

MINISTRY OF SCIENCE AND HIGHER EDUCATION OF THE RUSSIAN FEDERATION
FEDERAL STATE AUTONOMOUS EDUCATIONAL INSTITUTION OF HIGHER
EDUCATION
NORTH CAUCASIAN FEDERAL UNIVERSITY

Methodological instructions
for completing laboratory work
in the discipline "Signal and System / Сигналы и системы"
for students in the field of study
02.04.01 Mathematics and Computer Science
direction (profile)
"Training Program for Electronic Information"

Stavropol
2026

INTRODUCTION

The "Signal and System / Сигналы и системы" course is fundamental in training specialists in telecommunications, information technology, and automated control systems. In today's rapidly evolving digital environment and the increasing volume of transmitted information, a thorough understanding of the principles of data transmission, processing, and protection is particularly important. Practical and laboratory work in this course is aimed at developing students' solid theoretical knowledge and practical skills necessary for the design, analysis, and operation of modern communication networks and data transmission systems.

During their work, students will become familiar with a variety of physical data transmission environments, study the principles of signal generation and modulation, master digital and analog transmission methods, and explore the specifics of various communication technologies and standards—from traditional wired channels to satellite and radio relay systems. Particular attention is paid to practical mastery of signal measurement tools, research into the characteristics of various communication channel types, and analysis of the influence of physical factors on transmission quality.

Additionally, laboratory and practical classes will enable students to master data processing and encoding methods, become familiar with the design and operation of modems and other transmission media, and become familiar with modern data transmission technologies such as SDH, ATM, and others. Emphasis is placed on developing skills in system diagnostics and communication channel optimization, which are essential for successful professional work in telecommunications and information systems.

PRACTICAL WORK 1. SOUND SIGNAL CHARACTERISTICS

Objective of the work:

To study the basic characteristics of an audio signal, such as amplitude, frequency, phase and signal shape, as well as to become familiar with the methods of analysis and visualization of audio signals in digital information transmission systems.

Theoretical Section :

An audio signal is a mechanical vibration propagating through an elastic medium (e.g., air) and perceived by the human ear. In the context of information transmission systems, an audio signal is considered an analog signal that can be represented digitally through sampling and quantization.

The main characteristics of the sound signal are:

Amplitude is the maximum deviation of a signal from the average value, reflecting the strength (loudness) of the sound.

Frequency —the number of vibrations per unit of time (Hz)—determines the pitch of a sound. The human hearing range is approximately 20 Hz to 20 kHz.

Phase is the initial time shift of a wave relative to a reference signal. It can have an effect when multiple waves overlap.

Signal shape is a graphical representation of the dependence of amplitude on time, which determines the character of the sound (sinusoidal, triangular, sawtooth, etc.).

In data transmission systems, the audio signal must be converted to digital form using an ADC (analog-to-digital converter). This requires adherence to the Nyquist theorem: the sampling frequency must be twice the maximum frequency of the original signal.

Digital audio signal analysis can be performed using the Fourier transform, which allows one to move from the time domain to the frequency domain and determine the signal's spectral composition. A spectrogram—a graph showing the signal's spectrum changing over time—is often used for visualization.

Questions and tasks

1. What is an audio signal in terms of information transmission?
2. Define and explain the meaning of the amplitude of a sound signal.
3. How does signal frequency affect human perception?

4. What is signal phase and in what cases can its change be critical?
5. Explain the principle of converting an analog audio signal into a digital one.
6. What is the essence of Kotelnikov's theorem, and why is it important in discretization?
7. What are the differences between time and frequency domain signal analysis?
8. What is a spectrogram and how is it used?
9. Provide examples of the application of audio signal analysis in information transmission systems.

Practical tasks

Task 1. Record a short audio signal (up to 5 seconds) using a microphone and visualize its timing diagram using a software tool (e.g. Python + matplotlib or an audio editor) Audacity).

Task 2. Perform a Fourier transform of the recorded signal and plot its amplitude spectrum. Determine the dominant frequencies.

Task 3. Analyze the signal using a spectrogram. Analyze how the signal's frequency changes over time.

Task 4. Change the amplitude and frequency of the original signal, repeat the analysis and draw conclusions about the effect of parameter changes on the signal characteristics.

Task 5. Record in table form the values of amplitude, fundamental frequency, dominant harmonics and waveform for three different examples of sound signals (e.g. voice, musical note, noise).

Task 6. Answer the test questions in writing, supporting your answers with examples.

Example of a sound signal analysis table:

Signal number	Source	Amplitude (conventional units)	Frequency (Hz)	Signal form	Dominant harmonics
1	Voice	0.65	220	complex	220, 440, 660
2	Sinusoid	1.00	1000	sinusoidal	1000
3	White noise	0.40	-	random	wide range

Conclusion:

Based on the results of the laboratory work, the student should understand the basic characteristics of an audio signal, possess the skills to analyze it in both the time and frequency domains, and apply methods of visualization and interpretation of the obtained data in problems related to digital signal processing and information transmission systems.

PRACTICAL WORK #2.

CONVERTING AN AUDIO MESSAGE INTO AN ELECTRICAL SIGNAL

Objective of the work:

To study the principles of converting acoustic (sound) vibrations into an electrical signal, to understand the physical and technical principles of operation of microphone devices, types of microphones, as well as the features of processing and interpretation of the received electrical signal in information transmission systems.

Theoretical Section:

An audio message, like any other sound signal, consists of pressure fluctuations in air or another elastic medium. To transmit it over communication channels or process it in a digital system, it must be converted into electrical form. This conversion is accomplished using microphones — special devices that capture acoustic vibrations and generate an analog electrical signal corresponding to the change in sound pressure over time.

1. Microphone Operation Principle:

A microphone is based on a transducer element that responds to changes in air pressure. It can be designed in various ways, but its primary purpose is to transmit an acoustic wave to a sensitive element, which induces changes in physical properties (voltage, resistance, induction, etc.).

2. Main types of microphones:

A condenser microphone uses capacitance changes between a moving and fixed plate. It requires external power (phantom) for polarization. It is characterized by high sensitivity and recording quality.

Dynamic microphone – based on the principle of electromagnetic induction. A moving coil attached to a diaphragm moves in a magnetic field, generating a current proportional to the change in sound pressure. Durable and less sensitive, it is suitable for loud sources.

A piezoelectric microphone uses the piezoelectric effect : crystals deform under pressure, generating an electric charge. It is often used in specialized devices.

An electret microphone is a type of condenser microphone with a pre-charged dielectric. It is widely used in consumer electronics (headphones, telephones, headsets).

3. Electrical Signal Characteristics:

The signal received from the microphone is a continuous analog voltage waveform. Its amplitude, frequency, and shape correspond to the original acoustic vibrations. For transmission in digital systems, it must be digitized, which requires:

- **signal amplification** (since the amplitude of the microphone signal is small)
- **filtering** (to suppress noise)
- **sampling and quantization** (conversion to a digital stream)

4. The electroacoustic characteristics of microphones include frequency response, sensitivity, directivity, self-noise level, dynamic range and other parameters.

5. Information Transmission Systems

The electrical signal, converted from audio, can then be used in analog or digital communication channels. In analog systems, it is amplified and transmitted directly. In digital systems , it is converted using an ADC and transmitted as a bit sequence.

Practical tasks

Task 1. Study the design and operating principles of three types of microphones: condenser, dynamic, and electret. Write a brief description, highlighting their advantages and disadvantages.

Task 2. Record an audio message using an electret microphone and save the file in .wav format . Record the recording parameters: sampling frequency, bit depth , and duration.

Task 3. Using software (e.g. Audacity or Python), visualize the shape of the received signal and analyze its amplitude, noise level, and frequency response.

Task 4. Amplify the microphone signal using an analog or digital amplifier. Compare the signal waveforms before and after amplification.

Task 5. Compare recordings obtained using two different types of microphones (e.g., electret and dynamic). Evaluate the differences based on the following criteria: signal clarity, presence of noise, and amplitude range.

Task 6. Construct a table of comparative characteristics of different microphones.

Example table:

Microphone type	Operating principle	Sensitivity	Direction	Application	The need for nutrition
Capacitor	Change in capacity	High	Cardioid	Studio recording	Yes (phantom)
Dynamic	Electromagnetic induction	Average	Cardioid	Stage work	No
Electret	Permanently charged dielectric	Average	Comprehensive	Headsets, mobile devices	Yes

Questions and tasks

1. Why is it necessary to convert an audio signal into an electrical signal?
2. What is the difference between analog and digital forms of signal representation?
3. Describe the basic physical principles of operation of different types of microphones.
4. How is a weak microphone signal amplified?
5. When is it better to use a condenser microphone and when is it better to use a dynamic microphone?
6. Explain the importance of filtering a signal when recording it.

7. What recording parameters are most important for high-quality conversion of an audio message?
8. What is a microphone's frequency response and how does it affect recording quality?
9. What technical problems may arise during signal conversion and transmission?
10. Provide examples of practical use of knowledge of this topic in telecommunications, radio, video communications and information security.

Conclusion:

By completing this lab, students gain an understanding of the process of converting an acoustic signal into an electrical one, become familiar with the design features of microphone devices, and study methods for analyzing the received signal. Knowledge of these principles is critical for the design, debugging, and operation of modern information transmission systems, where audio signals are the primary data carrier.

PRACTICAL WORK #3.

SIGNAL TRANSMISSION OVER A DIGITAL COMMUNICATION CHANNEL

Objective of the work:

To study the principles of information transmission over a digital communication channel, to understand the stages of signal conversion before transmission, methods of protecting and restoring transmitted information, as well as to master the basic characteristics of digital channels and parameters affecting the quality of data transmission.

Theoretical Section:

Signal transmission over a digital communication channel is the process of delivering a sampled (digitized) message from a source to a receiver using a specific protocol and medium. Unlike analog channels, digital transmission uses a finite set of symbols (usually binary: 0 and 1) and offers increased resistance to interference, signal recovery, and high data transfer rates.

1. Stages of digital signal transmission:

Analog-to-digital conversion (ADC):

A primary analog signal (e.g., audio) is converted into digital form using sampling, quantization, and encoding.

Sampling is dividing the signal by time,

quantization is approximating the amplitude values to the nearest acceptable level,

and encoding is representing each level as a binary code.

Formation of a digital stream:

Digitized information is packed into packets or frames, to which service data is added: headers, checksums, sequence numbers.

Modulation:

To transmit digital data over a physical medium, it can be modulated: the characteristics of the carrier wave (frequency, phase, amplitude) are changed depending on the bit value. Common methods: OOK, FSK, PSK, QAM.

Physical transmission:

Transmission occurs via wired (twisted pair, coaxial cable, fiber optic) or wireless channels (radio waves, IR channels). Connection quality depends on bandwidth, interference, distortion, and delays.

Demodulation and processing:

At the receiving end, the signal is demodulated, checked and error corrected, and then restored to its original digital or analog form.

2. Characteristics of the digital channel:

Throughput is the maximum number of bits transmitted per unit of time.

Data rate is the actual number of bits per second.

Latency is the time it takes for a signal to travel from the source to the receiver. Bit

Error Rate (BER) is the proportion of bits transmitted incorrectly.

Reliability and stability are the degree to which a channel is susceptible to external factors.

3. Information protection methods:

Error checking and correction: checksums (CRC), Hamming codes, redundancy coding.

Encryption: protection from unauthorized access (e.g., AES, RSA).

Retransmission and acknowledgement: resending damaged packets.

4. Examples of digital channels:

Ethernet , Wi-Fi , fiber optic lines, 3G/4G/5G networks, Bluetooth , ZigBee , satellite digital communications.

Practical tasks

Task 1. Study the ADC process and demonstrate it with an example: digitize an analog audio signal , determine the sampling frequency and quantization depth.

Task 2. Plot a graph of the sampled and quantized signal. Compare it with the original analog form and analyze the loss of accuracy.

Task 3. Using software (e.g., MATLAB, Python), simulate the transmission of a digital signal through an ideal and noisy channel. Determine the percentage of distortion.

Task 4. Implement a simple method for encoding and recovering errors in a digital message (for example, using a checksum or Hamming code).

Task 5. Investigate the impact of bandwidth and data rate on channel latency and reliability. Build a dependency table.

Example table:

Transfer speed (Mbps)	Bandwidth (Mbps)	Average latency (ms)	BER (%)
10	8	120	0.05
100	90	30	0.02
1000	950	5	0.005

Questions and tasks

1. Describe the process of converting an analog signal to digital.
2. What is the difference between modulation and coding?
3. What effect does sampling frequency have on signal accuracy?
4. What methods are used to detect and correct errors in data transmission?
5. What is the advantage of a digital channel over an analog one?
6. Why is it important to control the channel error rate?
7. What parameters influence the quality of digital transmission?
8. Provide examples of real digital communication channels and describe their features.
9. How is digital signal integrity and security ensured?
10. What difficulties may arise when transmitting digital information in conditions of strong electromagnetic interference?

Conclusion:

During this course, students gain a practical understanding of the digital data transmission process, including its technical and software aspects. Key concepts are explored: sampling, coding, modulation, demodulation, channel capacity, and reliability. This knowledge is applied in the design of modern telecommunications systems, network development, security systems, and digital data processing.

PRACTICAL WORK #4.

WIRED ENVIRONMENT. STUDY OF PHYSICAL PARAMETERS AND FEATURES OF TRANSMISSION IN CABLES

Objective of the work:

Study of the physical characteristics of wired information transmission media, analysis of the main types of cables, research of their parameters and factors influencing the quality of signal transmission in telecommunication systems.

Theoretical Section:

A wired communication medium is the physical medium through which electrical signals are transmitted from a transmitter to a receiver. The main types of wired channels are twisted pair, coaxial cable, and fiber optic cable. Each of these types has its own properties, advantages, and limitations, which determine their areas of application.

1. Types of wire cables

Twisted pair (Twisted Pair :

The most widely used cable type, consisting of pairs of insulated conductors twisted together. Twisting reduces electromagnetic interference. There are two main types: UTP (unshielded twisted pair) and STP (shielded twisted pair).

Coaxial cable:

Consists of a central conductor surrounded by insulation, a metal braid, and an outer jacket. It has good interference protection and is used to transmit high-frequency signals, such as in television systems and early Ethernet networks .

Fiber optic cable:

Transmits data using light guided through a glass or plastic core. It offers high bandwidth, minimal signal loss, and complete immunity to electromagnetic interference. It is classified as single-mode or multimode fiber.

2. Physical parameters of wire cables

Resistance (R):

Determines energy loss in the form of heat. Depends on the conductor material, its length, and cross-section.

Inductance (L):

Affects the line's ability to withstand current changes. Can cause signal distortion at high frequencies.

Capacitance (C):

Occurs between conductors and determines the discharge rate. Affects signal attenuation, especially over long distances.

Attenuation : The decrease

in signal amplitude with distance. Dependent on the signal frequency and the line length.

Impedance (Z):

The total resistance of a line to alternating current. For optimal signal transmission, the impedances of the transmitter, cable, and receiver must be matched.

3. Influence of the external environment and transmission factors

Signal transmission over a wired line can be affected by external factors:

Electromagnetic interference (from household appliances, power lines);

Crosstalk – the influence of one signal on another in an adjacent pair;

Temperature fluctuations – change the conductor parameters (especially resistance);

Mechanical damage and bends in the cable – affect signal attenuation and integrity.

4. Features of using different types of cables

Twisted pair – used in local area networks (Ethernet), telephone communications;

Coaxial – used in video surveillance, cable television, and some older network standards;

Fiber optic – indispensable for trunk lines, high-speed channels, and long-distance data transmission.

5. Main characteristics and comparative analysis

Cable type	Bandwidth	Protection against interference	Transmission range	Price
Twisted pair (UTP)	Up to 10 Gbps (Cat6/7)	Average	Up to 100 m	Low
Coaxial cable	Up to 1 Gbps	High	Up to 500 m	Average
Fiber optic	Up to 100 Gbps and above	Very high	Up to 100 km and more	High

Practical tasks

Task 1. Study the physical structure of cables: twisted pair, coaxial, and fiber optic. Draw their structure and highlight key elements.

Task 2. Measure the length and resistance of a twisted pair sample. Calculate the resistance using the formula:

$$R = \rho \cdot \frac{L}{S}$$

where ρ is the resistivity of copper, L is the length, S is the cross-sectional area.

Task 3. Using a generator and oscilloscope, examine signal attenuation along a section of coaxial cable. Record the signal amplitude before and after passing through the cable.

Task 4. Compare the signal attenuation during data transmission through twisted pair and fiber optic cable using a lab kit or emulation in a software environment (e.g. Cisco Packet Tracer, MATLAB Simulink).

Task 5. Investigate the effect of external electromagnetic interference on signal transmission. To do this, place a switched-on electrical appliance near the cable and record the change in signal.

Questions and tasks

1. What types of cables are used in modern telecommunication systems?
2. What is the difference between shielded and unshielded twisted pair?
3. Why are fiber optic lines used to transmit data over long distances?
4. How does increasing signal frequency affect attenuation in copper cables?
5. What is impedance and what is its importance in cable design?
6. What measures are taken to reduce the impact of electromagnetic interference?
7. When is coaxial cable preferable to twisted pair?
8. Why is it important to measure cable resistance before use?
9. What parameters should be considered when choosing a cable type for a local network?
10. How can the external environment (temperature, humidity) affect cable performance?

Conclusion:

During the lab, students became familiar with the main types of wire cables, examining their internal structure and physical characteristics. Resistance and attenuation measurements were conducted, and the effect of interference on signal transmission quality was investigated. The knowledge gained will enable future specialists to intelligently select and design cable communication systems that ensure reliable and high-quality data transmission.

PRACTICAL WORK #5.

MODEMS FOR DIGITAL COMMUNICATION CHANNELS

Objective of the work:

To study the operating principles of modems used to transmit information over digital communication channels, to become familiar with the types of modulation, and to study the characteristics of modems and their role in data transmission systems.

Theoretical Section:

A modem (modulator-demodulator) is a device that converts a computer's digital signal into a form suitable for transmission over a communication channel, and vice versa. In digital channels, modems are most often used to adapt the signal to the characteristics of the communication line, improve noise immunity, ensure synchronization, and increase transmission efficiency.

Unlike modems used for analog telephone lines, modems for digital channels handle digital signals at all stages of processing, ensuring higher speed and reliability. They are widely used in data networks, DSL, fiber optic channels, cellular communications, and other areas.

Classification of modems for digital channels

modulation type : Modulation is the process of superimposing an information signal onto a carrier wave. The following types are used:

ASK (amplitude shift keying): simple but vulnerable to noise.

FSK (frequency shift keying): noise-resistant, used in older models.

PSK (phase shift keying): highly efficient, used in modern modems.

QAM (quadrature amplitude modulation): combines amplitude and phase modulation to increase speed.

2. By purpose and area of application:

DSL modems – for broadband access via a telephone line.

Cable modems – for transmission over a coaxial network.

Fiber optic modems – convert electrical signals into optical signals and vice versa.

GSM/3G/4G modems – for mobile network access.

Satellite modems – provide communications via satellite.

3. By installation method:

Built-in (integrated into routers, boards); External (connected via USB, Ethernet);

Virtual (software modems in emulators and virtualization systems).

Main characteristics of modems

Data transfer speed: measured in bits per second (bps) . Modern modems provide speeds from 56 kbps (older ones) to tens of gigabits per second.

Modulation type: determines the noise immunity and spectrum of the occupied band.

Error correction protocols: allow detection and correction of errors during transmission.

Synchronization: Ensures precise alignment between the receiver and transmitter.

Standards support: modern modems must comply with ITU-T, IEEE and other standards.

How a digital modem works

Data transfer includes the following stages:

1. Receiving digital data from a source (computer).
2. Modulation of a signal to prepare it for transmission.
3. Sending a signal over a communication channel.
4. Reception of signal on the recipient's side.
5. Demodulation is the restoration of original information.
6. Transmission of the recovered signal to the receiver.

Advantages of modems in digital channels

High transmission speed;

Support for reliable error correction algorithms; Compact size and energy efficiency ;

Ability to operate over long distances with minimal losses; Integration with modern network technologies.

Practical tasks

Task 1. Review the technical specifications of the modem available in the lab. Determine what modulation types it supports, its maximum transmission speed, and what interfaces are used for connection.

Task 2. Establish a connection between two computers via a digital modem. Transfer a test file, measure the transfer speed and check for errors. Draw conclusions about the stability of the connection.

Task 3. Using emulator software (for example, Cisco Packet Tracer), simulate a modem connection and analyze the signal flow. Change the modulation type and compare the system's behavior under different conditions (interference, speed).

Task 4. Compare two types of modems (for example, DSL and LTE) based on the following parameters: bandwidth, connection type, modulation, signal delay, and resistance to interference.

Task 5. Review the documentation for the modem used in your lab or classroom network. Determine which standards it supports (e.g., V.92, ADSL2+, LTE Cat4, etc.). Prepare a brief report.

Questions and tasks

1. What is a modem? What are its main functions in a digital channel?
2. What types of modulation are used in modern digital modems?
3. What is the difference between a DSL and a cable modem?
4. Why do modems use error correction protocols?
5. What parameters influence the choice of a modem for a home or corporate network?
6. How does the demodulation process occur?
7. What types of interference most often affect the operation of modems?
8. In what conditions is it preferable to use a fiber optic modem?
9. What is the purpose of QAM modulation?
10. What standards define the operation of digital modems?

Conclusion:

During the lab, students learned about the design and operating principles of modems used in digital communication channels. Particular attention was paid to modulation types and characteristics affecting transmission efficiency. This knowledge will enable students to make informed decisions about equipment selection for networks of various sizes and effectively use modems in telecommunications systems.

PRACTICAL WORK #6. WIRELESS ENVIRONMENT

Objective:

To study the characteristics of wireless communication environments, the main characteristics and parameters of wireless channels, and the operating principles of various types of wireless networks. To analyze the impact of environmental factors on communication quality and reliability.

Theoretical Section :

Wireless is a medium in which signals are transmitted without the use of wired connections, using electromagnetic waves. This enables mobile, flexible, and scalable communications in a wide variety of settings—from home and corporate networks to metropolitan and global communications systems.

Wireless transmission of information occurs in various frequency ranges, ranging from a few kilohertz to gigahertz, depending on the technology. The main types of waves used in wireless transmission are radio waves, microwaves, infrared radiation, and light.

Main technologies of wireless data transmission:

Wi-Fi (IEEE 802.11) – used to create local wireless networks. It operates at 2.4 GHz and 5 GHz frequencies. It provides transmission speeds ranging from several tens to several hundred Mbps, depending on the standard.

Bluetooth (IEEE 802.15.1) – used for short-range data transfer between devices. It's used in peripherals, headphones, gadgets, and more.

Cellular communications (GSM, 3G, 4G, 5G) – used to transmit voice and data over mobile networks. Provides broad coverage and high-speed internet access.

WiMAX (IEEE 802.16) is a broadband access technology, including for rural and remote areas.

Infrared (IRDA) systems are obsolete, limited in range and require line of sight.

Satellite communications are used for communications in hard-to-reach regions, maritime and aviation communications, and backup channels.

Advantages of wireless environment:

User mobility and flexibility in network construction

No cable installation costs Fast network scalability Convenience of connecting new devices

Disadvantages and limitations:

Susceptibility to interference and signal distortion

Limited coverage and transmission speeds Dependence on weather conditions (for some bands)

Vulnerability to interception and the need for data encryption

Physical characteristics of wireless transmission:

Signal strength – the farther from the transmitter, the weaker the signal.

Transmission frequency – affects range and the ability to penetrate obstacles.

Bandwidth – determines the amount of information transmitted.

Signal attenuation – is related to distance, obstacles, and absorption.

Interference – interference from other devices on the same frequencies.

Types of wireless networks:

PAN (Personal Area Network) – on short distance , Bluetooth, ZigBee .

LAN (Local Area Network) – Wi-Fi in offices , homes .

MAN (Metropolitan Area Network) – WiMAX, networks For cities or campus .

WAN (Wide Area Network) – mobile communications, satellite communications.

Practical tasks

Task 1.

Explore the parameters of the wireless Wi-Fi network using special software (for example, inSSIDer , WiFi Analyzer). Determine the signal level, noise, channel, frequency, and transmission speed. Record the obtained data in a table.

Parameter	Meaning
Network name (SSID)	example_network
Channel	6
Frequency	2.437 GHz
Signal level	-45 dBm
Speed	144 Mbps

Task 2.

Conduct a connection quality test at different distances from the access point. Measure the signal strength and download/upload speeds. Draw conclusions about the impact of distance and obstacles.

Task 3.

Review the parameters of your PC's wireless adapter. Determine the supported standards, antenna type, sensitivity, and transmitter power.

Task 4.

Set up a wireless connection between two devices via Bluetooth . Transfer a file and measure the transfer time. Assess the connection efficiency and potential interference.

Task 5. Create

a Wi-Fi access point placement plan for a classroom or room, taking into account coverage and minimizing areas with low signal strength. Justify your choice of installation locations.

Questions and tasks

1. What is wireless transmission medium?
2. What frequency bands are used in Wi-Fi ? How do they affect speed and range?
3. What is the difference between Bluetooth and Wi-Fi ?
4. What factors cause signal attenuation?
5. Which type of wireless network provides the most coverage?
6. Why is it necessary to encrypt traffic on a wireless network?
7. What is interference? How can it be dealt with?
8. What methods do you know for increasing communication reliability in a wireless environment?
9. Why might signal deterioration occur in buildings with concrete walls?
10. What precautions should be taken when designing a secure Wi - Fi network?

Conclusion:

During the lab, students studied the characteristics of the wireless environment, its performance, and the impact of various factors on signal transmission quality. The knowledge gained will enable them to more effectively design, configure, and maintain wireless networks, taking into account physical limitations and security requirements.

PRACTICAL WORK #7.**RADIO RELAY LINES****Objective:**

To study the design principles, characteristics, and operational features of radio relay communication lines (RRL), and their role in modern information transmission systems. To gain practical understanding of radio channel parameters and factors affecting their reliability and performance.

Theoretical Section:

Microwave radio links are a type of wireless communication in which data is transmitted via radio waves between antennas located at a certain distance from each other. These links enable medium- and long-distance communication without the use of cables, with the signal transmitted by line of sight from the transmitting to the receiving station.

A typical radio relay line consists of successive sections (relay sections), each of which includes a transmitter, receiver, and antenna. If line-of-sight distance is exceeded, intermediate relay stations are used to amplify or restore the signal.

Main parameters of the RRL:

Operating frequency range. Radio relay lines operate in the microwave range—from 1 GHz to 40 GHz; the most commonly used ranges are 6, 11, 18, and 23 GHz.

Bandwidth. Determines the maximum possible data transfer rate. Modern microwave links provide tens and hundreds of Mbps, and in some cases, up to several Gbps.

Transmission range. Typically 30 to 50 km between stations, limited by line-of-sight conditions and the Earth's curvature.

Antenna Gain. Directional parabolic antennas with high gain (30–40 dB) are used to minimize signal loss.

Modulation type. QAM (quadrature amplitude modulation), PSK (phase shift keying), and their variations are frequently used.

A typical RRL circuit includes:

- digital source (data/voice),
- radio transmitter with modulator,
- waveguide/coaxial cable,
- antenna,
- receiver with demodulator,
- digital signal processing and routing equipment.

Factors affecting the reliability and quality of radio relay links:

Line of sight is a key requirement for radio link operation. Obstacles (buildings, terrain, trees) can interfere with or completely block the signal.

Atmospheric phenomena. Precipitation, fog, and inversion, especially in bands above 10 GHz, can reduce signal strength.

Interference. Adjacent lines or equipment operating on the same frequencies may interfere with each other.

Antenna terrain and height. When designing, consider the Fresnel zone—the area around the direct signal path that must be kept clear of obstacles.

Redundancy and fault tolerance. Critical lines are duplicated, ring circuits are used, and automatic switching to a backup channel is provided.

Areas of application of microwave radio lines:

- trunk communication channels of telecom operators;
- communication between base stations of a mobile network;
- connection of remote objects (towers, weather stations, industrial enterprises);
- backup lines for cable networks.

Advantages of microwave radio:

- high transmission speed;
- independence from cable infrastructure;
- flexibility and rapid deployment ;
- wide coverage area.

Disadvantages:

- Requires line of sight;
- Impact of weather conditions;
- Limited bandwidth compared to fiber optics;
- Requires complex route design.

Practical tasks

Task 1.

Based on a terrain map and the given point coordinates, select a possible route for laying a 100-km radio relay line. Determine how many relay stations will be required, taking into account range limitations and terrain.

Task 2.

Using an online radio relay line calculator (for example, Radiolinks Calculator) calculate the Fresnel zone and the required antenna height for two communication points at a distance of 40 km from each other at an operating frequency of 18 GHz.

Task 3.

Simulate signal strength as a function of distance with fixed transmitter power and antenna characteristics. Plot a graph of signal strength versus distance.

Task 4.

Review the documentation for radio relay equipment (e.g. Huawei , NEC, Ceragon) and create a comparative table of the main technical characteristics: frequency range, power, transmission speed, modulation type.

Task 5.

Develop a redundancy scheme for a radio relay network for an industrial facility, taking into account fault tolerance and minimum communication restoration time.

Questions and tasks

1. What is a radio relay communication line and what is its main difference from other types of communication?
2. What frequency range do radio relays operate in?
3. What are the reasons for limiting the distance between RRL stations?
4. Explain the concept of the Fresnel zone. Why is it important to consider it in design?
5. What weather conditions have the greatest impact on the quality of the radio relay signal?
6. What is interference and how can it be avoided in radio relay communications?
7. List the main methods for increasing the reliability of radio relay channels.
8. What are the advantages of using microwave radio systems compared to cable systems?
9. What modulation technologies are most commonly used in radio relay?
10. Describe an example of using radio relay communication in the absence of optical infrastructure.

Conclusion:

Radio relay communication lines play a vital role in building flexible and reliable data transmission channels, especially in environments where cable is impossible or economically unfeasible. This lab examined the basic principles of their operation, the parameters and factors affecting their efficiency, and the methods for calculating and designing such systems. The knowledge gained can be applied in building corporate and operator communication networks.

PRACTICAL WORK #8.**SATELLITE COMMUNICATIONS****Objective:**

To study the principles of satellite communications, its architecture, orbit types, and data transmission channels. To acquire skills in analyzing satellite channel parameters and understanding their role in global and regional information transmission systems.

Theoretical Section:

Satellite communication is a type of wireless communication in which data is transmitted via artificial satellites in various orbits around the Earth. These satellites serve as repeaters, receiving the signal from a ground station, amplifying it, and transmitting it further to another satellite or ground station. This technology enables communication over long distances, including remote and inaccessible areas.

Classification of communication satellites by orbits:

Geostationary satellites (GEO) are located at an altitude of approximately 35,786 km above the equator. They "hover" over a single point on the Earth's surface, providing continuous coverage. They are used for television broadcasting, communications, and meteorology.

Medium-Earth Orbit (MEO) satellites are located at altitudes of 2,000–20,000 km. They are used, for example, in navigation systems (GPS, GLONASS).

Low-Earth Orbit (LEO) satellites – altitude 200–2000 km. Used for broadband access systems (Starlink , OneWeb), as well as Earth observation.

The main components of a satellite communication system:

Space segment. These are the satellites themselves, equipped with receiving and transmitting equipment and antennas.

Ground segment. This includes earth stations (hubs , terminals), antennas, switching equipment, and control centers.

Communication channels. These are determined by frequency ranges. The most common are:

- C-band (4–8 GHz),
- Ku -band (12–18 GHz),
- Ka -band (26.5–40 GHz),
- L-band (1–2 GHz, used in navigation).

Features of satellite communications:

Signal latency. In geostationary orbit, latency can reach 500–600 ms , limiting its use in voice communications and online gaming.

Weather conditions. Precipitation and cloud cover can affect signal quality, especially in high-frequency bands.

Cost. Launching satellites and operating a network requires significant investment, but with extensive coverage, they become an effective solution.

Types of satellite communication services :

- fixed satellite communication (between stationary objects);
- mobile satellite communication (sea vessels, aviation, automobiles);
- broadband Internet access;
- broadcasting (television, radio);
- monitoring and telemetry;
- navigation and positioning systems.

Modern satellite systems:

- **Starlink (SpaceX)** – a low-orbit system for providing internet access worldwide.
- **OneWeb** – a competing global system.
- **Inmarsat , Iridium** – mobile communications and navigation.
- **Gonets, Express (Russia)** – telecommunications satellites.
- **Intelsat , Eutelsat** – broadcasting and corporate communications.

Table: Comparison of satellites by orbit type

Parameter	LEO	MEO	GEO
Orbital altitude	200–2000 km	2000–20,000 km	35,786 km
Turnaround time	90–120 min	6–12 hours	24 hours
Signal delay	30–50 ms	100–200 ms	500–600 ms
Coating	Local	Regional	Global (one point)
Number of satellites	Hundreds-thousands	Dozens	3–5
Access cost	Average	High	Low for broadcasting

Practical tasks

Task 1.

Research the parameters of geostationary satellite communications. Determine the signal transmission delay between two points on Earth via a GEO satellite, taking into account the orbital altitude. Calculate the signal path and compare it with a similar fiber optic communication channel.

Task 2.

Conduct a simulation of data transmission through a satellite network using software (e.g. Cisco Packet Tracer or NetSim). Build a diagram: sending a signal from ground station A to station B via satellite. Analyze losses and delays.

Task 3.

Research the structure and characteristics of the Starlink and OneWeb systems . Compare the

number of satellites, orbital altitudes, access speeds, and coverage areas. Prepare a brief report in the form of a table or infographic .

Task 4.

Calculate the radio visibility zone of a geostationary satellite with a latitude of 0° and a longitude of 60° E. Determine which regions of the world it covers and which it does not.

Task 5.

Analyze the effect of atmospheric conditions on the Ku- and Ka -band signal. Plot a graph of the signal strength versus precipitation intensity using a 0.9-meter-diameter satellite dish.

Questions and tasks

1. What is satellite communication and how is it implemented?
2. What is the difference between LEO, MEO and GEO satellites?
3. Why is satellite communication subject to delays?
4. What frequency range is most commonly used for satellite internet?
5. What are the advantages of low-orbit satellites over geostationary satellites?
6. Name the main companies providing satellite communications services.
7. What is the ground segment of a satellite network?
8. What types of antennas are used to receive satellite signals?
9. How do weather conditions affect the quality of satellite communications?
10. For what purposes is satellite communication indispensable?

Conclusion:

During the lab, the fundamental principles of satellite communications, satellite classification, system architecture, and data transmission channel parameters were explored. The advantages and limitations of various orbit types were discussed, as well as modern solutions for global satellite internet. The practical assignment reinforced the understanding of satellite channel parameters and the specifics of their application in modern telecommunications systems.

**PRACTICAL WORK #9.
GEOSTATIONARY SATELLITE**

Objective:

To study the operating principles of geostationary satellites, their orbital positions, physical parameters, coverage characteristics, and application in communications systems. To acquire practical skills in analyzing geostationary satellite communication parameters and calculating radio visibility zones.

Theoretical Section:

A geostationary satellite (GEO) is a satellite in a circular orbit above the Earth's equator at an altitude of approximately 35,786 km, rotating at the same angular velocity as the Earth. This allows the satellite to "hover" over a fixed point on the equator, providing continuous communications with a specific part of the Earth's surface.

This type of orbit is widely used in telecommunications, meteorology, television broadcasting, and global navigation and weather satellite systems. Geostationary satellites provide broad coverage (up to 40% of the Earth's surface), but require a clear line of sight and proper installation of receiving equipment.

Main characteristics of a geostationary satellite:

Orbital altitude: 35,786 km

Orbital period: 24 hours

Latitude: 0° (above the equator)

Rotation speed: matches the Earth's rotation

Coverage area: approximately a third of the Earth's surface

Frequency ranges: C, Ku, Ka, X, etc.

Advantages: stable communication, no need for antenna tracking

Disadvantages: high signal latency, limited coverage, sensitivity to atmospheric phenomena

The operating principle of a GEO satellite:

A geostationary satellite receives a signal from a ground station, amplifies it, modulates it, and transmits it toward the target receiver. Because it is stationary relative to the ground, user antennas can be rigidly mounted and do not require automatic satellite tracking.

Applications of GEO satellites:

- Television and radio broadcasting
- Mobile and fixed satellite communications
- Data transmission (Internet, corporate networks)
- Meteorology (e.g. GOES satellites)
- Military communications and intelligence

Calculation of parameters:

1. Geostationary orbit radius (R):

$$R = R_{\oplus} + h$$

where $R_{\oplus} \approx 6371$ km (Earth's radius), $h = 35,786$ km $\rightarrow R = 42,157$ km

2. Length of the horizon arc (visibility range):

Estimated maximum observation latitude for a ground station: $\approx 81^\circ$ from the equator
Maximum distance to a receiving station on the surface: $\approx 17,000$ km

Table: Comparison of geostationary and low-orbit satellites

Characteristic	GEO	LEO
Orbital altitude	$\sim 35,786$ km	200–2000 km
Turnaround time	24 hours	90–120 minutes
Coverage area	$\sim 1/3$ of the Earth's surface	Local zone
Signal delay	500–600 ms	30–50 ms
Number of satellites	3 for global coverage	hundreds or thousands
Ground equipment	Stationary	Mobile with tracking
Type of service	TV, fixed-line communications	Internet, monitoring, IoT

Practical tasks

Task 1.

Calculate the round-trip delay for a signal traveling from a ground station to a satellite and back using a GEO satellite. Assume the speed of light in a vacuum is 3×10^8 m/s.

Task 2.

Construct a radio visibility diagram for a geostationary satellite located above 30°E . Determine which regions of Europe, Africa, and Asia are within the coverage area.

Task 3.

Study and describe the architecture of one of the operating geostationary satellites (e.g., Express-AM8 or Intelsat 35e). Indicate its purpose, coverage area, frequency range, and antenna characteristics.

Task 4.

Compare the internet connection schemes using a geostationary satellite and a fiber-optic communication line. Determine under which conditions the use of a satellite is more appropriate.

Task 5.

Simulate the reception of a signal from a geostationary satellite in the Network program Simulator or Packet Tracer. Create a server-satellite-client diagram. Configure the channel's latency and bandwidth parameters.

Questions and tasks

1. How is geostationary orbit different from other orbital configurations?
2. How is the altitude of the geostationary orbit calculated?
3. What are the advantages and limitations of a GEO satellite?
4. Explain why antennas for receiving signals from a GEO satellite can be installed permanently.
5. What frequency bands are most commonly used in geostationary communications?
6. Why is geostationary communication not suitable for low latency applications (e.g. online gaming)?

7. What is a satellite's "radio visibility zone" and how is it determined?
8. How many satellites are needed to completely cover the Earth's surface using GEO orbit?
9. Provide examples of commercial and government programs for the operation of geostationary satellites.
10. What atmospheric phenomena can affect the Ku -band signal ?

Conclusion:

The lab covered the operating principles of geostationary satellites, their physical parameters, and applications. Particular attention was paid to calculating signal delays, coverage areas, and frequency ranges. Practical exercises provided a better understanding of satellite system architecture and their role in the modern digital world, particularly in the context of global broadcasting, communications, and meteorological observations.

PRACTICAL WORK #10.

PDH (PLESIOCHRONOUS) TECHNOLOGY DIGITAL HIERARCHY)

Objective of the work:

Study of the principles and architecture of PDH technology, understanding of its role in digital telecommunication networks, mastering the basic methods of transmission and multiplexing of digital information flows in networks with non-uniform synchronization.

Theoretical part

of PDH technology (Plesiochronous Digital Plesiochronous digital hierarchy (also known as approximately synchronous digital hierarchy) is a digital data transmission method used to multiplex and transmit information at various levels in telecommunications networks. The term " plesiochronous " indicates that the data streams transmitted within the system operate at nearly the same, but not perfectly synchronized, frequency.

PDH was developed to combine multiple low-speed digital channels into higher-speed streams for efficient data transport over telecommunications lines. This technology was long the basis for wide-area data networks until the advent of more modern standards such as SDH (Synchronous Data Distribution). Digital Hierarchies).

The main PDH levels reflect the hierarchy of digital streams, where each level combines several streams from the previous level. In Europe and most countries, the E- carrier (European PDH) standard was used , while in the US and Japan, the T- carrier (American standard) was used.

Main characteristics of PDH:

- The use of multiple clock generators with close frequencies (plesiochronous), which requires compensation for desynchronization
- Multiplexing using complex redundant bit insertion procedures for synchronization
- Standard speeds: 2 Mbps (E1), 8 Mbps (E2), 34 Mbps (E3), 140 Mbps (E4)
- Multiplexing protocols and methods for combining channels of different speeds
- Lack of strict synchronization between different network elements, which complicates management and maintenance

Structure and levels of PDH

PDH uses a hierarchical aggregation principle: low-speed channels are combined into higher-speed streams. The core element is the E1 stream (2.048 Mbps), which consists of 32 time intervals (time slots), each of which carries a separate voice or data channel.

Next, E1 streams are combined into E2, then E3, and so on. Each subsequent combination adds additional control bits for synchronization and error control, resulting in a complex multiplexing structure.

Differences between the European (E- carrier) and American (T- carrier) systems:

In Europe, the primary stream is E1 with 2.048 Mbps, while in the US, it's T1 with 1.544 Mbps. Both standards implement a hierarchy, but with different speeds and formats.

Advantages of PDH:

- Long service life and widespread use
- Support for multiple simultaneous channels in one stream
- Reliability and immunity to transmission errors

Disadvantages of PDH:

- Difficulty managing desynchronization between elements
- Inconvenience for maintenance and diagnostics due to the lack of a unified synchronization system
- Limitations in scalability and transmission speed, compared to more modern SDH/SONET

Practical tasks**Task 1.**

Calculate the number of voice channels that can be transmitted over one E3 stream (34.368 Mbps) if each voice channel takes up 64 kbps.

Task 2.

Draw a diagram of the PDH hierarchy for 140 Mbps transmission, indicate the number of combined streams of each level (E1, E2, E3, E4) and allocate time slots for voice channels.

Task 3.

Investigate the effect of clock frequency desynchronization on data transmission in PDH. Describe the method of inserting redundant bits to compensate for desynchronization (stuffing). bits).

Task 4.

Compare PDH and SDH by the following parameters: synchronization, speed, scalability, network management, maintenance complexity.

Task 5.

Simulate the multiplexing of four E1 streams into an E2 stream using specialized software or the MATLAB package. Trace the process of inserting additional bits and identify the points where desynchronization occurs .

Questions and tasks

1. What does the term “ plesiochronous ” mean and how does it manifest itself in PDH technology?
2. What are the main levels and data rates in PDH?
3. Why is it necessary to insert redundant bits when multiplexing in PDH?
4. How does PDH cope with desynchronization between different network elements?
5. What are the main differences between PDH and SDH?
6. What are the challenges in maintaining and scaling PDH networks?
7. Under what conditions is the use of PDH still relevant today?
8. Describe the structure of one E1 flow and the distribution of time slots.
9. How do PDH standards differ in Europe and the US?
10. How can transmission quality be improved in networks using PDH?

Conclusion:

This lab provided a detailed examination of the design and operating principles of PDH technology—a key technology for the digital data hierarchy, which dominated telecommunications for several decades. Particular attention was paid to understanding multiplexing methods, desynchronization compensation , and the structure of the stream hierarchy. The knowledge gained will allow one to understand the limitations of this technology and the reasons for the transition of modern networks to more advanced standards, such as SDH and Optical. Transport Network (OTN). Practical exercises helped reinforce theoretical concepts and develop skills in modeling digital stream multiplexing.

PRACTICAL WORK #11.**SYNCHRONOUS DIGITAL HIERARCHY (SDH)****Objective of the work:**

Study of the architecture, operating principles and main characteristics of SDH technology (Synchronous Digital Hierarchy), development of methods for organizing and managing digital flows in modern telecommunication networks based on synchronous transmission.

Synchronous

Digital Hierarchy (SDH) is an international digital data transmission standard developed to address the challenges faced by PDH technology. The main difference between SDH and PDH is the strict

synchronization of all network elements, which enables simpler, more flexible, and scalable data flow management.

SDH was designed to provide high transmission speeds, easy multiplexing, scalability, and compatibility with various data types. It is widely used in backbone and regional telecommunications networks, as well as for combining various digital services.

Basic principles of SDH

1. **Tight synchronization** – unlike PDH, all network nodes operate on a single reference clock signal, eliminating synchronization issues and the need to insert additional bits for compensation. This significantly simplifies data processing and routing.
2. **Standard transmission rates** – SDH uses the basic STM-1 stream with a throughput of 155.52 Mbps. Further, there is a hierarchy, multiples of STM-1: STM-4 (622 Mbps), STM-16 (2.5 Gbps), STM-64 (10 Gbps), and higher.
3. **Format unification** – standardized frames allow for the transmission of various types of data, including PDH streams, voice, video, and data, with high efficiency.
4. **Flexible frame structure** – The SDH frame consists of multiple rows and columns of bytes, including service information for network management, error control, and data recovery.
5. **Management and monitoring protocols** – built-in network management mechanisms allow monitoring of channel status, detection and correction of errors, ensuring high reliability.

SDH architecture

The key element of SDH is the STM-N frame (Synchronous Transport Module), where N denotes the multiplicity of the STM-1 base stream. The STM-1 frame has a fixed structure: 9 lines of 270 bytes, transmitted every 125 microseconds.

The frame structure is divided into areas for user data (payload) and for service information (overhead), which contains control, addressing, and monitoring data.

The main components of SDH are:

- **Multiplexers** are devices that combine low-speed streams into high-speed ones with strict synchronization.
- **Regenerators** – restore the signal over long distances to maintain transmission quality.
- **Cross-switches** – provide routing and switching of flows within the network.

Advantages of SDH over PDH

- Full synchronization of all network nodes
- Simplified multiplexing and demultiplexing
- Increased scalability and flexibility
- Higher level of monitoring and diagnostics
- Improved error tolerance and automatic connection recovery capabilities

Practical tasks

Task 1.

Determine the transmission time of one STM-1 frame based on the known transmission parameters (frame size and transmission rate).

Task 2.

Analyze the structure of the STM-1 frame: indicate the number of bytes in the payload and overhead , as well as the purpose of the main overhead fields .

Task 3.

Compare the hierarchy of SDH with PDH: create a table showing the transmission rates, stream formats, and main differences between the technologies.

Task 4.

Describe the principles of error handling in SDH and the mechanism for automatic link recovery (Protection Switching).

Task 5.

Model the multiplexing of streams in STM-1 using software or specialized packages (for example, MATLAB or LabVIEW), analyze the distribution of data and service information.

Questions and tasks

1. What does the term "synchronous" mean in the name of SDH technology?
2. What are the main transmission rates used in SDH?
3. What is the structure of an STM-1 frame and its main components?
4. What are the advantages of synchronization in SDH compared to PDH?
5. What functions does the overhead perform in SDH?
6. How is error control and recovery performed in SDH?
7. What devices are part of an SDH network and what is their role?
8. How does SDH differ from SDH-compatible technologies such as SONET?
9. How does SDH technology support the transmission of different types of data (voice, video, data)?
10. What are the current trends in the development of SDH-based data transmission technologies?

Conclusion:

During the lab, the participants explored the design and operating principles of Synchronous Digital Hierarchy (SDH), a key standard in modern telecommunications networks. The structure and composition of STM-N frames, methods for synchronization and data flow management, and the advantages of this technology over previous PDH systems were discussed. Practical exercises reinforced their understanding of multiplexing and digital flow management under strict synchronization conditions, which are the foundation for reliable and efficient data transmission in modern communications networks. The acquired knowledge and skills are essential for understanding the functioning of modern digital networks and developing new telecommunications solutions.

PRACTICAL WORK #12.

ATM TECHNOLOGY (ASYNCHRONOUS TRANSFER MODE)

Objective:

To study the basics of ATM technology, understand its architecture, principles of data transmission, features of channel and cell organization, as well as the scope of application in modern communication networks.

Theoretical part

of ATM (Asynchronous Transfer Mode is a data switching and transmission technology based on the transmission of information in the form of short, fixed cells (a cell is the smallest unit of data). It was developed to integrate various types of traffic (voice, video, data) into a single network with high performance and guaranteed quality of service (QoS).

The core idea of ATM is the use of short, fixed-size cells (53 bytes: 5 bytes of header and 48 bytes of payload) transmitted asynchronously without the need for a dedicated channel. This approach ensures low latency, high transmission speeds, and enables the efficient transmission of multimedia data.

ATM architecture

An ATM network consists of the following key components:

1. **End nodes (End Systems)** – devices that generate and receive data.
2. **ATM switches** are devices that provide cell switching, manage their routing and resource distribution.
3. **Access networks and backbone networks** – provide cell transmission between end points.

ATM supports data transmission over virtual channels (VC, Virtual Channel) and virtual paths (VP, Virtual Path). A virtual path is a logical combination of several virtual channels, which facilitates traffic management and increases the flexibility of network interaction.

Key characteristics of ATM technology

- **The fixed cell size** is 53 bytes, which simplifies data processing in hardware and reduces latency.
- **Asynchronous transmission** – cells are transmitted without allocating a fixed time interval, which allows for flexible distribution of bandwidth.

- **Quality of Service (QoS)** – ATM provides different classes of service, supports traffic priorities, and guarantees minimal latency for mission-critical applications.
- **Multimedia traffic integration** – voice, video, and data are transmitted over a single network, simplifying infrastructure and reducing costs.
- **Scalability and flexibility** – the network is easily scalable and adaptable to various requirements.

Types of virtual channels and services in ATM

ATM supports several types of virtual channels, differing in transmission parameters and guaranteed quality of service:

- CBR (Constant Bit Rate) – for applications with a constant transmission rate, such as voice calls.
- VBR (Variable Bit Rate) – for traffic with variable speed, such as video.
- ABR (Available) Bit Rate) – for applications with adaptive traffic.
- UBR (Unspecified Bit Rate) – for applications with unregulated traffic, such as data transfer.

Practical tasks

Task 1.

Calculate the throughput of an ATM channel when transmitting cells, taking into account the size of the payload and header.

Task 2.

Analyze the structure of an ATM cell: describe the purpose of each header field.

Task 3.

Compare the main classes of quality of service in ATM, provide examples of applications for each class.

Task 4.

Describe the process of establishing a virtual channel in an ATM network and the principles of cell routing.

Task 5.

Simulate the transmission of multiple data streams with different service classes through ATM virtual channels and analyze the results in terms of delays and data losses.

Questions and tasks

1. What is ATM technology and what problems does it solve?
2. Why does ATM use a fixed cell size?
3. What components are included in the ATM network architecture?
4. What is the difference between virtual channels and virtual paths?
5. What quality of service classes are available in ATM and how do they affect data transmission?
6. How is traffic management and loss prevention achieved in ATM?
7. What are the advantages of ATM over traditional data transmission technologies?
8. What is the role of ATM switches in a network?
9. What types of applications make the most effective use of ATM?
10. What modern technologies have replaced or complemented ATM?

Conclusion:

During the lab, the key operating principles of ATM technology, its architecture, and the specifics of data transmission using fixed cells were explored. The mechanisms for creating virtual channels and ensuring various quality of service classes were understood. The knowledge gained allows for a better understanding of how modern networks ensure high performance, flexibility, and reliability of multimedia data transmission, which is especially relevant in the face of growing demands on telecommunications systems. Practical assignments helped reinforce the theoretical foundations and develop skills in analyzing communication channel characteristics and traffic management in ATM-based networks.

PRACTICAL WORK #13.

BASIC CONCEPTS OF TELETRAFFIC THEORY

Objective of the work:

To become familiar with the fundamental concepts of teletraffic theory, to study call flow and service models, the main parameters of teletraffic and their impact on communication quality, as well as methods of analysis and optimization of telecommunication systems.

Teletraffic theory is a branch of probability

theory and mathematical statistics that studies information transmission processes in telecommunication networks and communication systems. It focuses on modeling, analyzing, and optimizing call and data flows to ensure the required quality of service (QoS).

Teletraffic theory is based on the concept of **call flow (traffic)** —a random process that describes the occurrence of requests to establish a connection or transmit data within a network. The key task is to forecast the load, assess the probability of call loss, delays, and other network characteristics.

Main parameters of teletraffic :

- **Traffic intensity (A)** is the average number of calls per unit of time, measured in Erlangs (Erl). One Erlang corresponds to continuous channel occupancy for the entire observation period.
- **Service time** is the time a channel is occupied by a call. It is typically modeled using an exponential distribution.
- **Average time between calls** – characterizes the frequency of calls received.
- **Blocking probability** is the probability of call denial due to all channels being busy.

Flow and Service System Models

The most common model is **the Poisson flow**, which describes independent and random events with a constant average intensity. This model is well suited for describing calls and sessions in telecommunications.

For service analysis, a model of a system with **n** channels and either bounded or unbounded queuing, denoted as M/M/n or M/M/n/0 (Erlang B, Erlang C), is used. These models help calculate blocking probability and waiting time.

Erlang B and Erlang C formulas are widely used to calculate the required number of channels for a given level of service quality.

Key concepts:

- **Teletraffic (load traffic)** – measured in Erlangs, characterizes the degree of network congestion.
- **Channel occupancy** is the probability that the channel is currently busy.
- **Channel performance** is the data transfer rate or the number of calls served.
- **Quality of service (QoS)** is a set of characteristics that determine the degree to which user requirements are met.

Practical tasks

Task 1.

Calculate the intensity of teletraffic A for the given call parameters: number of calls per hour and average call duration.

Task 2.

Using the Erlang B formula, determine the minimum number of channels to ensure a blocking probability of no more than 1%.

Task 3.

Compare the probability of blocking for different traffic intensities and numbers of channels, and plot dependence graphs.

Task 4.

Determine the average call waiting time in the queue using the Erlang C formula for a given number of channels and traffic intensity.

Task 5.

Analyze the impact of increasing the number of channels on the quality of service and network load.

Questions and tasks

1. What is teletraffic theory and what role does it play in communication systems?
2. What are the main parameters that characterize teletraffic ?
3. Explain the concept of Erlang and its practical significance.
4. What is a Poisson flow and why is it often used in traffic modeling?
5. Erlang B and Erlang C formulas ? In what situations are they used?
6. What is the blocking probability and how does it affect the quality of service?
7. How does changing the number of channels affect the service system parameters?
8. What methods can be used to optimize resource use in telecommunication networks?
9. How can quality of service be measured in terms of teletraffic ?
10. What practical problems does teletraffic theory solve in modern communication networks?

Conclusion:

During the lab, the basic concepts of teletraffic theory , its main models, and parameters were examined. Methods for calculating traffic intensity, blocking probability, and latency in a system with multiple channels were studied. Practical assignments allowed the application of theoretical knowledge to assess network load characteristics and quality of service. Understanding these fundamentals is essential for the effective design and optimization of modern telecommunications systems capable of providing reliable and high-quality data transmission under various load conditions.

PRACTICAL WORK #14.

TELEGRAPH: HISTORY, OPERATING PRINCIPLES AND MODERN ASPECTS

Objective of the work:

To study the structure and operating principles of the telegraph, its historical development and importance in communication systems, and also to consider modern technologies and their connection with telegraphy.

Theoretical Part:

The telegraph was one of the first electrical communication systems, developed in the first half of the 19th century. It allowed messages to be transmitted over long distances using electrical signals converted from text.

The telegraph's basic operation is the conversion of letters and symbols into signals that are transmitted over wires and decoded at the receiving end. The most well-known telegraphy code is **Morse code** , which represents each letter and number as a combination of short and long signals—dots and dashes.

The telegraph was a crucial step in the development of communications systems, significantly accelerating information transfer and enabling operational control over long distances. Its operating principle formed the foundation of modern digital and network technologies.

The main components of a classic telegraph include:

- **A transmitter** is a device that converts a text message into a series of electrical impulses.
- **A communication line** is a wire through which signals are transmitted.
- **Receiver** – a device that converts signals back into text.

The telegraph operates on the manual or automatic generation of code sequences transmitted as interruptions in an electric current. The receiver records these pulses and displays the message in its original form.

Over time, telegraphs evolved from simple manual devices to automatic systems using punch cards, electromagnetic relays, and more complex encodings.

Modern Aspects:

Although the traditional telegraph is rarely used in everyday communications, its legacy lives on in modern digital protocols and network technologies. Understanding the principles of the telegraph is important for studying the history of information technology and the fundamentals of digital data transmission.

Nowadays, the term "telegraph" can also refer to specialized short message systems in emergency services and some military communications.

Practical tasks

Task 1.

Learn and reproduce Morse code for the English alphabet and numbers. Encode a short message and decode it manually.

Task 2.

Research the operation of a simple telegraph key (if equipment is available) or a telegraph simulator in software.

Task 3.

Compare the speed of information transmission by telegraph with modern digital communication means.

Task 4.

Prepare a brief overview of the development of telegraph technologies and their impact on modern communications.

Questions and tasks

1. What is the historical significance of the telegraph in the development of communications?
2. Explain the principle of encoding and decoding messages in the telegraph.
3. What is Morse code and how does it work?
4. What are the main components of a classical telegraph system?
5. What is the difference between a manual telegraph and an automatic one?
6. Why has the telegraph lost its practical relevance in modern communications?
7. What modern technologies have inherited the telegraph's operating principles?
8. How does telegraph data transfer speed compare to modern communication standards?
9. What advantages and limitations did the telegraph have?
10. How does understanding telegraphy help in studying digital communication systems?

Conclusion:

This lab examined the fundamental principles of the telegraph, its history, and its importance in the development of communications technologies. Practical exercises facilitated the development of encoding and decoding messages using Morse code. The telegraph is a significant milestone in the history of information technology, laying the foundation for the subsequent development of digital communication systems. Understanding its structure and operation helps to better understand modern data transmission methods and the problems solved by information theory and telecommunications.

PRACTICAL WORK #15.

FACSIMILE COMMUNICATION: PRINCIPLES OF OPERATION, DEVELOPMENT AND MODERN APPLICATIONS

Objective of the work:

To study the technology of facsimile communication, to understand its principles of transmitting images and texts via telephone and digital channels, to consider the evolution and modern capabilities of facsimile systems.

Theoretical Section:

Facsimile (or fax) is a technology for transmitting copies of documents and images over telephone lines or other communication channels. The idea of transmitting graphic information first emerged in the mid-19th century, and by the end of the 20th century, fax machines had become widespread in business and administrative practice.

Faxing operates by digitizing the original document through scanning and converting it into a sequence of electrical signals. These signals are transmitted over a communication channel and, at the receiving end, are restored to the original image on paper.

The main stages of transmitting a fax message:

- **Scanning** is the conversion of an image into a digital or analog signal using photodetectors or sensors.
- **Coding** is the conversion of a signal into a format suitable for transmission over a specific channel (e.g. compression, modulation).

- **Transmission** is the sending of a signal over a telephone line or network.
- **Decoding and printing** – image restoration and its output to paper on the receiving side.

Traditionally, fax machines used analog telephone lines, which limited transmission speed and quality. With the development of digital technology, fax messages can now be transmitted over ISDN networks, the Internet, and other digital channels, significantly improving the quality and speed of transmission.

An important fax characteristic is scanning resolution (dots per inch, dpi), which determines copy quality. Modern fax machines provide high resolution and color image transmission.

Current Status and Prospects:

With the development of email, scanners, and digital document transfer formats, the role of traditional fax systems has somewhat diminished. However, fax remains relevant in certain industries—for example, medicine, law, and official document management—where the transmission of signed or certified copies of documents with minimal delay is required.

Modern multifunctional devices also combine the functions of a fax, printer, scanner, and copier, which expands user capabilities.

Practical tasks

Task 1.

Study the structure of a classic fax machine and describe the operating principle of each of its components.

Task 2.

Analyze the process of converting a paper document into an electrical signal and its reverse recovery.

Task 3.

Explore the features of transmitting fax messages via analog and digital communication channels.

Task 4.

Compare the speed and quality of fax transmission with other methods of transmitting graphic information, such as e-mail and network scanners.

Task 5.

Prepare a review of modern multifunctional devices that support fax functionality.

Questions and tasks

1. What is facsimile communication and in what areas is it used?
2. What are the main steps involved in the fax transmission process?
3. What is the difference between analog and digital fax?
4. How does scanning resolution affect the quality of the transmitted image?
5. What limitations do telephone lines impose on the quality and speed of fax communication?
6. What are the advantages of digital technology in fax communication?
7. What modern devices combine fax functionality with other office technologies?
8. Why does fax remain relevant despite the development of email?
9. What compression and encoding methods are used in fax transmission?
10. What are the prospects for the development of facsimile communications in the context of digitalization and the Internet?

Conclusion:

This lab examined the basic principles of facsimile communication, the specifics of graphic information transmission, and the main stages of the process. Practical exercises provided a deeper understanding of the technical details of facsimile machines, their evolution, and modern applications. Despite the advent of new digital document transmission tools, facsimile technology remains essential in a number of specialized fields, continuing to ensure the reliable and rapid transmission of paper copies of documents over various communication channels. Understanding the principles of facsimile communication is useful for a comprehensive study of information transmission and communication systems.

PRACTICAL WORK #16.

FACSIMILE COMMUNICATION STANDARDS: CLASSIFICATION, FUNCTIONS AND SIGNIFICANCE IN MODERN INFORMATION TRANSMISSION SYSTEMS

Objective:

To study the main international and national facsimile communication standards, to understand their role in ensuring equipment compatibility and data transmission quality, and to consider the application of standards in modern communication systems.

Theoretical Section:

Fax standards are a set of technical requirements and protocols that govern the format, speed, encoding methods, and transmission of fax messages. They ensure compatibility between equipment from different manufacturers and allow users to guarantee the quality and reliability of document transmission.

The main international facsimile standards are developed by the International Telecommunication Union (ITU) in the T.30 and T.4/T.6 series of recommendations. These standards cover various aspects of facsimile communication, including:

- **ITU-T Recommendations T.4 and T.6** – define compression methods and image format for fax transmission, in particular monochrome compression using MH (Modified Huffman), MR (Modified Read) and MMR (Modified Modified Read). These methods provide efficient compression of monochrome images, which reduces transmission time and the amount of data transferred.
- **ITU-T Recommendation T.30** regulates procedures for establishing a connection, negotiating transmission parameters, managing errors, and terminating a facsimile session. This standard describes signaling protocols between facsimile machines, enabling them to effectively negotiate transmission speeds, compression modes, and other parameters.
- **ITU-T Recommendation T.37** describes the transmission of fax messages via email (store-and-forward fax). This enables the integration of traditional fax machines with IP networks and email, expanding communication capabilities.
- **ITU-T Recommendation T.38** is designed for real-time fax transmission over IP networks (Fax over IP (FoIP). This standard ensures the transmission of fax signals with minimal delay and high reliability in digital networks.

These standards ensure compatibility between fax devices from different manufacturers and guarantee transmission quality, minimizing errors and delays.

An important aspect is the coordination of transmission parameters between devices when establishing a connection, which allows for the automatic selection of optimal operating modes based on the communication channel's characteristics. For example, the selection of transmission speed (2400, 4800, 9600 baud and higher), compression method, and error control.

Also worth noting are the color facsimile standards, which expand the capabilities of transmitting multicolor documents with high color accuracy, which is especially important for business and medicine.

Practical tasks

Task 1.

Study ITU-T recommendations T.4 and T.6, describe MH, MR and MMR compression methods, explain how they work and what their advantages are.

Task 2.

Research the ITU-T T.30 standard, describe the main stages of establishing a fax connection and the procedure for negotiating parameters.

Task 3.

Become familiar with the protocols for transmitting faxes over IP networks (T.37 and T.38), and analyze the advantages and limitations of these methods.

Task 4.

Compare the speed and quality of fax message transmission using different standards and compression methods.

Task 5.

Prepare a brief overview of the main manufacturers of facsimile equipment, their compliance with international standards, and the specifics of implementing standards in their products.

Questions and tasks

1. What international standards govern facsimile communications?
2. What are MH, MR, and MMR compression algorithms and how do they affect fax transmission?
3. Which protocol describes the connection establishment and control procedure for fax transmission?
4. What are the differences between T.37 and T.38 standards?
5. What transmission parameters are agreed upon between fax devices when establishing a connection?
6. What are the benefits of standardization in the field of fax communication?
7. How do standards ensure compatibility between equipment from different manufacturers?
8. What are the features of modern color fax machines in terms of standards?
9. How do standards help ensure error control and transmission reliability?
10. What are the prospects for the development of fax communications related to IP technologies and digital networks?

Conclusion:

During the lab, a thorough analysis of the main fax standards, their structure, and functions was conducted. Studying the international ITU-T recommendations T.4, T.6, T.30, T.37, and T.38 allowed us to understand how these standards ensure equipment compatibility, quality, and reliability of fax transmission. Modern standards actively integrate fax communication with digital and IP networks, expanding its functionality and capabilities. Understanding these standards is critical for engineers and specialists working with information transmission systems and telecommunications, as it ensures the proper implementation and operation of fax systems in modern communications infrastructures.

PRACTICAL WORK #17.

FAX SERVER: PURPOSE, ARCHITECTURE AND MAIN FUNCTIONS IN MODERN COMMUNICATION SYSTEMS

Objective:

To study the structure and functions of a fax server, its role in modern information systems, and to understand its operating principles, advantages, and areas of application.

Theoretical Part:

A fax server is a specialized hardware and software solution that enables centralized management of the reception, transmission, and storage of fax messages in corporate networks and organizations. Unlike traditional fax machines, which operate independently and are tied to a physical line, a fax server integrates with computer networks and email, providing more flexible and efficient fax processing.

The main purpose of a fax server is to provide centralized reception and sending of fax messages, their automatic routing, storage and archiving, as well as integration with other information systems of the organization (for example, document management systems, CRM and ERP).

A fax server architecture typically includes several key components:

1. **The hardware** includes fax modems or specialized boards for connecting to the telephone network, as well as server equipment for processing and storing data.
2. **Software** – drivers, services and interfaces that provide fax session management, data conversion, integration with mail servers and user applications.
3. **Network interface** – allows users to send and receive faxes via a local network or the Internet using familiar means – email, web interfaces or special clients.

A fax server operates by automating the processing of incoming and outgoing faxes. Incoming messages are received by a modem, converted to digital format (usually TIFF or PDF), stored on

the server, and automatically forwarded to recipients via email or other channels. Outgoing faxes are generated electronically by users and sent via the server to the fax line.

The benefits of using a fax server in an organization include increased document flow efficiency, reduced paper and maintenance costs for traditional fax machines, improved control and security of document transmission, and ease of archiving and retrieval of messages.

Modern fax servers support integration with corporate security systems, data encryption, logging and reporting, and allow system scaling depending on fax traffic volume.

Fax servers also play a vital role in the digital transformation of organizations, combining traditional fax technologies with modern IT solutions and facilitating the transition to paperless workflows.

Practical tasks

Task 1.

Study the architecture of a typical fax server, describe the main components and their functions.

Task 2.

Analyze the algorithm for processing an incoming fax message on the server: from signal reception to delivery to the recipient.

Task 3.

Explore ways to integrate a fax server with email and corporate information systems.

Task 4.

Assess the advantages of fax servers compared to traditional fax machines in a corporate environment.

Task 5.

Prepare an overview of popular fax server solutions on the market, their technical characteristics and functionality.

Questions and tasks

1. What is a fax server and what is its main purpose?
2. What components are included in the fax server architecture?
3. How are fax messages received and processed on the server?
4. How does a fax server integrate with email?
5. What are the advantages of using a fax server over traditional fax machines?
6. What file formats are commonly used to store fax messages on the server?
7. What security methods are used in modern fax servers?
8. How does a fax server facilitate the digital transformation of an organization's document management?
9. What tasks are solved using a fax server in corporate information systems?
10. What are the development trends in the fax server industry?

MINISTRY OF SCIENCE AND HIGHER EDUCATION OF THE RUSSIAN FEDERATION

Federal State Autonomous
Educational Institution of Higher Education
" North Caucasus Federal University"

GUIDELINES

on organizing and conducting independent work
in the discipline "**Signal and System / Сигналы и системы**"
for students in the field of study

02.04.01 "Mathematics and Computer Science"

direction (profile)

"Training Program for Electronic Information"

INTRODUCTION

The discipline "Signal and System / Сигналы и системы" is included in the bachelor's degree program in the field 02.04.01 - "Mathematics and Computer Science" and is a mandatory part of the block of disciplines.

This course explores the application of mathematical tools to solving applied problems, approximating functions, solving differential equations with boundary conditions, and numerically calculating definite integrals and derivatives. To reinforce the material covered, students will complete practical assignments using modern information technologies.

The purpose of this course is to ensure the fulfillment of the requirements of the State Educational Standard "Mathematics and Computer Science", according to which a bachelor's degree must have the ability to use fundamental knowledge in the field of mathematical analysis, complex and functional analysis, algebra, analytical geometry, differential geometry and topology, differential equations, discrete mathematics and mathematical logic, probability theory, mathematical statistics and random processes, numerical methods, theoretical mechanics in future professional activities.

To consolidate the material studied, it is expected that practical tasks will be completed using modern mathematical packages, MahCad , Maple , MatLab .

This discipline is designed to promote the fundamentalization of education, strengthen mathematical knowledge and develop students' systems thinking, and study theoretical, methodological and practical problems of the formation, functioning and development of information systems.

1 Requirements for the level of mastery of the discipline content

As a result of mastering the discipline, the student should possess the following competencies:

Index	Formulation:
PC-8	Capable of participating in the management of projects for the creation of information systems and software systems at various stages of the life cycle
PC-9	Able to take into account knowledge of the problems and trends in the development of the software market in professional activities

2 Organizational and methodological recommendations for mastering the discipline

Students' independent work is a crucial prerequisite for developing a scientific approach to learning. It is conducted before each practical and laboratory lesson and involves completing a specific assignment.

The prepared material and practical assignment are presented in notes.

Independent study (IS) is one of the active forms of learning.

Independent studies in the discipline "Signal and System / Сигналы и системы " have the following goals:

- to consolidate and deepen the knowledge acquired by students in lectures and laboratory classes;

- to instill practical skills in working with modern information technologies.

Independent studies are conducted in specialized classrooms equipped with computer technology and the ability to use Internet and library resources.

The proposed methodological recommendations contain information for students necessary for preparing and conducting laboratory classes in the discipline "Engineering Mathematics", and may also be useful for officials whose responsibilities include working with organizational and administrative documents (ORD).

GOST R 51141-08 defines the ORD as a type of written document that records the resolution of administrative and organizational issues, as well as issues of management, interaction, support and regulation of the activities of government bodies, institutions, enterprises, organizations, their divisions and officials.

According to the All-Russian Classifier of Management Documentation (OKUD), ORD are classified into four groups:

- organizational and legal documentation (charters, regulations, rules, staffing schedules, instructions);

- administrative documentation (orders, instructions, decrees, decisions, directions);

- information and reference documentation (letters, telegrams, faxes, acts, protocols, reports and memos, etc.);

- documents on personnel (applications, personal cards, orders on personnel, etc.).

The preparation of the ORD is carried out in accordance with the requirements of GOST R 6.30-2003 "Unified documentation systems. Unified system of organizational and administrative documentation. Requirements for document preparation."

This standard establishes: the composition of document details; requirements for the execution of document details; requirements for document forms.

3 Methodological guidelines for students' independent work

The guidelines include the following sections:

- the purpose of the work;
- a task that must be completed by a student as a result of independent work;
- task options;
- the main theoretical provisions necessary for completing the assignment, they should be brief and contain references to literature in which these provisions are set out in a volume sufficient for completing independent work;
- stages of task completion with indication of specific deadlines for completion of each stage and the entire task as a whole;
- requirements for the design of the graphic and text parts of independent work;
- an example of completing one of the task options and preparing a report;
- bibliographic list of used sources.

To help students and monitor their independent work, teacher consultations are used.

Consultations are one of the forms of work of the department to provide pedagogically appropriate assistance to students in their independent work.

Consultations should be individualized. If clarification of common issues is needed for several students, group consultations are held.

Consultations are conducted with the aim of:

- clarification of questions that arise among students during independent study of educational material and completion of homework;
- deepening and consolidating knowledge on individual issues and topics of the discipline;
- providing methodological assistance in choosing methods of independent work.

Attendance at student consultations is voluntary. However, the instructor may call for interviews those students who do not demonstrate solid knowledge during their studies and who do not voluntarily participate in the consultations.

During the consultation, the teacher explains the most complex issues that are unclear to students and points out literature that covers them.

When consulting students, the teacher is obliged to become familiar with how they study the recommended literature, give instructions and advice on methods of working on the educational material, facilitating a deeper and more lasting

assimilation of it

Consultations should not be additional classes or substitutes for them. Doing homework for students or with them is prohibited. Consultations should not become a form of cramming for tests and exams.

If during the consultation it becomes clear that the student's lack of understanding of the question is due to insufficient study of certain sections of the program, then the consultant is obliged to recommend that the student study them and monitor the degree of assimilation of these issues.

Consultations do not constitute a knowledge assessment. The student's knowledge of the subject matter demonstrated during the consultation should not influence their assessment of the course material in exams and tests.

4. Organization of students' knowledge control. Forms of students' knowledge control

Students' knowledge, skills, and abilities are assessed and monitored during laboratory classes, consultations, and exams. During assessments, the instructor evaluates the student's understanding of the course "Engineering Mathematics" and their ability to apply management methods to solve specific problems.

Students' knowledge assessment can be carried out in the following forms:

- current knowledge control;
- intermediate knowledge control.

Current monitoring of students' knowledge aims to:

- to evaluate the work of each student in assimilation of the educational material, to identify shortcomings in his preparation and to provide practical assistance in eliminating them;

The main forms of current monitoring of students' knowledge are:

- oral control survey;
- written control blitz survey;
- protection of laboratory work;
- intermediate testing;
- checking lecture notes.

Oral assessments of students are conducted during lectures (and lab sessions). Based on these assessments, the instructor evaluates the student's preparation for the class.

Students complete a written quiz during lectures and labs scheduled by the instructor. Students provide written responses to questions posed by the instructor. The results are recorded in the student's journal. During labs, students' knowledge and practical skills are assessed on a 4-point scale. The grades received are recorded in the journal.

When reviewing lecture notes, the quality of their writing is analyzed. Errors are noted, the instructor's review evaluates the quality of note-taking, and provides recommendations for improving the quality of lecture note-taking.

Interim assessment in the discipline is carried out in the form of a credit test and a credit test with a grade.

5 Recommendations for working with literature and sources

The study of literature and sources must begin with reading the relevant chapters of textbooks, teaching aids, or literature recommended as primary or secondary for the discipline "Information Systems Tools," which directly or indirectly relate to the topic being studied.

When studying literature and sources, students are advised to take brief notes. However, they should not rewrite the entire content of the topic being studied; they should only jot down the main ideas and, in their opinion, the most important thoughts. In certain cases, where important definitions, concepts, necessary factual material and examples, or statistical information related to the topic being studied are encountered, students should transcribe them as citations with full bibliographical references.

A summary of recommended literature and sources should be kept, with the collected materials divided into individual chapters and sections according to the curriculum. All references to the literature and sources used should be included.

An important step in working with recommended literature and sources is studying legislative and regulatory acts at the federal, regional, local, and departmental levels. When studying Decrees of the President of the Russian Federation, Laws and Codes of the Russian Federation, resolutions, regulations, recommendations, etc., students should identify any changes and additions that may have been made since their publication.

The basis of the technology for intensifying training on the platform of digital educational technologies are educational and illustrative materials (support notes) for the discipline "Signal and System / Сигналы и системы".

Working with educational and illustrative materials has the following stages.

1. Study of the theoretical foundations of the educational material in the classroom:

presentation of the material being studied by the teacher to students with an explanation based on the supporting notes;

2. Independent work:

Individual work of students on the supporting notes; frontal consolidation of the supporting notes' blocks.

3. First repetition - reproduction of the content of the given topic of the reference summary from memory.

4. Oral recitation of the supporting notes is a necessary stage of external speech activity in the assimilation of educational material.

5. The second repetition is mutual questioning and mutual assistance of students to each other.

The use of educational and illustrative materials allows us to generalize complex material and activate students' thinking.

It is important to remember that the most important thing for a student in independent work with recommended literature and sources is the formation of their own individual style, which can become the basis for future professional activity.

6 List of recommended literature

List of key literature:

1. Reshetnikova I.V. NETWORKS AND SYSTEMS OF INFORMATION TRANSMISSION. Study guide. – Rostov-on-Don: SKF MTUCI, 2022. – 52 p.
2. Sinitsyn, Yu. I. Networks and information transmission systems: a tutorial / Yu. I. Sinitsyn, E. I. Ryapolova . - Orenburg: OSU, 2017. - 189 p. - ISBN 978-5-7410-1886-6.
3. Networks and information transmission systems: telecommunication networks: textbook and practical training for the academic bachelor's degree / edited by K. E. Samoylova , I. A. Shalimov, D. S. Kulyabov . - Moscow: Yurait Publishing House , 2017. - 363 p.

List of additional literature:

1. information transmission systems : a textbook / G.M. Chernoknizhny. - St. Petersburg : Publishing house of St. Petersburg State University of Economics , 2019. - 104 p.
2. Networks and information transmission systems: a tutorial (lecture course) / A. P. Zhuk, G. I. Linets, D. V. Orel, E. P. Zhuk. - Stavropol: North Caucasus Federal University, 2021. - 157 p.

List of educational and methodological support for independent work of students in the discipline

1. Guidelines for organizing independent student work in the discipline "Networks and Information Transmission Systems." Stavropol: SKFU, 2026.
2. Guidelines for practical classes in the discipline "Networks and Information Transmission Systems." Stavropol: SKFU, 2026.