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

Department of Radio Engineering

[RE-280] MICROWAVE DEVICES AND ANTENNAS IN IOT DEVICES

Curriculum of the academic discipline (Syllabus)

Course details

Level of higher education	First (bachelor's)
Field of knowledge	G - Engineering, manufacturing, and construction
Specialty	G5 - Electronics, electronic communications, instrument engineering, and radio engineering
Educational program	All
Discipline status	Elective (F-catalog)
Form of higher education	Full-time
Year of training, semester	Available for selection starting from the 3rd year, spring semester
Scope of the discipline	4 credits (Lectures 16 hours, Practical classes 30 hours, Laboratory work 30 hours, Independent work 74 hours)
Semester Control/control measures	Credit
Class schedule	https://schedule.kpi.ua
Language of instruction	Ukrainian / English
Information about the course director / teachers	Lectures: Vasilenko D. O., Lab: Vasilenko D. O., Independent work: Vasilenko D. O.
Course location	

Curriculum

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

Modern IoT devices contain up to 5-6 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.

For example, radio engineers who develop the microwave part of modern embedded systems use such concepts as antenna efficiency, antenna gain, beamwidth

, total radiated power (TRP), matching circuit efficiency, microstrip and coplanar transmission lines. All of this is covered in this discipline.

Mastering this discipline provides students with

knowledge

- the principles of construction, design, and operation of ultra-high frequency (UHF) devices and antennas, as well as 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 for experimental research of the characteristics of functional elements of the antenna-feeder path.

skills:

- calculate the parameters of simple UHF devices and antennas;
- select the most effective antennas and microwave devices for IoT devices;
- perform engineering calculations of the main characteristics of microwave devices and antennas;
- conduct experimental research on the characteristics and parameters of microwave devices and antennas.

Experience:

- performing calculations for narrowband matching devices of microstrip design;
- experimental research of the characteristics of microwave devices (power dividers, directional couplers);
- working with microwave range equipment.

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 discipline is based on the competencies acquired during the study of the following disciplines: "Higher Mathematics," "General Physics" (section "Electricity and Magnetism"), "Computer Science," "Fundamentals of Metrology," "Electrodynamics and Radio Wave Propagation."

The course is intended for all educational programs except "Educational Program: Information and Communication Radio Engineering."

3. Course content

LECTURE TOPICS on microwave devices

Section 1. Transmission lines in radio systems and microwave devices.

Topic 1.1 Basic characteristics and parameters of transmission lines in the design of microwave devices.

Topic 1.2. Planar and coaxial transmission lines and their characteristics.

Topic 1.3. Mathematical model of a regular transmission line. The effect of wave mode in a transmission line on efficiency and transmission power. Transformation of impedances in transmission lines.

Section 2. Elements of antenna-feeder paths (AFP).

Topic 2.1. AFT elements: matched loads, connectors, transitions between transmission lines.

Topic 2.2. Inhomogeneities in transmission lines and their equivalent circuits.

Section 3. Microwave multipoles and their characteristics

Topic 3.1. Wave scattering and transmission matrices, impedance and conductance matrices.

Physical meaning of their elements.

Topic 3.2. Mutual, non-dissipative multipoles, their properties.

Section 4. Power dividers and directional couplers.

Topic 4.1. Six-pole, matched divider into two (resistive) – topology, characteristics. Wilkinson divider

Topic 4.2. Quadrature hybrid power divider

Topic 4.3. Directional couplers (HB): principles of operation, general characteristics.
Topic .4.4. Directional couplers on coupled microstrip transmission lines.

Section 5. Microwave filters.

Topic 5.1. Classification of filters and examples of implementation. Prototype filter.

Topic 5.2. Approximation of filter characteristics. Synthesis of microwave filters. Filter with stepwise change in wave impedance (high Z low Z)

LECTURE TOPICS on Antennas

Section 6. Fundamentals of radiation theory. Antenna characteristics and parameters

Topic 6.1. Purpose and definition of antennas. Principle of reciprocity. Classification of antennas. Brief

history of the development of antenna technology

Topic 6.2. Amplitude, phase, and polarization characteristics (diagrams) of antennas

Topic 6.3. Parameters of transmitting antennas: radiation power, directivity coefficient, efficiency coefficient, gain coefficient, input resistance, radiation resistance, effective length (height), operating frequency range frequencies

Topic 6.4. Determination of the receiving antenna . Principle of reciprocity. Characteristics and parameters of the receiving antenna.

Topic 6.5. Power transmitted by the receiving antenna to a matched load. Noise temperature of the receiving antenna

Section 7. Types of antennas in IoT

Topic 7.1. Vibrating antennas. Symmetrical vibrator, its characteristics and parameters. Matching and symmetrical devices

Topic 7.2. PIFA and IFA Antennas

Topic 7.3. Multi-band and tunable IoT antennas

Topic 7.4. Broadband IoT antennas

RECOMMENDED LIST OF LABORATORY WORKS

The main goal of the lab work is for students to gain experience and skills in synthesizing simple microwave devices in the Cadence AWR Microwave Office software environment and practical work with microwave range equipment, as well as the ability to conduct experimental research on the characteristics and parameters of antennas and microwave devices. Process the research results and draw conclusions. In addition, laboratory work allows the teacher to monitor students' independent work throughout the semester.

Educational research is planned on the following topics:

1. Wilkinson divider
2. Quadrature hybrid power divider
3. Microwave band filters based on discrete elements
4. IoT antenna matching

3. Teaching materials and resources

Basic literature:

1. David M. Pozar. Microwave Engineering / David M. Pozar. – USA: John Wiley & Sons, 2005. – 700 p.
2. 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 KPI. – 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
3. 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
4. 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", RTF, 2015. – 58 p. A4 format. - Access: http://ela.kpi.ua/handle/123456789/16419
5.

Additional literature:

1. Bova, Nikolai Timofeevich. Antennas and Microwave Devices: Textbook for Radio Engineering Specialists in Higher Education Institutions / N. T. Bova, G. B. Reznikov. - Kiev: Vyshcha Shkola, 1982. - 278 p.: ill.; 22 cm.
2. Microelectronic Microwave Devices / [N.T. Bova, Yu.G. Efremov et al.]. - Kiev: Tekhnika, 1984. - 184 p.

Educational content

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

LECTURES

No No	Title of lecture topic and list of main questions (list of teaching aids, references to literature and assignments for independent study)
1	Lecture 1. Topic 1.1 Main characteristics and parameters of transmission lines in the design of microwave devices. Topic 1.2. Planar and coaxial transmission lines and their characteristics.
2	Lecture 2. Topic 1.3. Mathematical model of a regular transmission line. The effect of wave mode in a transmission line on efficiency and transmission power. Transformation of impedances in transmission lines .

3	Lecture 3. Topic 2.1. Elements of AFT: matched loads, connectors, transitions between transmission lines. Topic 2.2. Inhomogeneities in transmission lines and their equivalent circuits.

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 wave mode in transmission lines on efficiency and transmission power. Transformation of resistances in transmission lines.
5	Lecture 5. Topic 3.1. Wave scattering and transmission matrices, impedance and conductance matrices. Physical meaning of their elements. Topic 3.2. Mutual, non-dissipative multipoles, their properties.
6	Lecture 6. Topic 4.1. Six-pole, matched divider into two (resistive) – topology, characteristics. Wilkinson divider
7	Lecture 7. Topic 4.2. Quadrature hybrid power divider
8	Lecture 8. Topic 4.3. Directional couplers (HB): principles of operation, general characteristics. Topic 4.4. Directional couplers on coupled microstrip transmission lines.
9	Lecture 9. Topic 5.1. Classification of filters and examples of implementation. Prototype filter. Topic 5.2. Approximation of filter characteristics. Synthesis of microwave filters. Filter with stepwise change in wave impedance (high Z low Z)
10	Lecture 10. Topic 6.1. Purpose and definition of antennas. Principle of reciprocity. Classification of antennas. A brief history of the development of antenna technology
11	Lecture 11. Topic 6.2. Amplitude, phase, and polarization characteristics (diagrams) of antennas
12	Lecture 12. Topic 6.3. Parameters of transmitting antennas: radiation power, directivity coefficient (KSD), efficiency coefficient (KKD), gain coefficient, input resistance, radiation resistance, effective length (height), operating frequency range frequencies
13	Lecture 13. Topic 6.4. Determination of the receiving antenna . Principle of reciprocity. Characteristics and parameters of the receiving antenna. Topic 6.5. Power transmitted by the receiving antenna into a matched load. Noise temperature of the receiving antenna
14	Lecture 14. Topic 3.1. Vibrating antennas. Symmetrical vibrator, its characteristics and parameters. Matching and symmetrical devices.
15	Lecture 15. Topic 7.2. PIFA and IFA antennas
16	Lecture 16. Topic 7.3. Multi-band IoT antennas
17	Lecture 17. Topic 7.3. Multi-band IoT antennas
18	Lecture 18. Topic 7.4. Broadband IoT Antennas

LABORATORY CLASSES

The main goal of laboratory work is for students to gain experience in synthesizing microwave devices in Cadence AWR Microwave Office and experience and skills in practical work with microwave range equipment, as well as 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 instructor to monitor students' independent work throughout the semester.

No. No	Name of laboratory work
1	Wilkinson divider A synthesis of the Wilkinson divider is performed in Cadence AWR Microwave Office, and the influence of its geometric parameters on the device characteristics is investigated. The synthesized device is measured using Pocket VNA. A comparison of theoretical and experimental data.
2	Quadrature hybrid power divider A quadrature hybrid divider is synthesized in Cadence AWR Microwave Office, and the influence of its geometric parameters on the device characteristics is investigated. The synthesized device is measured with Pocket VNA. A comparison of theoretical and experimental data.
3	Microwave band filters based on discrete elements A filter is created for the 2.4, sub 1 GHz, and 5-6 GHz frequency ranges, starting with a prototype filter and refining it into a sample, taking into account microstrip lines, element landing points, and the actual S-parameters of discrete elements. and the actual S-parameters of discrete elements.
4	IoT antenna matching Synthesis of IoT antenna matching for one of the bands (900 MHz, 2.45 GHz) is performed it is placed on plastic or near metal structures.

5. Independent work of the student

For independent work, students are required to complete the following assignment:

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

Perform the matching using discrete capacitors and inductors.

Determine which matching circuit will be used and why, plot 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 diagram.

It is necessary to calculate the frequency dependence of the reflection coefficient of the resulting matching circuit in the frequency range 0.1f0 - 2f0.

Implement the resulting matching circuit in AWR Microwave Office using the S-parameters of real components and compare with the results of theoretical calculations.

Policy and control

6. Policy of the academic discipline (educational component) Attendance

Attendance of lectures, practical and laboratory classes - in accordance with the "Regulations on the organization of the educational process at Igor Sikorsky KPI." At least once a week, the instructor holds 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 homework, tests, and calculations.

Missed tests

The result for a student who did not attend the assessment is zero. If a student misses

an assessment for a valid reason, the student is given the opportunity to complete it (write an MCW, complete laboratory work) in the presence of the teacher. If the absence occurred without a valid reason, especially with regard to laboratory work, the issue of completing it is decided with the teacher in agreement with the department management.
A missed exam is not counted regardless of the reasons for the absence; in this case, the student receives a "did not appear" mark if they are eligible to take the exam and must take the exam during an additional session.

Announcement of test results

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

The defense of the completed section of the HCW takes the form of an interview with the teacher. During the defense, the student must be able to explain the results obtained and answer the main theoretical questions on the topics of the sections. The results of the defense are announced to the student in their presence or remotely and are accompanied by specific comments and remarks regarding errors. (Remote communication via Zoom, Telegram, Skype, Google Meets with video and audio).

The results for the completed laboratory work are posted upon 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.

Standards of ethical conduct

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.

Procedure for appealing the results of control measures

Students have the opportunity to raise any issue related to the procedure for conducting and/or evaluating control measures and expect that it will be considered in accordance with pre-defined procedures.

Students have the right to appeal the results of control measures, but they must provide a reasoned explanation of which criteria they disagree with according to the assessment sheet and/or comments.

7. Types of assessment and the learning outcomes assessment rating system (RAS)

The RAS consists of points received for the completion of the following tasks:

- Completion and defense of each of the 4 laboratory assignments - 15 (7.5 - synthesis and measurement, 7.5 - defense)
- Modular test – 10
- Completion and defense of HCW - 30 (10 - theoretical calculation, 10 - implementation in AWR, 10 - defense)

Each type of work is evaluated on a 100-point scale and converted proportionally into a point score.

Conditions for a positive interim assessment

To receive a "pass" on the first interim assessment (week 8), the student must receive at least 20

points.

To receive a "pass" on the second interim assessment (week 14), the student must receive at least 40 points.

The rating system for 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.

Grades are calculated during the last lecture of the semester.

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

8. Additional information on the discipline (educational component)

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

Laboratory work provides the basics of using the Cadence AWR Microwave Office program. Synthesized devices are measured on a modern VNA - Pocket VNA.

Work program for the academic discipline (syllabus):
Compiled by Vasilenko D. O.;
Approved by the RI Department (Minutes No. 06/2025 dated 06/24/2025)
Approved by the methodological commission of the faculty/research institute (protocol No. 06/2025 dated 26.06.2025)