculations.

Collinear antenna (straight antenna array with sequential feeding). Designs, principle of operation, potential characteristics, connecting the antenna to the power line. Calculations.

Section 8

Introduction to surface wave antenna designs: disc-rod, dielectric tube loaded with discs and rings.

Designs, principle of operation, potential characteristics, connecting antennas to the feed line. Calculations.

Section 9

Aperture antennas. Waveguide and horn antennas. Designs, principle of operation, potential characteristics, connecting the antenna to the feed line. Calculations.

Lens and horn-lens antennas. Designs, principle of operation of single-mirror antennas, maximum achievable characteristics. Examples of application. Irradiators of single-mirror antennas, their designs and characteristics.

Section 10

Double-mirror antennas. Cassegrain, Gregory, and quasi-parabolic antennas. Designs, operating principles, maximum achievable characteristics. Applications. Prospects for antenna development.

TOPICS OF PRACTICAL CLASSES

The purpose of practical classes is to gain experience in calculating the characteristics and parameters of certain antennas.

Solving problems to explain the physical meaning of antenna characteristics and parameters by finding the maximum range of a radio system, as well as the power or electromotive force at the input of the radio system receiver, if the radiation power or power at the input of the transmitter antenna and other necessary parameters of the transmitting and receiving antennas are given.

Engineering calculations of the characteristics and parameters of antennas studied in laboratory work.

Tasks using the principle of superposition for the graphical construction of directional diagrams of two- and three-element antenna arrays.

Familiarization of students with the exhibits of the antenna exhibition (antenna laboratory of the Radio Engineering Department), developed by students, staff, and teachers of the Radio Engineering Faculty.

RECOMMENDED LIST OF LABORATORY WORKS

The main purpose of laboratory work is for students to gain experience and skills in practical work with microwave range equipment. Familiarization with real antenna designs. Acquire the ability to conduct experimental research on the characteristics and parameters of antennas and analyze and process the results of research, learn to formulate conclusions about the work. In addition, laboratory work allows the teacher to talk to each student individually and monitor their self-study throughout the semester.

Laboratory work is planned on the following topics:

1. Study of the radiation characteristics of a system of vertical radiators in a horizontal plane.
2. Investigation of the radiation characteristics of a rhombic antenna.
3. Investigation of the radiation characteristics of a wave channel antenna.
4. Investigation of the radiation characteristics and matching of a horn, horn-lens, and open waveguide with a rectangular cross-section.
5. Investigation of the radiation characteristics of a single-mirror parabolic antenna.
6. Investigation of the radiation characteristics and matching of a log-periodic vibrator antenna.

4. Teaching materials and resources

Basic literature:

1. M. G. Bova, "Ultra-high Frequency Antennas" — lecture course. 1958–1959. Nanjing University. Nanjing. PRC. — 262 p.
2. M. G. Bova, G. V. Reznikov. "Antennas and Microwave Devices." Textbook. — 1982, 1997. — 280 p. — Kyiv: Higher School.
3. A. G. Dorokhov. Calculation and Design of Antenna Systems. Textbook. 1960. 450 p. Kharkiv.
4. Spindler, Eberhard Antennen. Anleitung zum Selbstbau Published by Verl. Technik, 1990 (Translated from German).
5. "Ultra-wideband Antennas" / edited by Benenson L. S. —1964 — 416 p. (Translated from English).
6. Rothammels Antennenbuch Krischke, Alois. - Baunatal: DARC-Verl., 2013, 13th, updated and expanded edition. (Translated from German).
7. V. M. Shokalo, V. I. Pravda, V. A. Usin, V. S. Vuntesmeri, D. V. Grechikh. "Electrodynamics and Radio Wave Propagation." — Part 1 — 2009 — 287 p.; Part 2 — 2010 — 435 p. — Kharkiv.
8. Thomas A. Milligan. Modern Antenna Design. Second Edition. — 2005. — 663 p.
9. C. A. Balanis. Antenna Theory, Analysis and Design. 2nd ed. — Wiley, New York, 1997.

10. V. H. Rumsey. Frequency Independent Antennas. Academic Press, New York, 1966.
11. F. F. Dubrovka, V. M. Glushenko, O. M. Kupriy. Patent No. 1 Ukraine. Published June 30, 1995. Bulletin of Inventions No. 2.
12. V. M. Glushenko, F. F. Dubrovka, O. M. Kupriy, O. E. Shrenk. "Logarithmic-periodic vibrator antennas." News of Higher Educational Institutions "Radio Electronics," 1998, No. 12, pp. 20–25.
13. Ilnytskyi L. Ya., Savchenko O. Ya., Sibruk L. V. "Antennas and devices of ultra-high frequencies." Textbook for higher educational institutions. Edited by L. Ya. Ilnytskyi. — Kyiv: Ukrtelecom, 2003. — 496 pp.
14. D. O. Vasilenko. "Narrowband and Broadband Matching of Complex Loads." — Kyiv: NTUU "KPI," 2015. — 60.25 pp.
15. O. M. Kupriy, S. E. Martynyuk, S. M. Litvintsev. Tutorial for bachelor's laboratory work in the discipline "Antennas." — Kyiv: NTUU "KPI," 2023. — 42 p.

Theses of the Department of TOR:

16. V.A. Lenivenko, "Disc-rod emitters for radio engineering systems with polarization control," Ph.D. thesis, Kyiv, 1988, 141 p., NTUU "KPI";
17. Pantov V.S. "Radiators and frequency-selective surfaces based on periodic metal-dielectric structures," dissertation for the degree of Candidate of Technical Sciences. Kyiv, 1996. NTUU "KPI";
18. Kim O.S. "Analysis and optimization of omnidirectional and directional axisymmetric dual-mirror antennas" dissertation, Ph.D. Kyiv, 2000. NTUU "KPI";
19. Martynyuk S.E. "Broadband strip antenna arrays" dissertation, Ph.D. Kyiv, 2003, NTUU "KPI";
20. Piltiay S.I. "Broadband coherent orthomode converters based on coaxial ribbed structures" dissertation, Ph.D. Kyiv, 2018, NTUU "KPI";
Master's thesis projects of the Department of TOR: Kim O.S. (1996), Varodi F.F. (1998), Zaskalny V.V. (1998), Yefimov O.V. (1999), Kozak O.V. (2000), Kravchenko R.V. (2001), Kupriy M.O. (2002), Konovalyuk P.P. (2005), Kolishchuk O.V. (2005), Zakordonets V.S. (2007), Verbnyak O.M. (2010), Butyrin Ya.V. (2012).
21. Ultra-high frequency devices and antennas: Part I. Antennas: methodological guidelines for laboratory work for students of the Radio Engineering Faculty. Compiled by V.S. Vuntesmeri, O.M. Kupriy, S.E. Martynyuk, F.M. Repa. Kyiv, 2015 – 36 p.
22. Lecture notes. Kupriy O.M.

Educational content

5. Methods of mastering the academic discipline (educational component)

LECTURES

Lecture No. 1, 2. Introduction.

Purpose, main functions, and classification of antennas. Main tasks of antenna theory. Comparative analysis of antennas of different frequency ranges in terms of their directivity and efficiency. Brief description of programs for numerical calculation of antennas.

Assignment for self-study: Review elementary electromagnetic wave emitters, their parameters, and characteristics.

Lecture No. 3-5. Main characteristics and parameters of antennas – physical meaning and mathematical definition.

- complex characteristic of antenna directivity (directionality);
- directional action, gain, and efficiency coefficients of an antenna;
- polarization characteristics of an antenna;

- antenna matching characteristic;
- operating frequency band of the antenna;
- effective length and area of the antenna;
- antenna area utilization factor;
- antenna radiation power;
- antenna radiation resistance and input resistance;
- antenna noise temperature;
- far field and far field boundary of the antenna.

Assignment for self-study:

1) Find the directional coefficients of elementary electromagnetic waves.

2) Find the effective length of a symmetrical half-wave vibrator.

3) Find the effective area of an open waveguide with a rectangular cross-section at a wave of H10.

Lectures 6-7. Theory of a symmetrical vibrator.

Distribution of current and charge along the length of a symmetrical vibrator. Application of the Kirchhoff-Huygens approach to find the radiation field of a symmetrical vibrator. Its analysis. Radiation resistance, input resistance, and directivity coefficient of a symmetrical vibrator as a function of its relative length. Conclusions.

Assignment for self-study: Familiarize yourself with accurate methods for finding the current distribution along the length of a symmetrical vibrator (references to sources are given in Lecture No. 6).

Lectures 8-9. Radiation from rectangular and circular apertures with different laws of field amplitude distribution at the aperture and different laws of field phase change at it. Found according to the Kirchhoff-Huygens approach. Analysis of directivity diagrams. Conclusions.

Assignment for self-study: Independently study the analysis of the directional pattern of a circular aperture given in.

Lecture No. 10. Antenna array (AA) radiation.

General provisions and definitions. Classification of AR. Theorem of multiplication of antenna array directional patterns. Finding the radiation field of a straight-line, equidistant, equal-amplitude, linear-phase AR and preliminary analysis of the directional pattern of this AR.

Lecture No. 11. The effect of linear, quadratic, and cubic phase distortions on the DS of a straight, equidistant, and equal-amplitude AR. Approximate formulas for calculating the directivity coefficient of a straight, equidistant AR in different operating modes.

Lectures 12-13. Vibrator antennas. Design of symmetrical and asymmetrical vibrators in different frequency ranges. Symmetrization and matching devices when powering a symmetrical vibrator with a coaxial transmission line.

Lecture No. 14. Uda-Yagi antenna (wave channel).

Designs, principles of operation, potential characteristics, connecting the antenna to the feed line. Calculations.

Log-periodic antennas. Designs, principles of operation, potential characteristics, connecting the antenna to the feed line. Calculations. Butterfly antenna.

Lecture No. 15. Spiral, collinear, zigzag antennas. Their designs, principles of operation, maximum achievable characteristics, connection to the feed line. Calculations.

Lecture No. 16. Introduction to surface wave antenna designs: disc-rod, dielectric tube loaded with discs or rings. Their characteristics, power supply, calculations.

Lectures № 17-18. Aperture antennas: horn, horn-lens, and lens antennas. Designs, principles of operation, power supply, potential characteristics.

Single-mirror parabolic antennas. Designs, principle of operation, maximum achievable characteristics, power supply, application.

Mirror antenna irradiators. Examples of designs and their characteristics.

Double-mirror antennas. Cassegrain, Gregory, and quasi-parabolic antennas. Designs, principles of operation, maximum achievable characteristics, applications. Prospects for the development of antennas.

PRACTICAL CLASSES (list of topics):

1. Construction of directional diagrams of two- and three-element antenna arrays (AA) at different amplitudes of AA element supply currents using the principle of superposition.

2. Analysis of the radiation patterns of a straight, equidistant, equal-amplitude AR in normal radiation mode.

3. Analysis of the radiation patterns of a straight, equidistant, equal-amplitude AR in inclined radiation mode.

4. Analysis of the DS of a straight, equidistant, equal-amplitude AR in axial radiation mode.

5, 6. Determination of the range of a radio engineering system, as well as the power or voltage at the receiver input, given the known radiation power or power at the receiving antenna input and other specified necessary parameters of the transmitting and receiving antennas (KND, KSH, G).

7, 8, 9. The procedure for calculating antennas considered in the lecture notes for the discipline "Antennas."

LABORATORY CLASSES (list of titles):

No. 1. Investigation of the radiation characteristics of vertical vibrator systems in the horizontal plane (magnetic field plane).

No. 2. Investigation of the radiation characteristics of a rhombic antenna.

No. 3. Investigation of the radiation characteristics of a wave channel antenna and its elements.

No. 4. Investigation of the radiation characteristics and matching of horn, horn-lens antennas, and open waveguides with a rectangular cross-section.

No. 5. Investigation of the radiation characteristics of a single-mirror parabolic antenna.

No. 6. Investigation of the radiation characteristics and matching of a log-periodic vibrator antenna.

Laboratory work is provided with methodological guidelines.

In addition, in laboratory No. 328 of the Department of TOR, students can view an exhibition of antennas developed by students and teachers of the department.

6. Self-study of the student

Students must prepare in advance for lectures, practical and laboratory work. Before lectures, it is necessary to review the material from the previous lecture and complete homework assignments.

Homework assignments for practical and laboratory work must be completed in advance, not on the eve of these classes.

To complete the calculation and graphic work (CGW), students should use the recommended literature, lecture notes, and other sources. CGW must be completed before the start of laboratory work, as the CGW tasks relate to antennas that are experimentally studied in laboratory work.

Content of the CGW task:

Briefly describe the designs, principles of operation, and maximum achievable characteristics and parameters of the following antennas: Uda-Yagi, log-periodic vibrating antenna, horn antenna, and single-mirror parabolic antenna (directivity coefficient, operating frequency band, side lobe level). Indicate the frequency ranges in which they are most competitive. Provide drawings of these antennas. What feed lines are used in the frequency ranges of their application?

Policy and control

7. Policy of the academic discipline (educational component)

Class attendance

Attendance at lectures, practical classes, and laboratory work is mandatory. Missed laboratory work must be made up on days agreed with the instructor. Missed tests or exams are marked as "absent" and must be taken during an additional session.

Announcement of test results

The results of the coursework are summarized during an interview with the instructor. The results are announced after the interview. The results of the laboratory work are summarized with each student individually after they have completed the laboratory work reports through an interview. The results are announced after the interview.

Academic integrity and ethical standards in accordance with the regulatory documents of Igor Sikorsky KPI.

Procedure for appealing the results of control measures

Students have the right to appeal the results of control measures by submitting a reasoned statement addressed to the deputy dean for student affairs of the Radio Engineering Faculty with a written explanation of their disagreement within the time limits set by the university.

8. Types of assessment and the learning outcomes assessment rating system (LOAS)

A student's grade in a discipline (RD) is calculated as the sum of the points received during the semester – the starting grade (RS) and exam points (RE):

RD = RS + RE.

The size of the starting scale SR = 45 points.

The size of the starting scale RE = 55 points.

The size of the subject rating scale SR = 100 points.

The RS rating point system and criteria for their assessment:

1. Completion and defense of the CGW:

a) writing and formatting the work on time in accordance with the requirements (independently) – 15 points;

b) writing and formatting the work on time with errors (independently) – 10 points;

c) writing and formatting the work late (not independently) < 10 points.

2. Completion, formatting, and defense of six laboratory works:

a) maximum number of points – 30 (5 points for each laboratory work);

b) maximum number of points for completion, formatting, and defense of the work no later than two weeks after completion of the work and qualified answers during the defense;

c) the number of points is reduced for the defense of work within an unspecified period.

3. For 100% attendance of classes (lectures, practical and laboratory), as well as timely defense of laboratory works and CGW, the grade received on the exam or test is increased by 5 points.

The maximum rating for the semester is RS = 45 points.

Conditions for a positive interim assessment:

a) attendance of at least 75% of classes;

b) depends on the semester curriculum and class schedule.

Conditions for admission to the exam or test:

a) completion and defense of the CGW, as well as all laboratory work;

b) obtaining at least 30 points during the semester.

RE rating point system and assessment criteria:

The exam or test consists of a written assignment with an additional interview. Each assignment contains two theoretical questions and one problem.

Maximum score:

1) For the first question - 20 points;

2) For the second question - 15 points;

3) Problem - 20 points.

The maximum RE is 55 points.

The grading system is communicated to students during the first lecture of the semester by the lecturer.

Table of correspondence between rating points and grades on the university scale

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)

The department's antenna laboratory has a permanent exhibition of antennas developed by teachers, staff, and students of the department.

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

Laboratories, equipment, software, description of models for conducting laboratory work and their quantity

Work program of the academic discipline (syllabus):
Compiled by Kupriy O. M.;
Approved by RED (protocol No. 06/2025 dated 06/26/2025).
Approved by the REF Methodological Commission (protocol No. 06/2025 dated 26.06.2025).