Національний технічний університет України «КИЇВСЬКИЙ ПОЛІТЕХНІЧНИЙ ІНСТИТУТ імені ІГОРЯ СІКОРСЬКОГО»	Radio Engineering Faculty Department of Engineering

Signals and Processes in Radio Engineering. (GT16) Course Syllabus

Details of the academic discipline (2025-2026)

Level of higher education	***First (bachelor's)***
Field	*G Engineering, Manufacturing and Construction*
Special	*G5 Electronics, Electronic Communications, Instrument Engineering and Radio Engineering*
Educational program	*Radio Engineering Computerized Systems* *Radio Electronic Warfare Technologies* *Intelligent radio- electronic engineering technologies* *Information and Communication Radio Engineering*
Status of the discipline	*Compulsory (standard) (general training cycle)*
Form of study	*Full-time (daytime)*
Year of training, semester	*2nd year (full term of study), 1st year (accelerated term of study) spring semester*
Scope of the discipline	*Total: (5 credits) 150 hours Lectures: 30 hours* *Practical classes: 30 hours* *Laboratory classes (computer workshops): 16 hours Independent work by students: 74 hours*
Semester control/ assessment measures	*MT; CGW, homework, individual assignments for computer workshops, exam*
Class schedule	https://schedule.kpi.ua/
Language teaching	*Ukrainian*
Informationabout the course leader/teachers	*Lecturer: Senior Lecturer Oleg Pavlov (pavlov.oleg1@lll.kpi.ua)* *Practical classes: Associate Professor Olena Gusieva (guseva.elena@lll.kpi.ua)* *Laboratory: Associate Professor Olena Gusieva (guseva.elena@lll.kpi.ua)*
Course location	https://do.ipo.kpi.ua/course/view.php?id=452, http://dtsp.kiev.ua

Curriculum

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

The discipline "Fundamentals of Telecommunications and Radio Engineering Theory. Part 2. Signals and Processes in Radio Engineering" (hereinafter referred to as SPRE) belongs to the cycle of general training of specialists of the first (bachelor's) level of higher education in the specialty 172 "Telecommunications and Radio Engineering", is compulsory (normative) and according to the OP "Information and Communication

Radio Engineering" (introduced into effect from the 2024/2025 academic year by order of the rector of Igor Sikorsky KPI dated 10.06. 2024 No. MOM/434/24) has the code GT16.

The aim of the SPRE course is to develop students' competencies in the field of analysis, synthesis, and processes of radio signal conversion in radio systems for the effective transmission of information via radio and wired communication channels, the use of signals and their processing for radar, radio control, telemetry, radio navigation, remote sensing, etc.

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

KNOWLEDGE (the result of studying the phenomena and patterns of the objective world, which can be logically or factually justified and empirically or practically verified):

- the purpose and structure of modern radio engineering and telecommunications systems, and the processes that occur within them;
- classification of radio signals and their main properties;
- representation of signals in time and frequency spaces, the relationship between them, Fourier and Laplace representations of signals;
- the relationship between signal representations, their ACF, and energy spectrum;
- description of LSS in time, frequency, and operator spaces, description of nonlinear and parametric systems;
- the relationship between input and output signals of systems in time, frequency, and operator spaces;
- the relationship between control signals and radio signals, modulation and demodulation of signals;
- models of narrowband signals, analytical signal, complex envelope, quadrature components and quadrature signal processing, analysis of signal propagation through radio circuits,
- methods of model research of signal characteristics and functional elements of radio-electronic devices.

SKILLS (ability to perform activities, "trained to perform actions," formed by repeating an action and bringing it to automatism):

- calculation of spectra and images of simple deterministic signals;
- calculation of the correlation function and energy spectrum of simple deterministic signals;
- calculation of signals and their spectra at the output of linear and nonlinear circuits using time, spectral, and simplified methods;
- analysis of circuits designed for nonlinear signal amplification, modulation, spectrum shifting, and frequency multiplication;
- computer modeling of information and radio signals and calculation of their main parameters.

SKILLS (a mastered method of performing an action, which is ensured by a set of acquired knowledge and skills**,** and which makes it possible to perform an action not only in familiar conditions, but also in changed ones):

- calculation of spectra and images of complex signals by reducing them to a set of known cases;
- application of mastered methods and calculations to assess changes in signal properties during their conversion by radio-electronic devices;
- analyzing and evaluating the results of model studies of the characteristics of basic signals for the creation of devices with specified parameters.

After completing the course, students must demonstrate program competencies (a range of topics in which they have a good knowledge) and learning outcomes in accordance with the educational and professional program "*Information and Communication* Radio Engineering" (see https://osvita.kpi.ua/op), including, but not limited to (according to the educational and professional program introduced in the 2024/2025 academic year by order of the rector of Igor Sikorsky KPI No. MOM/434/24 dated June 10, 2024):

General competencies (GC)

GC 1 — Ability to think abstractly, analyze, and synthesize.

GC 2 — Ability to apply knowledge in practical situations.

GC 4 — Ability to understand the subject area and professional activity. GC 7 —
Ability to learn and master modern knowledge.

GC 8 — Ability to identify, pose, and solve problems.

Professional competencies (PC)

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

PC 4 — Ability to perform computer modeling of devices, systems, and processes using universal application software packages.

PC 6 — Ability to perform instrumental measurements in information and telecommunications networks, telecommunications and radio engineering systems

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

Program learning results (PLR)

PLR 1 — 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.

PLR 2 — Apply the results of personal research and analysis of information to solve qualitative and quantitative problems of a similar nature in information and communication networks, telecommunications, and radio engineering systems

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

PLR 5 — Skills in evaluating, interpreting, and synthesizing information and data.

PLR 7 — Competently apply terminology in the field of telecommunications and radio engineering.

PLR 8 — Describe the principles and procedures used in telecommunications systems, information and telecommunications networks, and radio engineering.

PLR 9 — Analyze and evaluate the effectiveness of methods for designing information and telecommunications networks, telecommunications and radio engineering systems.

PLR 13 — Apply fundamental and applied sciences to analyze and develop processes occurring in telecommunications and radio engineering systems.

PLR 18 — Find, evaluate, and use information from various sources necessary for solving professional tasks, including reproducing information through electronic search.

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

2.1. The study of the SPRE discipline is based on the competencies acquired while studying the following disciplines: "Fundamentals of Circuit Theory" and "Fundamentals of Electronic Communications Theory."

2.2. The competencies acquired during the study of SPRE are used in the study of "Digital Signal Processing."

3. Content of the academic discipline

Introduction. Telecommunications and Radio Engineering [1, pp. 5–9, 15–17; 2, pp. 5–13, 21–24, 282–300]

- Purpose and objectives of the SPRE discipline. Discipline program.
- Telecommunications and radio engineering.
- Subject and areas of application of radio engineering and radio engineering methods.
- Frequency ranges used in radio engineering.
- Signals and systems, and their role in the process of information transmission. Classification of radio engineering circuits.
- Block diagrams of the main functional components of a typical radio communication system (channel) (direct amplification and superheterodyne transmitters and receivers).
- Basic (typical) radio engineering processes of signal conversion using the example of a radio communication channel.
- Problems of noise immunity and electromagnetic compatibility of radio engineering systems.

Section 01. Classification and models of signals and systems [1, §1.1—§1.4, pp. 9—50].

Topic 01.1. Classification and mathematical models of signals and processes [1, §1.1, pp. 11–21].

- Classification of signals depending on the domain of definition and the domain of acquired values: continuous, discrete, and digital signals [1, §1.1, pp. 12–13].
- Periodic and non-periodic (aperiodic) signals [1, §1.1, pp. 13–14].
- Complex signals and spectra [1, §1.1, pp. 14–17].
- Energy and power signals. Energy signals and power signals [1, §1.1, pp. 17–20].
- Orthogonality of signals in terms of energy and power [1, §1.1, pp. 20–21].

Topic 01.2. Singular functions and their use in modeling deterministic signals [1, pp. 21–27].

- Unit function (Heaviside function, step function, unit jump function) [1, §1.2, pp. 21–24].
- Sign function [1, §1.2, pp. 24–24].
- Delta function (Dirac function, unit impulse function) [1, §1.2, pp. 24–27].

Topic 01.3*. Signal space [1, §1.3, pp. 27–39].

- Signal sets [1, §1.3, pp. 28–30].
- Metric spaces [1, §1.3, pp. 30–33].
- Linear spaces [1, §1.3, pp. 33–34].
- Normed linear spaces [1, §1.3, pp. 34–35].
- Spaces with scalar product [1, §1.3, pp. 35–39].

Topic 01.4. Classification and mathematical models of radio engineering circuits and systems [1, §1.4, pp. 39–45].

- Description using differential equations [1, §1.4, pp. 40–41].
- Description using integral expressions [1, §1.4, pp. 41–42].
- Continuous and discrete circuits and systems [1, §1.4, pp. 42–42].
- Systems with constant and time-varying parameters [1, §1.4, pp. 42–42].
- Causal and non-causal systems and circuits [1, §1.4, pp. 42–43].
- Inertial and non-inertial systems and circuits [1, §1.4, pp. 43–43].
- Linear and nonlinear systems and circuits [1, §1.4, pp. 43–45].

Section 02. Theoretical foundations of generalized spectral analysis of signals [1, §2.1—§2.4, pp. 52—99].

Topic 02.1. Representation of an arbitrary signal as a sum of elementary oscillations. Generalized Fourier series [1, §2.1, pp. 54–65].

- Basic function systems and their properties [1, §2.1, pp. 55–56].
- Generalized Fourier series [1, §2.1, pp. 56–58].
- Bessel's inequality, Parseval's equality [1, §2.1, pp. 58–61].
- Properties of Fourier series [1, §2.1, pp. 61–65].

Topic 02.2*. Orthogonalization of systems of linearly independent functions. Gram-Schmidt procedure [1, §2.2, pp. 65–72].

Topic 02.3*. Some classical orthogonal systems of functions in space L^2 (in a space with scalar product) [1, §2.3, pp. 72–89].

- Legendre polynomials of the first kind [1, §2.3, pp. 72–75].
- Chebyshev polynomials of the first kind [1, §2.3, pp. 75–79].
- Haar function system [1, §2.3, pp. 79–82].
- The Walsh function system [1, §2.3, pp. 82–85].

- System of Laguerre polynomials and functions [1, §2.3, pp. 85–89].

Topic 02.4*. Representation of signals in vector space [1, §2.4, pp. 89–95].

Section 03. Spectra of deterministic signals and their properties [1, §3.1—§3.4, pp. 102—187].

Topic 03.1. Harmonic analysis of periodic signals [1, §3.1, pp. 103–125].

- The concept of periodic signal harmonics [1, §3.1, pp. 103–104].
- Three forms of recording the Fourier series of periodic signals [1, §3.1, pp. 104–115].
- Relationship between Fourier series coefficients recorded in cosine and complex exponential forms [1, §3.1, pp. 115–115].
- Features of the spectra of periodic signals [1, §3.1, pp. 115–125].

Topic 03.2. Spectral analysis of non-periodic signals [1, §3.2, pp. 125–138].

- Fourier transform [1, §3.2, pp. 125–131].
- Spectral energy density, energy spectrum of a non-periodic signal [1, §3.2, pp. 131–138].

Topic 03.3. Properties of the Fourier transform. Theorems about spectra [1, §3.3, pp. 138–162].

- Linearity (superposition) theorem [1, §3.3, pp. 138–140].
- Signal time shift theorem (signal delay) [1, §3.3, pp. 140–142].
- Time scale change theorem [1, §3.3, pp. 142–143].
- Time inversion theorem [1, §3.3, pp. 143–145].
- Duality theorem [1, §3.3, pp. 145–146].
- Frequency Spectrum Shift Theorem [1, §3.3, pp. 146–146].
- Modulation theorem [1, §3.3, pp. 146–148].
- Differentiation theorem in the time domain [1, §3.3, pp. 148–148].
- The theorem of differentiation in the frequency domain [1, §3.3, pp. 148–149].
- Signal multiplication by t theorem [1, §3.3, pp. 149–152].
- Integration theorem in the time domain [1, §3.3, pp. 152–154].
- Conjugate theorem [1, §3.3, pp. 154–155].
- Convolution theorem [1, §3.3, pp. 155–161].
- Multiplication theorem in the time domain [1, §3.3, pp. 161–162].

Topic 03.4. Limit transition in Fourier transform. Spectra of signals that do not satisfy the conditions of applicability of Fourier transform [1, §3.4, pp. 162–179].

- Spectrum of the delta function, periodic sequence of delta functions, and constant [1, §3.4, pp. 163–166].
- Spectrum of a sign function and an inclusion function [1, §3.4, pp. 166–172].
- Spectral density of a periodic signal [1, §3.4, pp. 172–176].
- The pattern of decrease in the amplitude spectrum with increasing frequency [1, §3.4, pp. 176–179].

Section 04. Spectral energy density and spectral average power density. Correlation [1, §4.1–§4.3, pp. 189–233].

Topic 04.1. Spectral energy density and correlation function of signals with finite energy [1, §4.1, pp. 190–213].

- Spectral energy density [1, §4.1, pp. 190–192].
- Properties of spectral energy density [1, §4.1, pp. 192–195].
- Active width of the signal spectrum [1, §4.1, pp. 195–206].
- Autocorrelation function (ACF) of energy signals and its properties [1, §4.1, pp. 206–211].
- Mutual correlation function (MCF) of energy signals and its properties [1, §4.1, pp. 211–213].

Topic 04.2. Spectral density of average power and correlation function of signals with finite average power and infinite energy [1, §4.2, pp. 213–220].

- Spectral density of average power [1, §4.2, pp. 213–216].
- Properties of spectral density of average power [1, §4.2, pp. 216–217].
- ACF of signals with finite average power and its properties [1, §4.2, pp. 217–219].
- Power spectrum of signals [1, §4.2, pp. 219–220].

Topic 04.3. Spectral density of average power and correlation function of periodic signals [1, §4.3, pp. 220—228].

Section 05. Discrete and digital signals and methods of their analysis [1, §5.1–§5.3, pp. 234]. Laplace transform [3, pp. 50, 51, 55–59, 496–498; 4, pp. 61–65].

Signals and processes of DC, their representation and analysis: Discretization and quantization. PFD, RFD, DFT, and Z-transform for DC

Topic 05.1. Discretization and quantization of continuous signals [1, §5.1, pp. 236–255].

- Sampling theorem for signals with a limited spectrum in the time domain. Spectrum of the sampled signal [1, §5.1, pp. 236–241].
- Reconstruction of a continuous signal from a sampling (discrete) signal [1, §5.1, pp. 241–248].
- Sampling theorem in the frequency domain [1, §5.1, pp. 248–250].
- Analog-to-digital signal conversion [1, §5.1, pp. 250–255].

Topic 05.2. Discrete-time Fourier transform (DTFT), discrete-time Fourier series (DTFS), and discrete Fourier transform (DFT) [1, §5.2, pp. 255–266; 2, pp. 255–266].

- Forward and inverse discrete Fourier transforms [1, §5.2, pp. 255–258].
- DFT and Fourier series. Errors arising from the use of DFT [1, §5.2, pp. 258–266].

Topic 05.3. Mathematical apparatus for analyzing discrete signals and systems. z-transform [1, §5.3, pp. 266–288].

- Direct z-transform [1, §5.3, pp. 266–272].
- Properties of z-transforms. Theorems about z-transforms [1, §5.3, pp. 272–277].
- Inverse z-transform [1, §5.3, pp. 277–288].

Laplace transform: Representation of signals in the complex frequency domain. Laplace transform and its properties. Operator method

Topic 05.4. Representation of signals in the complex frequency domain. Laplace transform and its properties [3, pp. 50, 51, 55–59, 496–498; 4, pp. 61–65].

Section 06. Narrowband signals (NB) [1, §6.1–§6.5, pp. 297–327].

Topic 06.1. Envelope and instantaneous frequency of a narrowband signal [1, §6.1, pp. 298–305].

- The Hilbert transform and its properties [1, §6.1, pp. 302–305].

Topic 06.2. Analytical signal [1, §6.2, pp. 305–308].

- The complex envelope of a narrowband signal [1, §6.2, pp. 306–308].

Topic 06.3. Representation of a narrowband signal s(t) using an analytical signal z(t) [1, §6.3, pp. 308–317].

Topic 06.4. Discretization of narrowband signals [1, §6.4, pp. 317–322].

Topic 06.5. ACF of narrowband signals [1, §6.5, pp. 322–327].

Section 07. Amplitude-modulated (AM) signals [1, §7.1–§7.8, pp. 334–389].

Topic 07.1. Tonal AM. Representation of signals in the time and frequency domains. Vector diagrams [1, §7.1, pp. 336–345].

Topic 07.2. Energy characteristics of oscillations with AM [1, §7.2, pp. 345–349].

Topic 07.3. Oscillations with AM arbitrary signal [1, §7.3, pp. 349–357].

- Quadratic modulator [1, §7.3, pp. 357–358].
- Quadratic detector [1, §7.3, pp. 358–359].

Topic 07.4*. Balanced (two-band) modulation with carrier suppression [1, §7.4, pp. 359–361].

- Balanced modulator [1, §7.4, pp. 361–361].
- Synchronous (coherent) detection of oscillations with double-sideband modulation [1, §7.4, pp. 361–367].

Topic 07.5*. Quadrature amplitude modulation [1, §7.5, pp. 367–369].

Topic 07.6*. Single-band modulation (SB) [1, §7.6, pp. 369–370].

- Description of OM signals in the frequency domain [1, §7.6, pp. 370–372].
- Description of single-band modulated signals in the time domain [1, §7.6, pp. 372–379].
- Method of generating single-band AM signals based on phase discrimination [1, §7.6, pp. 379–379].
- Demodulation of single-sideband AM oscillations [1, §7.6, pp. 379–381].

Topic 07.7*. Single-sideband AM with incomplete (partial) suppression of the sideband — Vestigial sideband modulation (VSB) [1, §7.7, pp. 381–382].

- Description of signals with VSB modulation in the frequency domain [1, §7.7, p. 382].
- Generation of signals with VSB modulation [1, §7.7, pp. 382–386].

Topic 07.8*. Comparative analysis of signals and systems with amplitude modulation [1, §7.8, pp. 386–389].

Section 08. Angle-modulated (AM) signals [1, §8.1–§8.8, pp. 395–481].

Topic 08.1. Angle modulation: basic concept [1, §8.1, pp. 396–400].

Topic 08.2. Representation of tone angle-modulated signals in the time domain [1, §8.2, pp. 400–404]. Topic 08.3. Spectra of tone angle-modulated signals [1, §8.3, pp. 404–423].

Topic 08.4*. Generation and detection of signals with angular modulation [1, §8.4, pp. 423–431].

Topic 08.5*. Angular modulation with a non-harmonic modulating signal [1, §8.5, pp. 431–437].

Topic 08.6. Radio pulses with linear frequency modulation (LFM) [1, §8.6, pp. 437–452].

- Radio pulse with LFM, its characteristics and properties [1, §8.6, pp. 437–439].
- Spectrum of a radio pulse with linear frequency modulation [1, §8.6, pp. 439–448].
- ACF of a radio pulse with LFM [1, §8.6, pp. 448–452].

Topic 08.7. Radio signals with phase modulation (FMN) [1, §8.7, pp. 452–475].

- ACF of radio pulses with phase modulation [1, §8.7, pp. 454–455].
- ACF of Barker's FM signals [1, §8.7, pp. 455–457].
- Spectra of FM signals of Barker [1, §8.7, pp. 457–561].
- Generation of FM signals of Barker [1, §8.7, pp. 461—461].
- Binary pseudorandom sequence [1, §8.7, pp. 461–465].
- Signals with phase modulation by binary pseudorandom sequences [1, §8.7, pp. 465–466].
- ACF of signals manipulated by M-sequences [1, §8.7, pp. 466–470].
- Spectra of signals manipulated by M-sequences [1, §8.7, pp. 470–475].

Section 09 (§22). Signal conversion in nonlinear radio engineering circuits (systems) [3, §22.1–§22.6, pp. 281–361].

Topic 09.1. Properties of nonlinear systems [3, §22.1, pp. 282–285].

Topic 09.2. Nonlinear elements of electrical circuits and their characteristics [3, §22.2, pp. 285–292].

Topic 09.3. Approximation of nonlinear element characteristics [3, §22.3, pp. 292–307].

Topic 09.4. Transformation of the spectral composition of current in an inertia-free nonlinear resistive element [3, §22.4, pp. 307–330].

Topic 09.5. Methods of spectral analysis of oscillations in circuits with inertia-free nonlinear elements [3, §22.5, pp. 330–362].

Topic 09.6. Main types of functional signal transformations in nonlinear systems [3, §22.6, pp. 362–377].

Section 10 (§23). Feedback systems [3, §23.1—§23.6, pp. 434—474].

Topic 10.1. Frequency transfer function of a linear system with feedback [3, §23.1, pp. 434–451].

Topic 10.2. Stability of systems with feedback [3, §23.2, pp. 451–474].

Section 11 (§24). Generation of sinusoidal (harmonic) oscillations. Self-oscillating systems [4, §24.1–§24.8, pp. 3–170], [2, §9.1–§9.11, pp. 270–299], [3, §14.4–§14.5, pp. 364–382].

Topic 11.1. Brief description of methods for analyzing nonlinear self-oscillating systems [4, §24.1, pp. 5–8]; [2, §9.1, pp. 270–273].

Topic 11.2. The emergence of oscillations in an oscillator [4, §24.2, pp. 8–25]; [2, §9.2, pp. 273–276].

Topic 11.3. Steady state of an autogenerator [4, §24.3, pp. 25–34]; [2, §9.3, pp. 276–279].

Topic 11.4. Soft and hard modes of generator operation [4, §24.4, pp. 34–54]; [2, §9.4, pp. 279–280].

Topic 11.5. Influence of higher harmonics on the frequency and amplitude of generator oscillations. Stability of the frequency of oscillations at the generator output [4, §24.5, pp. 54–69].

Topic 11.6. Transient mode of a sinusoidal generator. Method of slowly changing amplitudes [4, §24.6, pp. 69–96].

Topic 11.7. Phase plane method [4, §24.7, pp. 965–127]; [2, §9.7, pp. 285–289].

Topic 11.8. Some circuits of sinusoidal oscillation self-oscillators [4, §24.8, pp. 127–159]; [2, §9.5, pp. 280–282].

4. Teaching materials and resources **Basic recommended literature:**

Main

1. Voloshchuk Yu.I. Signals and Processes in Radio Engineering (Part 1),
2. Voloshchuk Yu.I. Signals and processes in radio engineering (part 2),
3. Voloshchuk Yu.I. Signals and processes in radio engineering (part 3),
4. Voloshchuk Yu.I. Signals and processes in radio engineering (part 4),

Additional

5. Edited by Mazor Yu. L. et al. Radio Engineering. Encyclopedic Educational Reference Book. — Kyiv: Vyshcha Shkola,

1999 Note on the main literature for the second part of the discipline

6. Voloshchuk Yu.I. Signals and processes in radio engineering (part 3), (Sections: §22. Signal conversion in nonlinear radio engineering circuits (systems), pp. 281-361; §23. Feedback systems, pp. 433-474).
7. Voloshchuk Yu.I. Signals and processes in radio engineering (part 4), (§23. Generation of sinusoidal (harmonic) oscillations. Self-oscillating systems, pp. 3-170).

Manuals and methodological guidelines

8. Modeling signals and processes in radio engineering in MathCAD and Multisim environments. Part I. [Electronic resource]: textbook for students majoring in 172 "Telecommunications and Radio Engineering" / Compiled by: O.V. Guseva, O.I. Pavlov; Igor Sikorsky KPI. — https://drive.google.com/file/d/1dHixDBS0UNpgukc3Lrnxe5KuBmEHwdxj/view?usp=sharing
9. Modeling of signals and processes in radio engineering in MathCAD and Multisim environments. Part 2. [Electronic resource]: textbook for students majoring in 172 "Telecommunications and Radio Engineering" / Compiled by: O.V. Guseva, O.I. Pavlov; Igor Sikorsky Kyiv Polytechnic Institute. — Electronic text data (1 file, 3.173 MB). — Kyiv: Igor Sikorsky Kyiv Polytechnic Institute, 2022. — 109 p. — https://drive.google.com/file/d/19IsfgO4dEm2i9C7bvV2PiGwgZmZPqV2k/view?usp=sharing
10. Modeling signals and processes in radio engineering in MathCAD and Electronics Workbench environments. Part I [Electronic resource]: textbook for students majoring in 172 "Telecommunications and Radio Engineering" / Compiled by: O. V. Guseva, O. I. Pavlov; Igor Sikorsky Kyiv Polytechnic Institute. — Kyiv: Igor Sikorsky Kyiv Polytechnic Institute, 2021. — 128 p. — https://ela.kpi.ua/handle/123456789/43832
11. Signals and Processes in Radio Engineering. Spectral Analysis. Signal Discretization. Independent Work for Bachelor's Degree Students. / Compiled by: Guseva O. V., Pavlov O. I. — Kyiv: NTUU "KPI", 2025. — 83 p.
12. Methodological guidelines for practical tasks on the topic "Elements of spectral analysis" / Compiled by A. V. Bulashenko, M. I. Yastrebov. — Kyiv: NTUU "KPI", 2011. — 82 p.
13. Fundamentals of Telecommunications and Radio Engineering Theory. Parts I, II. Methodological guidelines for laboratory work for students of the Radio Engineering Faculty of all forms of training in the specialty 172 "Telecommunications and Radio Engineering" / V. P. Gololobov, S. M. Litvintsev. — Kyiv: Igor Sikorsky Kyiv Polytechnic Institute, 2017. — 72 p. — 3rd edition, revised and supplemented
14. Signals and processes in radio engineering. Calculation and graphic work 2 / Compiled by: Guseva O. V., Pavlov O. I. — Kyiv: NTUU "KPI", 2024. — 61 p.

15. SDN server of the Department of Radio Engineering for the discipline SPRE at dtsp.kiev.ua (electronic versions of literature, methodological guidelines, tasks, ratings), as well as SDN on the university-wide platform of NTUU KPI, https://do.ipo.kpi.ua/course/view.php?id=452.

Educational content

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

Lectures

No	*Lecture topic and list of main questions*
1	**Introduction. Telecommunications and Radio Engineering [1, pp. 5–9, 15–17; 2, pp. 5–13, 21–24, 282–300]** • Purpose and objectives of the SPRE discipline. Discipline program. • Telecommunications and radio engineering. • Subject and areas of application of radio engineering and radio engineering methods. • Frequency ranges used in radio engineering. • Signals and systems, and their role in the process of information transmission. Classification of radio engineering circuits. • Block diagrams of the main functional components of a typical radio communication system (channel) (direct amplification and superheterodyne transmitters and receivers). • Basic (typical) radio engineering processes of signal conversion using the example of a radio communication channel. • Problems of noise immunity and electromagnetic compatibility of radio engineering systems. • Noise and interference in radio-electronic systems. Sources of noise and interference. Main types and properties of noise in RES. Main types and properties of interference.
2	**Section 01. Classification and models of signals and systems [1, §1.1—§1.4, pp. 9—50].** Topic 01.1. Classification and mathematical models of signals and processes [1, §1.1, pp. 11–21]. • Classification of signals depending on the domain of definition and the domain of acquired values: continuous, discrete, and digital signals [1, §1.1, pp. 12–13]. • Periodic and non-periodic (aperiodic) signals [1, §1.1, pp. 13–14]. • Complex signals and spectra [1, §1.1, pp. 14–17]. • Energy and power of signals. Energy signals and power signals [1, §1.1, pp. 17–20]. • Orthogonality of signals in terms of energy and power [1, §1.1, pp. 20–21]. Topic 01.2. Singular functions and their use in modeling deterministic signals [1, pp. 21–27]. • Unit function (Heaviside function, step function, unit jump function) [1, §1.2, pp. 21–24]. • Signal function [1, §1.2, pp. 24–24]. • Delta function (Dirac function, unit impulse function) [1, §1.2, pp. 24–27]. Topic 01.3*. Signal space [1, §1.3, pp. 27–39]. • Signal sets [1, §1.3, pp. 28–30]. • Metric spaces [1, §1.3, pp. 30–33]. • Linear spaces [1, §1.3, pp. 33–34]. • Normed linear spaces [1, §1.3, pp. 34–35]. • Spaces with scalar product [1, §1.3, pp. 35–39]. Topic 01.4. Classification and mathematical models of radio engineering circuits and systems [1, §1.4, pp. 39–45]. • Description using differential equations [1, §1.4, pp. 40–41]. • Description using integral expressions [1, §1.4, pp. 41–42]. • Continuous and discrete circuits and systems [1, §1.4, pp. 42–42]. • Systems with constant and time-varying parameters [1, §1.4, pp. 42–42]. • Causal and non-causal systems and circuits [1, §1.4, pp. 42–43].

	• Inertial and non-inertial systems and circuits [1, §1.4, pp. 43–43]. • Linear and nonlinear systems and circuits [1, §1.4, pp. 43–45].
3	**Section 02. Theoretical foundations of generalized spectral analysis of signals [1, §2.1–§2.4, pp. 52–99].** Topic 02.1. Representation of an arbitrary signal as a sum of elementary oscillations. Generalized Fourier series [1, §2.1, pp. 54–65]. • Basic function systems and their properties [1, §2.1, pp. 55—56]. • Generalized Fourier series [1, §2.1, pp. 56–58]. • Bessel's inequality, Parseval's equality [1, §2.1, pp. 58–61]. • Properties of Fourier series [1, §2.1, pp. 61–65]. Topic 02.2*. Orthogonalization of systems of linearly independent functions. Gram-Schmidt procedure [1, §2.2, pp. 65—72]. Topic 02.3*. Some classical orthogonal systems of functions in space L^2 (in a space with scalar product) [1, §2.3, pp. 72—89]. • Legendre polynomials of the first kind [1, §2.3, pp. 72–75]. • Chebyshev polynomials of the first kind [1, §2.3, pp. 75–79]. • Haar function system [1, §2.3, pp. 79–82]. • The Walsh function system [1, §2.3, pp. 82–85]. • The system of Laguerre polynomials and functions [1, §2.3, pp. 85–89]. Topic 02.4*. Representation of signals in vector space [1, §2.4, pp. 89–95].
4	**Section 03. Spectra of deterministic signals and their properties [1, §3.1–§3.4, pp. 102–187].** Topic 03.1. Harmonic analysis of periodic signals [1, §3.1, pp. 103–125]. • The concept of periodic signal harmonics [1, §3.1, pp. 103–104]. • Three forms of recording the Fourier series of periodic signals [1, §3.1, pp. 104–115]. • Relationship between Fourier series coefficients recorded in cosine and complex exponential forms [1, §3.1, pp. 115–115]. • Features of the spectra of periodic signals [1, §3.1, pp. 115–125]. Topic 03.2. Spectral analysis of non-periodic signals [1, §3.2, pp. 125–138]. • Fourier transform [1, §3.2, pp. 125–131]. • Spectral energy density, energy spectrum of a non-periodic signal [1, §3.2, pp. 131–138].
5	**Section 03. Spectra of deterministic signals and their properties [1, §3.1–§3.4, pp. 102–187].** Topic 03.3. Properties of Fourier transform. Theorems about spectra [1, §3.3, pp. 138–162]. • Linearity (superposition) theorem [1, §3.3, pp. 138–140]. • Signal time shift theorem (signal delay) [1, §3.3, pp. 140–142]. • Time scale change theorem [1, §3.3, pp. 142–143]. • Time inversion theorem [1, §3.3, pp. 143–145]. • Duality theorem [1, §3.3, pp. 145–146]. • Frequency Shift Theorem [1, §3.3, pp. 146–146]. • Modulation theorem [1, §3.3, pp. 146–148]. • Differentiation theorem in the time domain [1, §3.3, pp. 148–148]. • The theorem of differentiation in the frequency domain [1, §3.3, pp. 148–149]. • Signal multiplication by t theorem [1, §3.3, pp. 149–152]. • Integration theorem in the time domain [1, §3.3, pp. 152–154]. • Conjugate theorem [1, §3.3, pp. 154–155]. • Convolution theorem [1, §3.3, pp. 155–161]. • Multiplication theorem in the time domain [1, §3.3, pp. 161–162]. Topic 03.4. Limit transition in Fourier transform. Spectra of signals that do not satisfy the conditions of applicability of Fourier transform [1, §3.4, pp. 162–179]. • Spectrum of the delta function, periodic sequence of delta functions, and constant [1, §3.4, pp. 163–166]. • Spectrum of the sign function and the inclusion function [1, §3.4, pp. 166–172].

	• Spectral density of a periodic signal [1, §3.4, pp. 172–176]. • The pattern of decrease in the amplitude spectrum with increasing frequency [1, §3.4, pp. 176–179].
6	**Section 04. Spectral energy density and spectral average power density. Correlation [1, §4.1–§4.3, pp. 189–233].** Topic 04.1. Spectral energy density and correlation function of signals with finite energy [1, §4.1, pp. 190–213]. • Spectral energy density [1, §4.1, pp. 190–192]. • Properties of spectral energy density [1, §4.1, pp. 192–195]. • Active width of the signal spectrum [1, §4.1, pp. 195–206]. • Autocorrelation function (ACF) of energy signals and its properties [1, §4.1, pp. 206–211]. • Mutual correlation function (MCF) of energy signals and its properties [1, §4.1, pp. 211–213].
7	**Section 04. Spectral energy density and spectral average power density. Correlation [1, §4.1–§4.3, pp. 189–233].** Topic 04.2. Spectral average power density and correlation function of signals with finite average power and infinite energy [1, §4.2, pp. 213–220]. • Spectral density of average power [1, §4.2, pp. 213–216]. • Properties of spectral density of average power [1, §4.2, pp. 216–217]. • AKF signals with finite average power and its properties [1, §4.2, pp. 217–219]. • Power spectrum of signals [1, §4.2, pp. 219–220]. Topic 04.3. Spectral density of average power and correlation function of periodic signals [1, §4.3, pp. 220–228].
8	**Section 05. Discrete and digital signals and methods of their analysis [1, §5.1–§5.3, pp. 234]. Laplace transform [3, pp. 50, 51, 55–59, 496–498; 4, pp. 61–65].** ***Signals and processes of DC, their representation and analysis: Discretization and quantization. PFD, RFD, DFT, and Z-transform for DC*** Topic 05.1. Discretization and quantization of continuous signals [1, §5.1, pp. 236–255]. • Sampling theorem for signals with a limited spectrum in the time domain. Spectrum of the sampled signal [1, §5.1, pp. 236–241]. • Reconstruction of a continuous signal from a discrete signal [1, §5.1, pp. 241–248]. • Discrete theorem in the frequency domain [1, §5.1, pp. 248–250]. • Analog-to-digital signal conversion [1, §5.1, pp. 250–255]. Topic 05.2. Discrete-time Fourier transform (DTFT), discrete-time Fourier series (DTFS), and discrete Fourier transform (DFT) [1, §5.2, pp. 255–266; 2, pp. 255–266]. • Forward and inverse discrete Fourier transforms [1, §5.2, pp. 255–258]. • DFT and Fourier series. Errors arising from the use of DFT [1, §5.2, pp. 258–266].
9	**Section 05. Discrete and digital signals and methods of their analysis [1, §5.1–§5.3, pp. 234]. Laplace transform [3, pp. 50, 51, 55–59, 496–498; 4, pp. 61–65].** ***Signals and processes of DC, their representation and analysis: Discretization and quantization. PFD, RFD, DFT, and Z-transform for DC*** Topic 05.3. Mathematical apparatus for analyzing discrete signals and systems. z-transform [1, §5.3, pp. 266—288]. • Direct z-transform [1, §5.3, pp. 266–272]. • Properties of z-transform. Theorems about z-transform [1, §5.3, pp. 272—277]. • Inverse z-transform [1, §5.3, pp. 277–288]. ***Laplace transform: Representation of signals in the complex frequency plane. Laplace transform and its properties. Operator method*** Topic 05.4. Representation of signals in the complex frequency domain. Laplace transform and its properties [3, pp. 50, 51, 55–59, 496–498; 4, pp. 61–65].
10	**Section 06. Narrowband signals (NB) [1, §6.1—§6.5, pp. 297—327].** Topic 06.1. Envelope and instantaneous frequency of a narrowband signal [1, §6.1, pp. 298–305].

	• The Hilbert transform and its properties [1, §6.1, pp. 302–305]. Topic 06.2. Analytical signal [1, §6.2, pp. 305–308]. • The complex envelope of a narrowband signal [1, §6.2, pp. 306–308]. Topic 06.3. Representation of a narrowband signal s(t) using an analytical signal z(t) [1, §6.3, pp. 308–317]. Topic 06.4. Discretization of narrowband signals [1, §6.4, pp. 317–322]. Topic 06.5. ACF of narrowband signals [1, §6.5, pp. 322–327].
11	**Section 07. Amplitude-modulated (AM) signals [1, §7.1–§7.8, pp. 334–389].** Topic 07.1. Tonal AM. Representation of signals in the time and frequency domains. Vector diagrams [1, §7.1, pp. 336–345]. Topic 07.2. Energy characteristics of oscillations with AM [1, §7.2, pp. 345–349]. Topic 07.3. Oscillations with AM arbitrary signal [1, §7.3, pp. 349–357]. • Quadratic modulator [1, §7.3, pp. 357–358]. Quadratic detector [1, §7.3, pp. 358–359].
12	**Section 07. Amplitude-modulated (AM) signals [1, §7.1–§7.8, pp. 334–389].** Topic 07.4*. Balanced (two-band) modulation with carrier suppression [1, §7.4, pp. 359—361]. • Balanced modulator [1, §7.4, pp. 361–361]. • Synchronous (coherent) detection of oscillations with dual-band modulation [1, §7.4, pp. 361—367]. Topic 07.5*. Quadrature amplitude modulation [1, §7.5, pp. 367–369]. Topic 07.6*. Single-band modulation (SB) [1, §7.6, pp. 369–370]. • Description of OM signals in the frequency domain [1, §7.6, pp. 370–372]. • Description of single-band modulated signals in the time domain [1, §7.6, pp. 372–379]. • Method of generating signals with single-band AM based on phase discrimination [1, §7.6, pp. 379–379]. • Demodulation of single-sideband AM oscillations [1, §7.6, pp. 379–381]. Topic 07.7*. Single-sideband AM with incomplete (partial) suppression of the sideband — Vestigial sideband modulation (VSB) [1, §7.7, pp. 381–382]. • Description of signals with VSB modulation in the frequency domain [1, §7.7, p. 382]. • Generation of signals with VSB modulation [1, §7.7, pp. 382–386]. Topic 07.8*. Comparative analysis of signals and systems with amplitude modulation [1, §7.8, pp. 386–389].
13	**Section 08. Angle Modulation (AM) Signals [1, §8.1—§8.8, pp. 395—481].** Topic 08.1. Angular modulation: basic concept [1, §8.1, pp. 396–400]. Topic 08.2. Representation of tone angle-modulated signals in the time domain [1, §8.2, pp. 400–404]. Topic 08.3. Spectra of tone angle-modulated signals [1, §8.3, pp. 404–423]. Topic 08.4*. Generation and detection of signals with angular modulation [1, §8.4, pp. 423–431]. Topic 08.5*. Angular modulation with a non-harmonic modulating signal [1, §8.5, pp. 431–437].
14	**Section 08. Angle-modulated signals (AM) [1, §8.1—§8.8, pp. 395—481].** Topic 08.6. Radio pulses with linear frequency modulation (LFM) [1, §8.6, pp. 437–452]. • Radio pulse with LFM, its characteristics and properties [1, §8.6, pp. 437–439]. • Spectrum of a radio pulse with linear frequency modulation [1, §8.6, pp. 439–448]. • ACF of a radio pulse with LFM [1, §8.6, pp. 448–452]. Topic 08.7. Radio signals with phase modulation (FMN) [1, §8.7, pp. 452–475]. • AKF radio pulses with phase modulation [1, §8.7, pp. 454–455].

	• AKF of Barker FM signals [1, §8.7, pp. 455–457]. • Spectra of Barker FM signals [1, §8.7, pp. 457–561]. • Generation of Barker FM signals [1, §8.7, pp. 461–461]. • Binary pseudorandom sequence [1, §8.7, pp. 461–465]. • Signals with phase modulation by binary pseudorandom sequences [1, §8.7, pp. 465–466]. • ACF of signals manipulated by M-sequences [1, §8.7, pp. 466–470]. Spectra of signals manipulated by M-sequences [1, §8.7, pp. 470–475].
15	**Section 09 (§22). Signal conversion in nonlinear radio engineering circuits (systems) [3, §22.1—§22.6, pp. 281–361].** Topic 09.1. Properties of nonlinear systems [3, §22.1, pp. 282–285]. Topic 09.2. Nonlinear elements of electrical circuits and their characteristics [3, §22.2, pp. 285–292]. Topic 09.3. Approximation of nonlinear element characteristics [3, §22.3, pp. 292–307]. Topic 09.4. Transformation of the spectral composition of current in an inertia-free nonlinear resistive element [3, §22.4, pp. 307–330]. Topic 09.5. Methods of spectral analysis of oscillations in circuits with inertia-free nonlinear elements [3, §22.5, pp. 330–362]. Topic 09.6. Main types of functional signal transformations in nonlinear systems [3, §22.6, pp. 362–377].
16	**Section 10 (§23). Feedback systems [3, §23.1—§23.6, pp. 434—474].** Topic 10.1. Frequency transfer function of a linear feedback system [3, §23.1, pp. 434—451]. Topic 10.2. Stability of systems with feedback [3, §23.2, pp. 451—474]. Problems [3, §23.4, pp. 514—518].
17	**Section 11 (§24). Generation of sinusoidal (harmonic) oscillations. Self-oscillating systems [4, §24.1–§24.8, pp. 3–170], [2, §9.1–§9.11, pp. 270–299], [3, §14.4–§14.5, pp. 364–382].** Topic 11.1. Brief description of methods for analyzing nonlinear self-oscillating systems [4, §24.1, pp. 5–8]; [2, §9.1, pp. 270–273]. Topic 11.2. The emergence of oscillations in an autogenerator [4, §24.2, pp. 8–25]; [2, §9.2, pp. 273–276]. Topic 11.3. Steady state of an autogenerator [4, §24.3, pp. 25–34]; [2, §9.3, pp. 276–279]. Topic 11.4. Soft and hard modes of generator operation [4, §24.4, pp. 34–54]; [2, §9.4, pp. 279–280]. Topic 11.5. Influence of higher harmonics on the frequency and amplitude of generator oscillations. Stability of the frequency of oscillations at the generator output [4, §24.5, pp. 54–69]. Topic 11.6. Transient mode of a sinusoidal generator. Method of slowly changing amplitudes [4, §24.6, pp. 69–96]. Topic 11.7. Phase plane method [4, §24.7, pp. 965–127]; [2, §9.7, pp. 285–289]. Topic 11.8. Some circuits of sine wave oscillators [4, §24.8, pp. 127–159]; [2, §9.5, pp. 280–282].
18	**Section 12. Analysis of signal transmission through radio-electronic devices.** Topic 12.1. Filtering properties of linear electronic devices. Topic 12.2. Passage of oscillations through linear REPs. Spectral, operator, and time methods of analysis. Topic 12.3. Passage of oscillations through nonlinear radio-electronic devices.

Practical classes

No	*Name of the topic and list of main questions* (list of teaching aids, references to literature, and assignments for independent study)
1	Spectral analysis of periodic signals. Physical and mathematical spectra (amplitude, phase, and average power). Estimation of the width of such signal spectra. [1, §3.1, pp. 103–125; 5, pp. 641–644]. Assignment for independent study: Prepare for the class using the manual [11].
2	Spectral analysis of non-periodic signals. Fourier transform. Spectral density of amplitudes and energies. Physical and mathematical spectra. Relationship between the spectra of a single pulse and a periodic sequence of such pulses. [1, §3.2, pp. 125–138; 5, pp. 635–639]. Homework assignment: Prepare for class using the textbook [11].
3	Spectral analysis theorems and their use. Spectra of signals with infinite energy. [1, §3.3, pp. 138–162; 5, pp. 638–641]. Assignment for independent study: Prepare for class using the textbook [11].
4	The concept of signal spectrum width and its practical calculation. The relationship between signal duration and spectrum width. Spectrum decay rate. [1, §4.1, pp. 190–213]. Assignment for independent study: Prepare for class using the manual [11].
5	Correlation analysis of deterministic signals. Connection between spectral and correlation characteristics of signals. [1, §4.1—§4.3, pp. 189—233]. Assignment for independent study: Prepare for class using the manual [11].
6	Laplace transform as a generalization of Fourier transforms. [3, pp. 50, 51, 55–59, 496–498; 4, pp. 61–65]. Assignment for independent study: Prepare for class using the textbook [11].
7	Discretization and quantization of continuous signals [1, §5.1, pp. 236–255]. Sampling theorem for signals with a limited spectrum in the time domain. Spectrum of the sampling signal [1, §5.1, pp. 236–241]. Reconstruction of a continuous signal from a sampling (discrete) signal [1, §5.1, pp. 241–248]. Sampling theorem in the frequency domain [1, §5.1, pp. 248–250]. Analog-to-digital signal conversion [1, §5.1, pp. 250–255]. Discrete-time Fourier transform (DTFT), discrete-time Fourier series (DTFS), and discrete Fourier transform (DFT) [1, §5.2, pp. 255–266; 2, pp. 255–266]. Forward and inverse discrete Fourier transforms [1, §5.2, pp. 255–258]. DFT and Fourier series. Errors arising from the use of DFT [1, §5.2, pp. 258–266]. Homework assignment: Prepare for class using the textbook [11].
8	Mathematical apparatus for analyzing discrete signals and systems. z-transform [1, §5.3, pp. 266–288]. Forward z-transform [1, §5.3, pp. 266–272]. Properties of the z-transform. Theorems on z-transforms [1, §5.3, pp. 272–277]. Inverse z-transforms [1, §5.3, pp. 277–288]. Homework assignment: Prepare for class using the textbook [11].
9	AM radio signals, their types and spectra. AM radio signals, balanced AM with periodic and non-periodic control signals, and their spectra. Overmodulation. [1, §7.1–§7.8, pp. 334–389; 5, pp. 630–632]. Assignment for independent study: Prepare for class using the manual [11].
10	Radio signals from CM, their types and spectra. Radio signals with frequency (FM) and phase (PM) modulations, their spectra. The relationship between instantaneous frequency and phase. The spectrum of a signal with tonal FM, its features and width estimation. [1, §8.1—§8.8, pp. 395—481; 5, pp. 632—633]. Assignment for independent study: Prepare for class using the manual [11].
11	Representation of narrowband radio signals in complex form. The need for complex representation of radio signals and related problems. The Hilbert transform as a solution to these problems, its characteristics in the time and spectral domains. Analytical signal, complex envelope, and their properties. [1, §6.1—§6.5, pp. 297—327; 5, pp. 629—631, 633—634]. Assignment for independent study: Prepare for class using the manual [11].
12	Precise methods for finding the response of a linear circuit to an arbitrary input signal. [2, §17.1—§17.4, pp. 381—432]. Assignment for independent study: Prepare for class using the manual [11].
13	Simplified (approximate) methods for analyzing the conversion of radio signals in narrowband circuits. Complex envelope method. [3, §18.1—§18.3, pp. 9—67; 3, §19.1—§19.4, pp. 70—114]. Homework assignment: Prepare for the class using the manual [11].
14	Approximation of nonlinear characteristics. Tasks, stages (determination of the approximation interval, selection of the type of approximating function, calculation approximation coefficients approximation, verification, evaluation of errors). Approximation by degree polynomials, exponential polynomials, piecewise linear functions, and find the coefficients using the selected points and least squares methods. [3, §22.3, pp. 292–307]. Homework assignment: Prepare for class using the manual [11].

15	Harmonic analysis of oscillations in nonlinear circuits. Cutoff angle methods (Berg's method), 3x and 5y ordinate formulas, etc. Methods of multiple argument formulas, modified Bessel functions. [3, §22.4, pp. 307–330; 3, §22.5, 330–362]. Assignment for independent study: Prepare for class using the manual [11].
16	Frequency conversion (heterodyning). The essence and purpose of the process. Principles and circuit implementation. Basics of calculations. Transducer parameters. [3, §22.1–§22.6, pp. 281–361]. Assignment for independent study: Prepare for class using the textbook [11].
17	Amplitude modulation. The essence and purpose of the process. Principles of obtaining and circuit options. Main characteristics of modulators and their calculations. Balanced modulators. Methods and circuits for obtaining single-band modulation (filter method and phasing method). [1, §7.1—§7.8, pp. 334—389]. Homework assignment: Prepare for class using the textbook [11].
18	Amplitude detection. The essence and purpose of the process from a spectral and temporal point of view. Classification and main characteristics and parameters of amplitude detectors. Serial and parallel linear diode detectors. Quadratic detection. Transistor amplitude detectors, comparison of their parameters with diode detectors. [1, §7.3, pp. 358–359; 1, §7.4, pp. 361–367; 1, §8.4, pp. 423–431]. Assignment for independent study: Prepare for class using the manual [11].

Laboratory classes (computer workshops)

No	*Class topic*
1	Spectral analysis of control signals and radio signals with amplitude modulation
2	Investigation of the passage of amplitude-modulated oscillations through frequency-selective circuits
3	Spectral analysis of angle-modulated oscillations and study of their passage through active frequency-selective circuits
4	Study of amplitude modulation and amplitude detection processes
5	Study of LC self-oscillating systems with external feedback
6	Investigation of an RC self-oscillating system with external feedback

Modular tests (MT)

Modular tests are performed in the form of tests (which ensures objective assessment of knowledge) and downloads (which ensures subjective assessment of skills) in the *Moodle* LMS (https://do.ipo.kpi.ua/course/view.php?id=452, http://dtsp.kiev.ua) [15]. When performing MT, it is recommended to use materials [11].

No	*Name of the task*

1	**MT-2.1**
	Modular test on the topics:
	Signal discretization (2 questions) [1]. **Radio signals and their spectra** (8 questions) [1]. 10 questions in total.
	Recommended topics from Voloshchuk's textbook [1]:
	• **Section 5. Discrete and digital signals** (0) Voloshchuk Yu.I., SPRE, volume 1, pp. 234—255.
	  ○ **5.1. Discretization and quantization of continuous signals** (0) Voloshchuk Yu.I., SPRE, vol. 1, pp. 236—255.
	• **Chapter 6. Narrowband signals** (0) Voloshchuk Yu.I., SPRE, vol. 1, pp. 297–333.
	  ○ **6.1. Envelope and instantaneous frequency of an FS signal** (0) Voloshchuk Yu.I., SPRE, vol. 1, pp. 298–305.
	  ○ **6.2. Analytical signal** (0) Voloshchuk Yu.I., SPRE, vol. 1, pp. 305–308.
	  ○ **6.3. Representation of the VS signal using an analytical signal** (0) Voloshchuk Yu.I., SPRE, vol. 1, pp. 308–317.
	• **Chapter 7. Amplitude-modulated signals** (0) Voloshchuk Yu.I., SPRE, vol. 1, pp. 334–394.
	  ○ **7.1. Signals with tonal AM** (0) Voloshchuk Yu.I., SPRE, vol. 1, pp. 336–345.
	  ○ **7.2. Energy characteristics of oscillations with AM** (0) Voloshchuk Yu.I., SPRE, vol. 1, pp. 345–349.

	○ **7.3. Oscillations with AM arbitrary signal** (0) Voloshchuk Yu.I., SPRE, vol. 1, pp. 349–359. ○ **7.4. Balanced (two-band) modulation** (0) Voloshchuk Yu.I., SPRE, vol. 1, pp. 359–367. ○ **7.5. Quadrature AM** (0) Voloshchuk Yu.I., SPRE, vol. 1, pp. 367–369. ○ **7.6. Single-band modulation** (0) Voloshchuk Yu.I., SPRE, vol. 1, pp. 369–381. • **Chapter 8. Angle-modulated signals** (0) Voloshchuk Yu.I., SPRE, vol. 1, pp. 395–485. ○ **8.2. Representation of signals with tonal CM in the time domain** (0) Voloshchuk Yu.I., SPRE, vol. 1, pp. 400–404. ○ **8.3. Spectra of signals with tonal CM** (0) Voloshchuk Yu.I., SPRE, vol. 1, pp. 404–423. ○ **8.6. Radio pulses with LCM** (0) Voloshchuk Yu.I., SPRE, vol. 1, pp. 437–452. References: 1. Voloshchuk Yu.I., SPRE, vol. 1, pp. 234–255, 297–485.
2	**MT-2.2** **Modular test (MT) on the topics:** **Approximation of VAC NE** (3 questions) [1]. **Spectral analysis in nonlinear circuits** (10 questions) [1]. A total of 13 questions. Recommended topics from Voloshchuk's textbook [1]: • **Chapter 22. Signal conversion in nonlinear RT circuits (systems)**(0) Voloshchuk Yu.I., SPRE, vol. 3, pp. 281—433. ○ **22.1. Properties of nonlinear systems** (0) Voloshchuk Yu.I., SPRE, vol. 3, pp. 282—285. ○ **22.2. Nonlinear elements of electrical circuits and their characteristics** (0) Voloshchuk Yu.I., SPRE, vol. 3, pp. 285—291. ○ **22.3. Approximation of the characteristics of nonlinear elements** (0) Voloshchuk Yu.I., SPRE, vol. 3, pp. 292—307. ○ **22.4. Transformation of the spectral composition of current in an inertia-free nonlinear resistive element** (0) Voloshchuk Yu.I., SPRE, vol. 3, pp. 307—330. ○ **22.5. Methods of spectral analysis of oscillations in circuits with inertia-free NE** (0) Voloshchuk Yu.I., SPRE, vol. 3, pp. 330—362. ○ **22.6. Main types of functional signal transformations in nonlinear systems** (0) Voloshchuk Yu.I., SPRE, vol. 3, pp. 362—377. ○ **22.7. Transformation of random processes (signals) in inertia-free nonlinear circuits** (0) Voloshchuk Yu.I., SPRE, vol. 3, pp. 377—412. ○ **22.8. Nonlinear transformation of multidimensional (vector) random variables** (0) Voloshchuk Yu.I., SPRE, vol. 3, pp. 412—420. References: 1. Voloshchuk Yu.I., SPRE, vol. 3, pp. 281—433.
3	**MT-2.3** **Modular test (MT) on the topics:** **Generation of harmonic oscillations** (13 questions) [1]. 13 questions in total. Recommended topics from Voloshchuk's textbook [1]: • **Section 24. Generation of harmonic oscillations. Self-oscillating systems** (0) Voloshchuk Yu.I., SPRE, vol. 4, pp. 3—171. ○ **24.1. Characteristics of methods for analyzing nonlinear self-oscillating systems** (0) Voloshchuk Yu.I., SPRE, vol. 4, pp. 3—8. ○ **24.2. The emergence of oscillations in an autogenerator** (0) Voloshchuk Yu.I., SPRE, vol. 4, pp. 8—25. ○ **24.3. Steady state of an autogenerator** (0) Voloshchuk Yu.I., SPRE, vol. 4, pp. 25–34. ○ **24.4. Soft and hard modes of generator operation** (0) Voloshchuk Yu.I., SPRE, vol. 4, pp. 34–54. ○ **24.5. Influence of higher harmonics on the frequency and amplitude of generator oscillations. Stability of the frequency of oscillations at the generator output** (0) Voloshchuk Yu.I., SPRE, vol. 4, pp. 54–69. ○ **24.6. Transient mode of a sinusoidal generator. Method of slowly changing amplitudes** (0) Voloshchuk Yu.I., SPRE, vol. 4, pp. 69–96. ○ **24.7. Phase plane method** (0) Voloshchuk Yu.I., SPRE, vol. 4, pp. 96—127. ○ **24.8. Some circuits of sine wave oscillators** (0) Voloshchuk Yu.I., SPRE, vol. 4, pp. 127—159. References: 1. Voloshchuk Yu.I., SPRE, vol. 4, pp. 3–171.

4	**MT-2.4** **Modular test (MT) on the topics:** **Signal detection** (3) [1]. **Modulation of oscillations** (2) [1]. 5 questions in total. Recommended topics from Voloshchuk's textbook [1]: • **Section 7. Amplitude-modulated signals** (0) Voloshchuk Yu.I., SPRE, vol. 1, pp. 334–389. ○ **7.3. Oscillations with AM arbitrary signal** (0) Voloshchuk Yu.I., SPRE, vol. 1, pp. 349–359. ▪ **Quadratic modulator** (0) Voloshchuk Yu.I., SPRE, vol. 1, pp. 357–358 ▪ **Quadratic detector** (0) Voloshchuk Yu.I., SPRE, vol. 1, pp. 358–359 ○ **7.4. Balanced (two-band) modulation with carrier suppression** (0) Voloshchuk Yu.I., SPRE, vol. 1, pp. 359–367.
	▪ **Synchronous (coherent) detection of oscillations with dual-band modulation** (0) Voloshchuk Yu.I., SPRE, vol. 1, pp. 361—367. ○ **7.5. Quadrature amplitude modulation** (0) Voloshchuk Yu.I., SPRE, vol. 1, pp. 367–369. ○ **7.6. Single-band modulation (SB)** (0) Voloshchuk Yu.I., SPRE, vol. 1, pp. 361—367. • **Chapter 8. Angle-modulated signals** (0) Voloshchuk Yu.I., SPRE, vol. 1, pp. 395–475. ○ **8.4. Generation and detection of signals with angular modulation** (0) Voloshchuk Yu.I., SPRE, vol. 1, pp. 423—431. References:

Calculation and graphical work (CGW)

The computational and graphical work (CGW) "Spectra of periodic sequences, single video pulses, and radio pulses" is performed at the end of studying Section 03 [11, pp. 31-51].

6. Independent work of the student (SS)

Students must prepare in advance for lectures, practical and laboratory classes (computer workshops). Before lectures, it is necessary to review the theoretical material provided in previous lectures. Before practical and laboratory classes (computer workshops), it is necessary to review the relevant theoretical material.

It is mandatory to complete individual assignments for computer workshops, which must be completed before the next laboratory class. To prepare for individual assignments, students should use the recommended literature and lecture notes.

To better consolidate the theoretical material, students must complete thematic and modular tests (in *the Moodle* LMS), the preparation for which requires careful review of the theoretical material from the relevant lectures during independent study hours.

Policy and control

7. Academic discipline (educational component) policy

Attendance

Attendance at lectures, practical classes, and laboratory classes is mandatory in accordance with the Regulations on the Organization of the Educational Process at Igor Sikorsky KPI. In case of illness, students are required to submit a duly completed certificate of treatment from the institution where they were treated. In other cases (e.g., family circumstances), the issue is resolved on an individual basis with the instructor. Material from classes that were missed for one reason or another must be mastered independently. To assist students, the SDN dtsp.kiev.ua contains links to video recordings of all lectures.

Missed tests

The submission of the results of simulation work, MT is mandatory. Late submission will result in a zero grade. In case of late submission for valid reasons (e.g., illness) confirmed by relevant documents, the student has the opportunity to take the test at another time agreed upon with the teacher without a grade reduction. For the purpose of self-improvement and improvement of their own results, it is permissible to retake the MT.

A missed exam will not be counted regardless of the reasons for the absence; in this case, the student will receive a "did not appear" mark and must take the exam during an additional session.

Announcement of test results

The results of independent work are entered into the Moodle LMS and announced to each student individually in person or remotely, accompanied by assessment sheets (in the Moodle LMS) in which students can see their grades according to specific criteria, as well as the main mistakes and comments on them.

The results of the written exam are indicated on the forms for the written exam (tasks performed by students) with an indication of all errors, correct or incorrect answers, as well as comments, remarks, etc. The exam can be conducted in the form of tests and tasks using the capabilities of the Moodle LMS.

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 behavior

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 ask any question regarding the procedure for conducting and/or evaluating tests and expect that it will be considered in accordance with predetermined 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.

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

Continuous assessment

Ongoing assessment is carried out during classes and aims to check the level of students' preparation for classes. During laboratory classes, students are surveyed on topics related to the subject. Modular tests are conducted twice per semester to assess residual knowledge of the most important sections of the academic discipline. Express assessments in the form of tests are conducted after each lecture.

Calendar control

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

Semester control

Semester control is considered a final test.

Assessment and control measures

1. Task completion and student ratings are tracked in the Moodle DTSP.KIEV.UA learning management system. From the first day of the course, students create personal profiles in the learning management system and gain access to all course materials, including the rules of the rating system and their own grade book.

2. The student's rating for the credit module is calculated on a 100-point scale (100% success rate)

$$R_m = R_s + R_e = 100;$$

$$R_{s\,max} = 60; R_{emax} = 40.$$

The starting rating R_s (semester component) consists of points that the student receives for:

- completing laboratory (simulation) tasks (6 assignments);
- completing modular control works (4 works);
- completion of thematic tests (1 test for each topic);
- completion of calculation and graphic assignments (1 assignment);
- additional activities.

3. Completion, formatting, and defense of reports on the completion of laboratory work (LW) (computer workshops), which provide the following performance rating points:

completion of laboratory work (computer workshop)	40%
report formatting in accordance with requirements	20
report preparation with violations	0...10
complete answer (at least 90% of the required information) during the defense of the lab report during the current or next laboratory session	40
incomplete answer (at least 60% of the required information and some errors) or untimely defense of the LW	20
answer with significant errors	10
unsatisfactory answer	0

The contribution of points for six LW to the semester component of the rating is 25%.

Completion of modular tests (MT) with manual assessment:

full answer (at least 90% of the required information)	95–100%
sufficiently complete answer (at least 75% of the required information or minor inaccuracies)	75–94%
incomplete answer (at least 60% of the required information and some errors)	60...74%
unsatisfactory answer	0...59%

Contribution to the semester component of the rating points for MT (theoretical classes) – 35%

Performing of calculation and graphic work "Spectra of periodic sequences, single video pulses, and radio pulses" (CGW) with manual evaluation:

complete answer (at least 90% of the required information)	95–100%
sufficiently complete answer (at least 75% of the required information or minor inaccuracies)	75–94
incomplete answer (at least 60% of the required information and some errors)	60...74
unsatisfactory answer	0...59

Contribution to the semester component of the CGW score rating (theoretical classes) – 15%

Contribution to the semester component of the rating points for tests and homework (practical classes) – 25%

4. The condition for *a* positive *first assessment* is to obtain a current rating of at least 50% (50 points) (provided that all M T and other planned tasks are completed by the time of assessment). The condition for *a* positive *second assessment* is to obtain a current rating of at least 50% success (50 points) (provided that all MT and other planned tasks are completed by the time of assessment).

5. The condition for admission to the exam is the completion of all laboratory work (computer practicals), calculation work, and a starting rating of at least 40% (40 points).

6. During the exam, students complete a written test. Each task contains two theoretical questions and one calculation task. The list of exam tasks is available on the MOODLE website for the discipline.

Each theoretical question is worth 30% of the maximum exam score, and the calculation task is worth 40% of the final grade.

As a result

$R_e = 2\times30 + 40 = 100\%$ of the final grade = 40 points (exam component).

7. The sum of the starting points and the points for the exam test is converted to an exam grade according to the table:

Points	Grade
100…95	Excellent
94	Very good
84	Good
74…65	Satisfactory
64	Sufficient
Less than 60	Unsatisfactory
There are uncredited modeling tasks or uncredited module test	Not admitted

Work program for academic discipline (Syllabus):

Compiled by Senior Lecturer,
Department of Radio Engineering — Oleg Pavlov
Associate Professor,
Department of Radio Engineering — Elena Guseva

Approved by the Department of Radio Engineering (Minutes No. 06/2025 dated June 23, 2025).

Approved by the Methodological Commission of the RTF (Minutes No. 06/2025 dated 26.06.2025)