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SYSTEM FOR LEARNING RESOURCES REMOTE ACCESS IN THE FIELD OF TELECOMMUNICATION AND INFORMATION SYSTEMS

AUTHOR`S SUMMARY

of a dissertation for acquiring the educational and scientific degree of "Doctor"

Field of higher education: 5. Technical sciences

Professional area: 5.3. Communication and Computer engineering

Doctoral program: Automatization of areas in the intangible sphere (medicine, education, science, administrative work, etc.)

ADVISER: ASSOC. PROF. SOTIR SOTIROV, PHD

Plovdiv, 2023

The dissertation work is 147 pages in total, including 91 figures and 19 tables, which represent an introduction, six chapters, conclusions, scientific and applied contributions and a list of the author`s publications. The list of references includes 99 titles in Cyrillic and Latin. The symbols of the formulae, the figures and the tables in the author`s summary coincide with those in the dissertation work.

The dissertation work was discussed and forwarded for a defense procedure on an expanded meeting of the Department of ELECTRONICS, COMMUNICATIONS AND INFORMATION TECHNOLOGIES at *PAISII HILENDARSKI* UNIVERSITY OF PLOVDIV on 31.10.2023, Record № 56

The defense of the dissertation work will take place at a meeting of the scientific panel on 20.02.2024 at 11.00 o`clock in hall "БИ 15", 21 Kostaki Peev Str., *PAISII HILENDARSKI* UNIVERSITY OF PLOVDIV

The materials related to the defence of the doctoral student are at the interested parties` disposal in the administrative office of the Faculty of Physics and Technology at *PAISII HILENDARSKI* UNIVERSITY OF PLOVDIV, 21 Kostaki Peev Str., 4th floor, room 1

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Title: SYSTEM FOR REMOTE ACCESS TO TEACHING RESOURCES IN THE FIELD OF TELECOMMUNICATION AND INFORMATION SYSTEMS

Circulation: 30 copies

INTRODUCTION

One of the biggest challenges of distance learning is how to train and prepare professionally the students enrolled in engineering majors. The University should meet the needs and necessities of students, to prepare them for their prospective career in a world where they can give their real potential with confidence. With relation to the vocational training, lecturers should not only teach students, but also should create motivation and interest in them towards knowledge, should form in them skills in order to apply theoretical knowledge into practical work.

The high requirements towards vocational training assume the need that the class-lesson system should be enriched with effective modern approaches aiming at active participation of students in class-cognitive work and better results achieved from the training. The main goal of education is the whole and comprehensive development of students, development of their interests, needs for knowledge. In order to achieve this particular goal in distance learning, I have applied the present approach - **the use of distant laboratories**, which is up-to-date and directed to the goals of modern training.

The process of organizing and planning qualitative electronic learning (e-Learning) is related to numerous technological, organizational, methodological and other aspects. A detailed analysis of the e-Learning in Bulgaria has reported that it has been developed mostly in the Universities offering studies in humanities and arts.

The main difficulty in distance learning for students in technical majors is related to the performance of laboratory seminars. One possible decision is the development and formation of distant laboratories, which should be equipped and adjusted for making research work and experiments with different objects being a subject of study in a given curriculum discipline.

The use of distant labs gives opportunity to students to work with real equipment and real data. Distant labs eliminate some limitations, being typical for the traditional labs, such as: lack of sufficient room, access to expensive equipment, their availability during non-working hours, etc. Application of distant labs gives greater possibility for achieving a unified standard and sharing training resources in a particular course or syllabuses between different universities.

One of the features of remote laboratories is that the laboratory equipment must be accessible to only one user at a given time. Therefore, one of the important elements in remote laboratories is the management system. It is used to organize the schedule for access to the laboratory equipment, authentication of users, provision of the necessary theoretical and methodical materials, storage of research results, etc. Establishing and maintaining a remote laboratory requires considerable time and resources. When developing such systems for access to

remote experiments, it must be ensured that the laboratory can be expanded with new models, and the exercises that are performed must be tailored to the specific course.

The relevance of the topic of the dissertation work is determined by the increased interest in the introduction of distance learning in the field of technical sciences.

In recent years, conducting remote laboratory experiments has become an increasingly widely used method of teaching. The main reason for this is due to the ability to provide access to expensive experimental equipment from anywhere in the world. In this way, students gain practical knowledge by having the opportunity to conduct real experiments at any time and from any place.

Aim of the dissertation work: The aim of this dissertation work is to create a system for remote access to educational resources in the field of telecommunications and information systems.

Tasks for achieving the main goal:

1. Research and analysis of existing systems for remote access to educational resources (remote laboratory management systems), as well as the requirements they must meet.
2. Formulation of the main characteristics and parameters of the system for remote access to educational resources to be used for the needs of students studying in the field of technical sciences.
3. Design and development of a system providing remote access to a series of laboratory exercises in the field of telecommunications.
4. Integration of the developed remote laboratories into the system.
5. Development of theoretical and methodical materials for the implementation of laboratory exercises.
1. Conducting experiments with students and teachers to use the developed system. Analysis of the obtained results of the experiment.

CHAPTER ONE. RESEARCH AND ANALYSIS OF THE SYSTEMS FOR REMOTE ACCESS TO TRAINING RESOURCES

The main goal of the teachers in the technical disciplines is to prepare the students with the necessary theoretical knowledge and skills in the relevant field. Therefore, it is extremely important what methods, means and forms of teaching will be applied in the learning process, so as to achieve maximum results – both in the assimilation of the taught theory and for the successful professional realization of the students in life.

Intensive processes of globalization and scientific and technical progress in modern society lead to the need to use new methods and approaches to achieve maximum results in the learning process. The changes are mainly expressed in the approach, the tools, the inclusion of different methods and techniques for teaching. This requires a new vision in engineering education as well. It should contribute to building a certain amount of knowledge and professional skills. The new educational paradigm also affects educational approaches. The need to develop such teaching tools as **remote laboratories** comes to the fore.

Table 1 shows some of the most popular distant learning laboratories.

Table.1: Distant learning labs

№	Дистанционна лаборатория	Местоположение	Използвани технологии за разработка	Приложение	Особености
1.	ACEL	Ниш, Сърбия	MATLAB/Simulink и LabVIEW	За изследване на високоскоростни серво-механизми и магнитни полета.	Изисква инсталиране на LabVIEW Run Time Engine на клиентския компютър.
2.	RECOLAB	Елче, Испания	Matlab/Simulink, Common Gateway Interface и PHP (v.4.3.2), работещ на Apache HTTP сървър	За управление и измерване на параметрите на постояннотокови двигатели.	Система за заснемане на изображения и уеб видео сървър: Sony EVI-D31/Axis 2400 видео сървър. Система за събиране на данни: NI6024E платка за събиране с аналогови и цифрови I/O.
3.	AIM-Lab	Хеллер, Норвегия	Java, LabVIEW, Common Gateway Interface, HTML, ActiveX/DCOM	За изследване на характеристиките на полеви транзистори.	Дистанционната лаборатория не може да бъде разширявана.
4.	LAB-onWEB	Хеллер, Норвегия		За изследване на характеристиките и параметрите на радиоелектронни схеми.	
5.	NetLab	Аделаида, Австралия	MATLAB/Simulink, LabVIEW, Java, Java Runtime Environment	За свързване и измерване на електронни схеми.	Притежава система за резервации. Изисква инсталиране на допълнителен софтуер на потребителския компютър.
6.	VISIR	Различни университети и учебни заведения в Европа	LabVIEW, Microsoft Visual C++, Flash, PHP, MySQL	За свързване и измерване на електронни схеми.	Системата притежава собствена LMS и поддържа четири типа потребители. Използва PXI платформата, свързана към релейната комутационна матрица.
7.	uCV-Lab	Новосибирск, Русия	LabVIEW, HTTP, DSTP, ActiveX	За изучаване и изследване на микроконтролери и сигнални процесори.	Дистанционната лаборатория не може да бъде разширявана.

Current research on learning issues suggests that distance labs increase the effectiveness of the learning process. For the provision of quality distance learning in technical specialties, it is extremely important that students can remotely conduct laboratory exercises in the relevant discipline.

There are various remote lab solutions developed and used by universities and educational organizations. Some of them use real equipment, others represent computer simulations or a combination of both approaches.

A given system for laboratory exercises can be evaluated in two aspects: as an educational context and pedagogical scenario in which it is integrated, or as a technical implementation. There is no general approach for evaluating remote laboratories, but the following requirements may apply to them:

- To be able to integrate with other systems.
- To use open source software and libraries in their development.
- To allow the inclusion of additional elements, trials and experiments without the need for a complete restructuring of the existing system.
- To be platform independent.
- Do not require installation of additional software on the client computer.
- To offer the necessary theoretical material that provides familiarity with the object of research.
- To offer an easy and intuitive user interface.
- To provide means of communication between the students and the teacher during the experiment.
- To enable saving of research results.
- To provide means of administration with which to manage.

Compliance with the specified requirements when developing a remote laboratory can ensure the creation of a flexible and effective learning environment. Most of the known remote laboratories cannot demonstrate and investigate the studied objects and phenomena in engineering disciplines. Therefore, after the overview, the need to develop **new remote laboratories** that can provide quality electronic learning in engineering disciplines becomes obvious. The presence of such laboratories can improve the effectiveness of teaching in the traditional form of education.

CHAPTER TWO. PROJECTING AND DEVELOPING A SYSTEM FOR REMOTE ACCESS TO TRAINING RESOURCES

In the second chapter, the prototype and program implementation of the system for managing remote access to educational resources is presented. The purpose of this system is to support the work of teachers when conducting laboratory exercises - both in distance learning and in-person learning in the laboratory. This chapter describes the stages through which the development of the system for remote access to educational resources passes, and they are as follows:

1) Selection of a software model (methodology) for system development – this model is the framework used to structure, plan and control the software systems development process.

2) Formulation of the main characteristics and parameters of the system for remote access to real laboratory equipment based on the research and analysis done in the first chapter.

3) Development of a system prototype.

4) Selection of technologies for system software development.

5) Choice of system software architecture.

6) Development of the user interface of the system.

7) Development of the functionality of the system software.

8) Development of the system database.

2.1. SELECTION OF A MODEL USED FOR THE DEVELOPMENT OF THE SYSTEM`S SOFTWARE

Design and development of software systems is the modeling of software processes and the application of computer technology. Software processes represent a sequence of actions in the creation of a given software system. These activities usually include the following actions:

1) Analyzing and defining the functionalities of the system.

2) Projecting (design) of the system and selection of software technologies.

3) 3)Writing code.

4) Testing.

5) Integration.

6) Exploitation.

7) Support.

For the aims of the dissertation work it has been chosen one of the most popular and most often applied models for software creation – ***the cascade model*** (Figure 9).
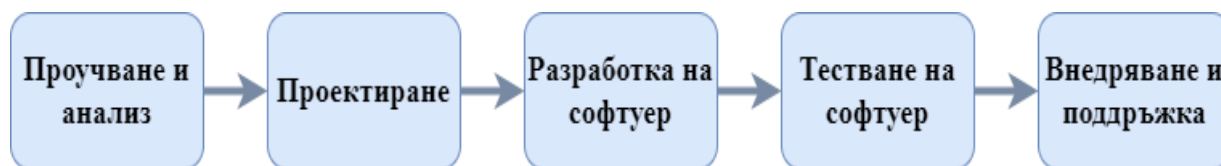

Figure.9: A cascade model for the development of the software of
the training resources remote access system

2.2. FUNCTIONAL REQUIREMENTS TO THE SYSTEM OF REMOTE ACCESS TO TRAINING RESOURCES

As a result of the studies of the existing systems for remote access to remote laboratories and the analysis of various literary sources, the following functional requirements for the developed system can be formulated:

1) To provide a schedule for the implementation of the laboratory exercises.
2) To provide the necessary theoretical material for the experiment.
3) To manage and maintain user account information.
4) To authorize and control access to the laboratory servers.
5) To provide an opportunity for communication between the teacher and the student during the experiment.
6) To provide students with the necessary information to access the laboratory exercise they must complete.
7) To provide an opportunity for students to request a change in the schedule for a given experiment from the teacher/administrator.

2.3. PROTOTYPE OF THE SYSTEM FOR REMOTE ACCESS TO TRAINING RESOURCES

The general architecture and main elements of the system for remote access to learning resources are demonstrated in Figure 12. The developed system consists of the following 3 elements: system users, web server and laboratory servers.

➢ ***Users of the system*** – these are students or teachers/administrators.
➢ ***Web Server*** – The web server that is selected to install the system software is XAMPP.
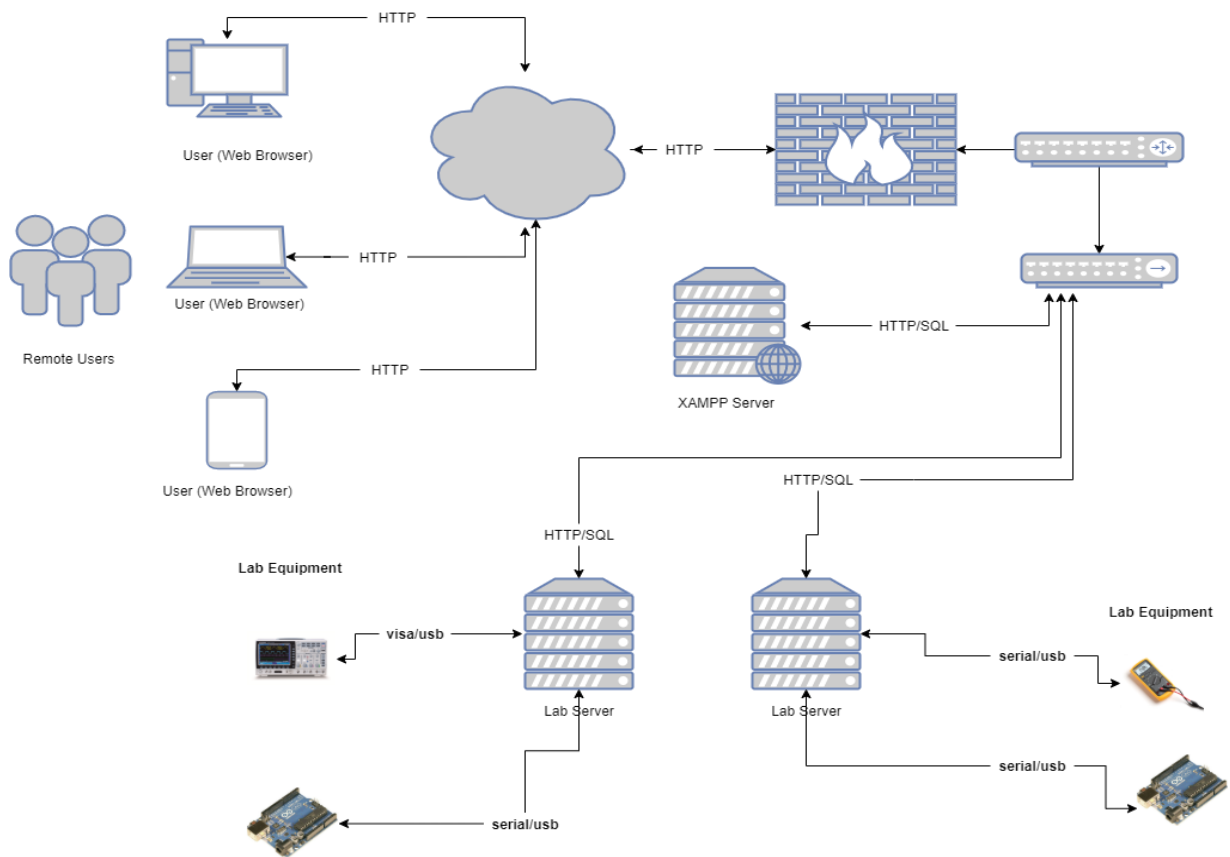➢ ***Laboratory servers*** – consist of two main modules - software and hardware.

Figure.12: A prototype of the remote access to training resources system

2.4. **A** SELECTION OF TECHNOLOGIES USED FOR THE DEVELOPMENT OF THE SYSTEM FOR REMOTE ACCESS TO TRAINING RESOURCES

The following programming languages and software frameworks have been selected to develop the remote access system software: PHP, JavaScript, HTML, MySQL and the open source client-side environment Bootstrap.

2.4.1. DEVELOPING THE LAYER FOR THE USER`S INTERFACE OF THE SYSTEM

A separate interface has been developed for each of the user profiles:

A. **Administrator`s interface** – allows management of the schedule of laboratory exercises, management of teaching accounts, addition or removal of theoretical materials in the system, access to the e-mail and chat application of the system.

B. **Student`s interface –** allows to see the current schedule of laboratory exercises and provides access to theoretical and methodical materials for a given laboratory exercise. Through it, the student can make a request to perform a laboratory experiment by filling out a web form or using the chat application to communicate with the teacher.

2.4.2. DEVELOPING THE LAYER FOR PROGRAM LOGIC OF THE SYSTEM

This point covers the functionality of the system for remote access to learning resources. It should provide laboratory management functions such as: experiment planning, user authentication, access to laboratory experiments, theoretical materials, user information storage, etc. One of the important aspects in the design of such systems is the implementation of the access schedule to the laboratory exercises. There are two main strategies: using a queue [60] and using time slots [60].

The system operation algorithm is demonstrated in Figure 16 and uses the time slot strategy to organize the access schedule to the laboratory exercises.
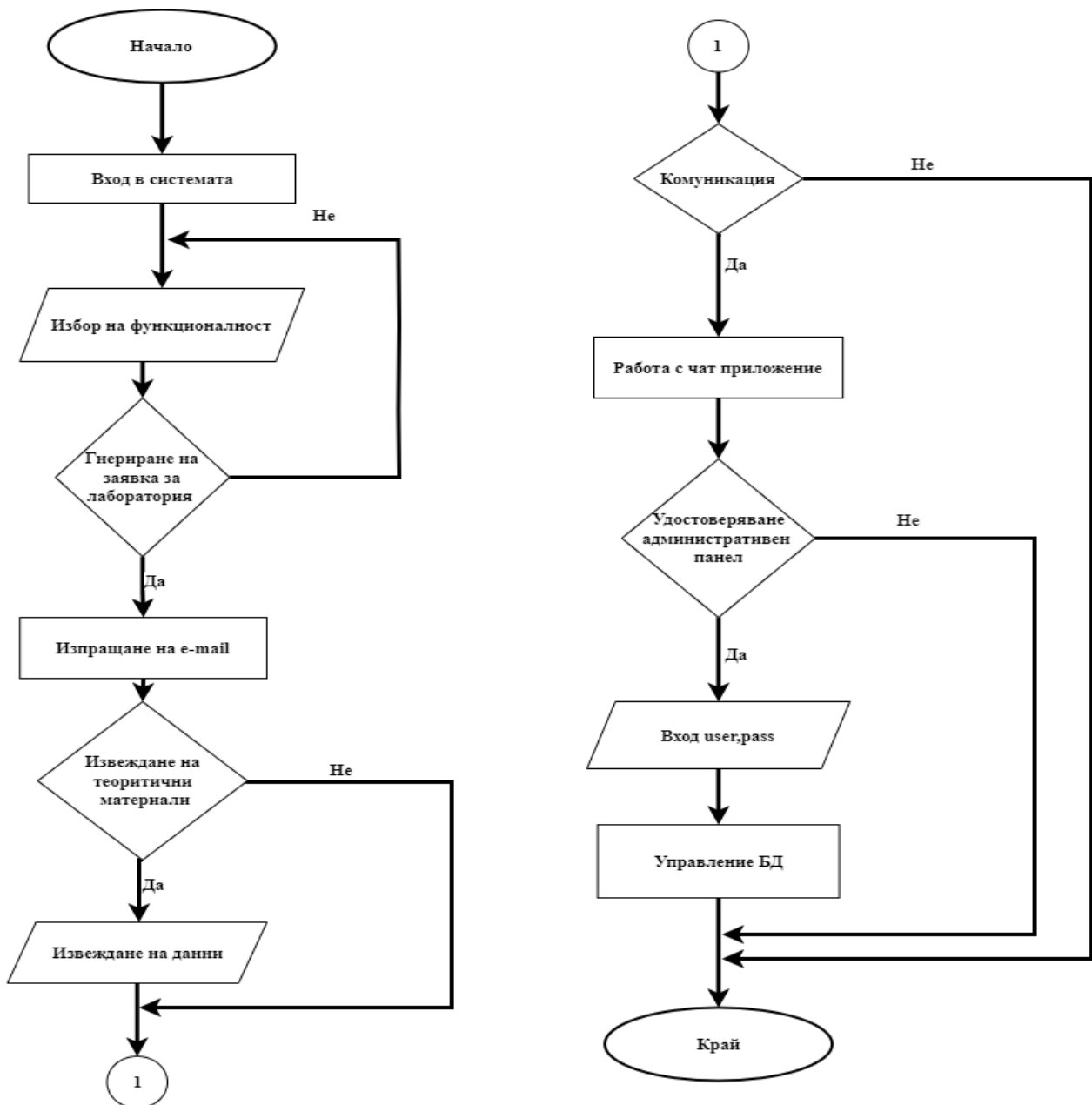

Figure.16: A block scheme of the system

2.4.3. DEVELOPING THE LAYER OF DATABASES OF THE SYSTEM

In designing and developing the database of the system, the approach described by Orduña and Garcia-Zubia [61] was used, which includes:

➢ Defining the purpose of the database.

➢ Separation of information into tables.

➢ Creating the fields of the tables.

➢ Set primary key for each table.

➢ Creating relationships between tables.

➢ Normalization etc.

The database (DB) of the system contains 3 tables. Each of them uses a primary key (PC) and a foreign key (FC) to link to other tables. The general scheme of the database is presented in Figure 31 using a UML diagram. The MySQL DBMS was used for the physical implementation of the database.
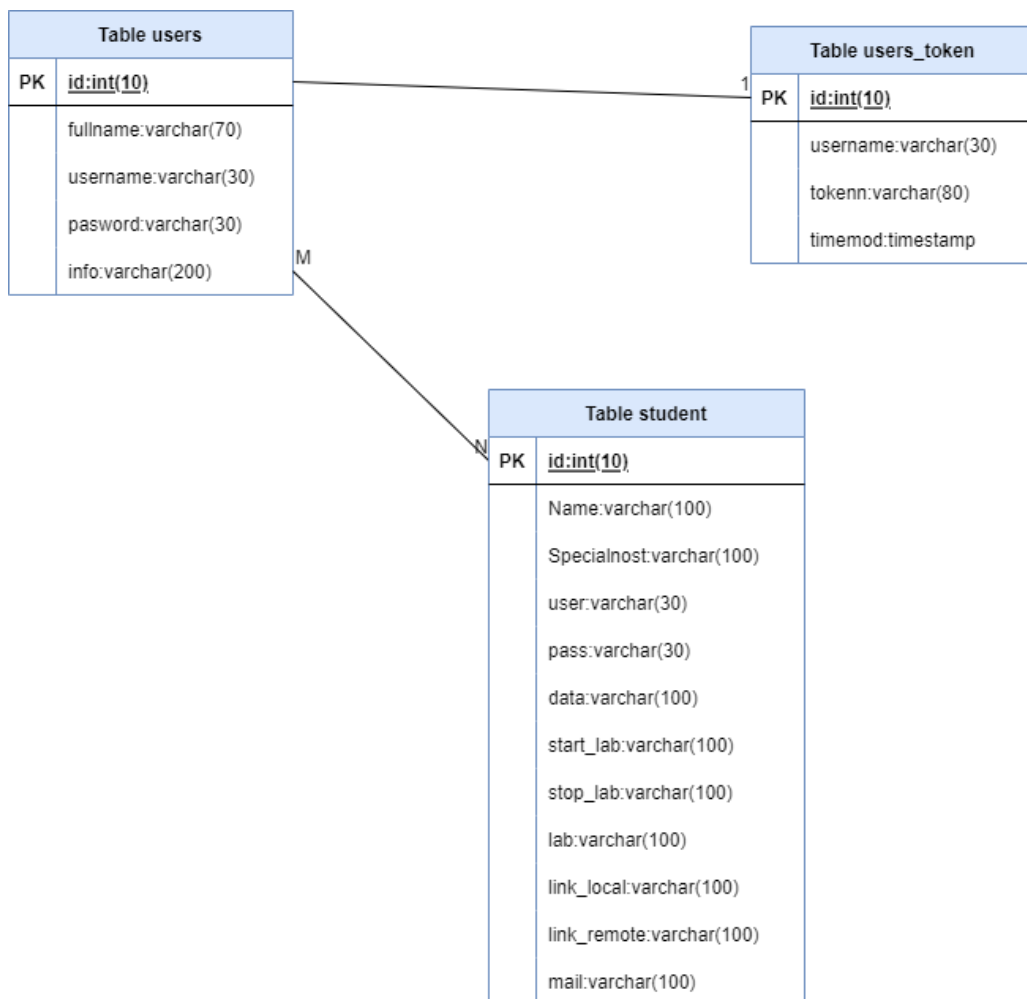

Figure.31: A general scheme of MySQL BD of the system

2.5. RESULTS AND CONCLUSIONS

In the second chapter, the methodology for developing the system for remote access to educational resources is presented. The system software prototype and user profiles are described. The functionality of the system is demonstrated using case diagrams. The software architecture and main modules of the system are reviewed. The design of the system and the software technologies and languages used in its implementation are presented. A relational database model is used and the tables in it are described in detail. The entire functionality of the developed system for remote access to educational resources is described.

The operating principle of the system for remote access to learning resources, which is used, is based on time intervals (slots). It avoids competition when trying to access the remote lab (learning resource). Each student has a strictly defined time interval in which he must complete the laboratory exercise, or he can request a change in his schedule by filling out a web form.

The developed remote access system and educational resources do not require the installation of additional software by students and teachers, only the presence of a web browser. Because the system's web interface and remote labs use HTML, CSS, and JavaScript, users do not need to install any web browser plug-ins. The software is designed in such a way that it is easy to add, remove or change various modules implementing the functionality of the system.

CHAPTER THREE. PROJECTING AND DEVELOPING THE REMOTE LABORATORY

3.1. GENERAL DATA FOR THE DISTANT LAB.

This chapter describes the software and hardware modules of the developed telecommunications and information systems remote laboratory, which provides access to real laboratory equipment. The need to create such a laboratory is determined by the following two main factors:

1) Rapidly developing information and communication technologies, which allow an inert system such as higher education to be updated and provide future graduates with an educational environment and resources adequate to modern business.

2) The COVID-19 pandemic and other lockdowns forced traditional face-to-face learning to very quickly shift to a distance option.

The developed remote laboratory enables students to conduct experiments with real laboratory measuring equipment. The use of such learning resources improves the quality of the learning process and enables flexible and personalized learning tailored to the needs of students. The designed and developed remote laboratory is shown in Figure 32. It consists of two main modules: hardware and software.
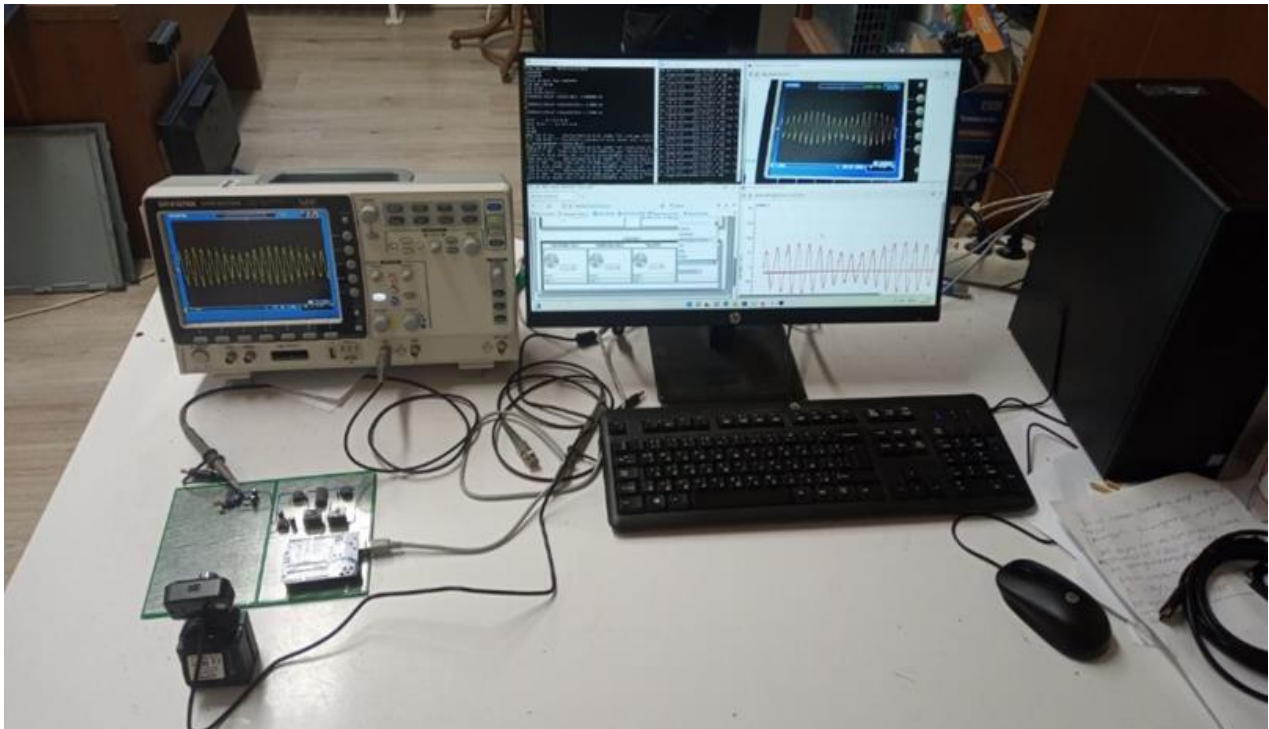

Figure.32: Remote lab

The remote lab hardware module contains the following devices: a digital oscilloscope, a lab mockup, a lab server, and a web camera.

The remote lab software module uses a client-server architecture. Programming languages Python, JavaScript, HTML and MySQL were used for the development.

3.2. SELECTION OF TECHNOLOGIES FOR DEVELOPING THE SOFTWARE OF THE DISTANT LAB

There are different technologies that are suitable for the development of the system software and the laboratory exercises for it. These technologies can be divided into two main groups: **commercial** and **non-commercial**.

A. ***Commercial remote lab software development environments*** – LabVIEW and MatLab/Simulink software packages are most commonly used. These software packages enable remote access to experiments over the Internet using an embedded web server.

B. ***Non-commercial environments for remote lab software development*** – the most commonly used are Python, JAVA, .NET, etc. In recent years, the Python scripting language has gained more and more popularity. It is a platform independent language and is supported by various operating systems such as: Linux, Windows and MacOS. Python's syntax is intuitive and easy to understand, making it suitable for use by a wide range of professionals. Python is the language of choice when it comes to performing data analysis and visualization. According to Gómez-Rodríguez and Ruíz-Méndez [67], Python is a programming language that is widely used in various areas of software engineering, including the development of remote laboratories. The Rython language supports libraries for working with various interfaces and system buses. One of these libraries is PyVISA, which is developed according to the VISA (Virtual Instrument Software Architecture) standard. This standard serves to configure, program, and troubleshoot instrumentation systems incorporating GPIB, VXI, PXI, serial (RS232/RS485), Ethernet/LXI, and/or USB interfaces.

In Table 5, **a summary comparison is made according to the main criteria** for the selection of software for the development of the remote laboratory. Based on these criteria and the information described in item 3.1.2, the remote laboratory described in the dissertation was implemented in the Python language.

Table.5: Criteria for the selection of the distant lab software

Criteria	LabVIEW	Matlab/ Simulink	JAVA	.NET	Python
Platform independence	Limited	Limited	Yes	Limited	Yes
Freely accessible environment for development	No	No	Yes	Limited	Yes
Presence of open code libraries	No	No	Limited	Limited	Yes
Possibility for web application development	Yes	Yes	Yes	Yes	Yes
Quick operation	High	High	Lower	Lower	Lower

3.3. SOFTWARE REALIZATION OF THE DISTANT LAB

3.3.1. THREE-LAYER ARCHITECTURE CLIENT-SERVER

To implement the remote laboratory, the three-layer client-server architecture is used, which is presented in Figure 35.
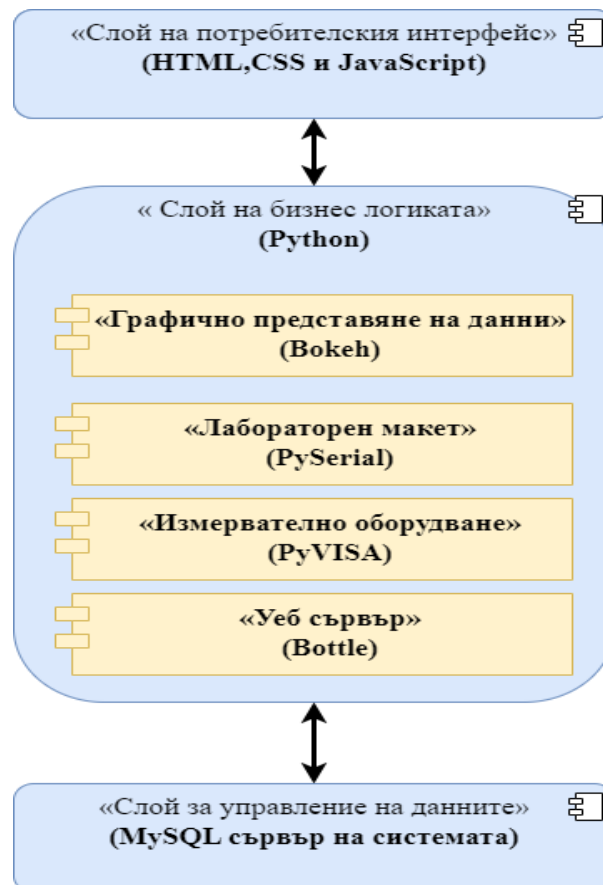

Figure.35: A three-layer architecture client-server, used for the realization of the distant lab

The choice of a three-tier client-server architecture [81, 82] for the development of the remote laboratory is tailored to the functionality and performance of the system and the amount of data to be generated and processed.

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In the three-layer architecture, each of the layers can be implemented with different software tools and can be upgraded and changed without affecting the other layers. The following programming languages Python, JavaScript, HTML, CSS, as well as Python libraries were used to implement the remote laboratory software: Bottle, Bokeh, PyVISA, PySerial, etc. The following points present the individual layers of the three-layer client-server architecture for implementing the remote laboratory.

3.3.2. LAYER OF THE USER`S INTERFACE

The user`s interface of the developed distant lab is presented on Figure 36.
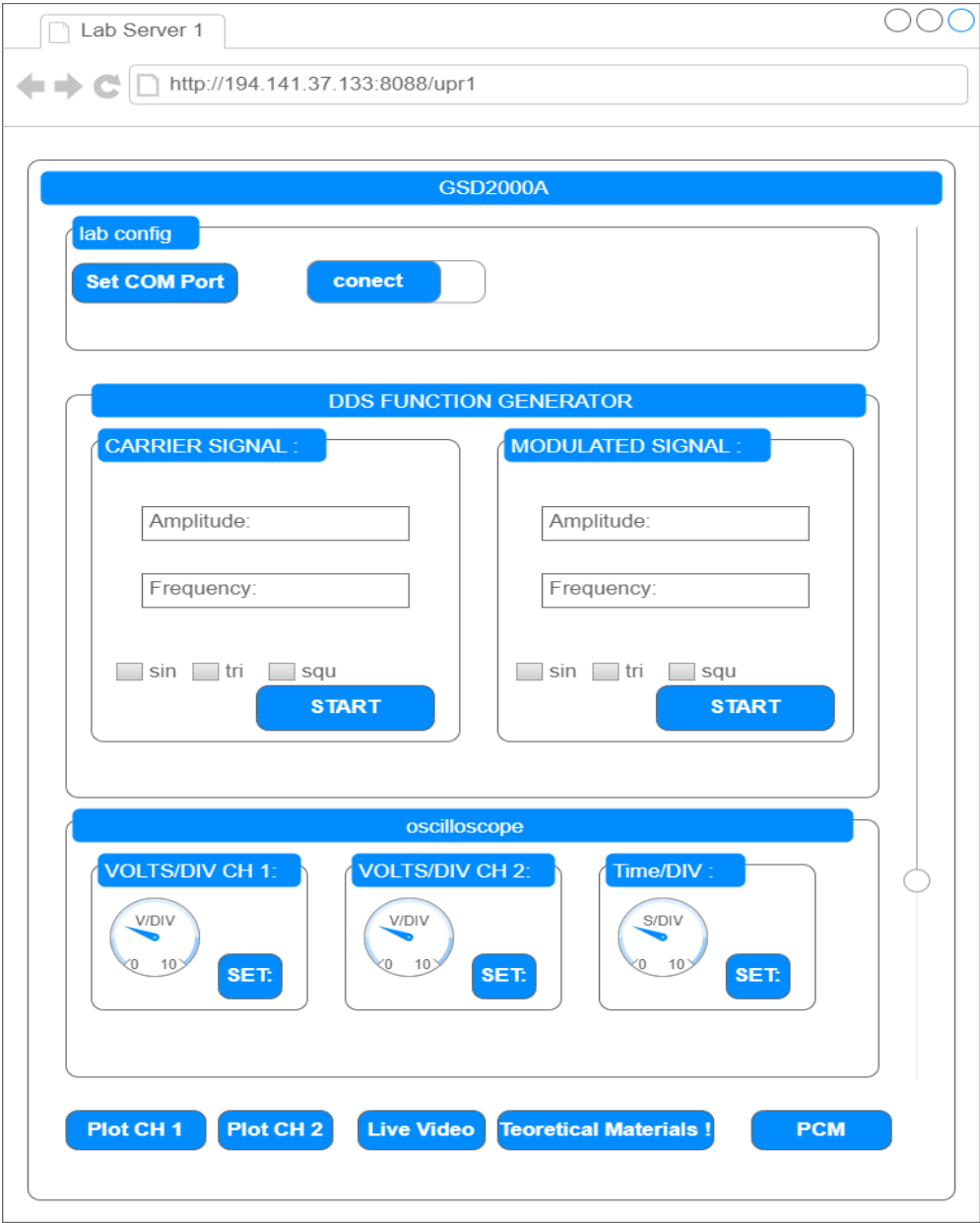

Figure 36: A prototype of the user`s interface

The user interface is designed to allow easy and intuitive control of the laboratory mock-up and measurement equipment. Some of its elements are specially designed to resemble operation of real laboratory equipment, such as the buttons that control the scope of the oscilloscope. They are developed in HTML, JavaScript and CSS. The user interface of the developed remote laboratory consists of the following three web forms (Figure 36):

A. *Lab config* – serves for configuration of the functional generator.

B. *Dds function generator* – serves for parameter setting of the carrying and modulating signal.

C. *Oscilloscope* – serves for the configuration of oscilloscope parameters.

When conducting measurements, the following additional options are provided:

A. *Monitoring the oscilloscope readings in real time* – this is done through the remote lab's video server, implemented through the Live Video button.

B. *Graphical representation of the obtained measurement results* – for this purpose, depending on the selected channel of the oscilloscope, the Plot CH1 buttons (corresponding to channel 1) and/or the Plot CH2 button (corresponding to channel 2) are used. When the user presses one of the two buttons, a new page opens in the client browser, on which the graph of the measured signal from the oscilloscope is visible.

C. *Generating a file with the obtained results* - through the interface of the remote laboratory, students can download the results of the measurement in the form of an excel file. This file is generated when calling the plotting functions for channel 1 or channel 2 of the oscilloscope.

3.3.3. LAYER OF THE BUSINESS LOGIC

The business logic layer is the middle layer in the three-tier client-server architecture and is responsible for implementing the business logic and presenting the data to the user through the application interface. Functionalities that implement the application logic are developed in this layer, as they are independent of the way the data is presented and the way the data is stored in the database.

The business logic layer is developed in the Python language and consists of the following **four modules** (Figure 35):

➢ Web server module (Bottle);

➢ Measuring Equipment Module (PyVISA);

➢ Lab mock-up management module (PySerial);

➢ Module for graphical representation of data (Bokeh).

3.3.4. LAYER FOR DATA MANAGEMENT

The main functions of the data management layer are as follows:

➢ Establishing a connection to the database or file system.

➢ Executing queries and commands to retrieve, add, edit or delete data.

➢ Transaction management to ensure reliability in data manipulation.

➢ Handling errors and exceptions related to data access.

➢ Ensuring abstraction and independence between the other layers of the architecture and the concrete data storage implementation.

3.4. CONCLUSIONS

The Distance Learning Lab is an innovative educational resource that provides multiple real-time distance learning opportunities. Such type of laboratories allow students to apply theoretical knowledge in practice without the need for physical presence in the laboratory.

Distance learning laboratories have a number of advantages over traditional laboratories. First of all, they allow students to work at a time and place convenient for them, which is important for those who cannot visit the physical laboratory due to geographical location, financial or other reasons. Second, distance learning labs allow for much broader student outreach because there is no limit to the number of students who can attend the lab.

In addition, distance learning labs can be much more effective for learning because multiple scenarios can be created to explore and test theoretical models and concepts that can be modified and adapted according to student needs.

CHAPTER FOUR. STUDYING THE AMPLITUDE MODULATION VIA DISTANT LAB

In the fourth chapter, general information about signal modulation is given, amplitude modulation, types of analog amplitude modulation and a laboratory exercise for studying amplitude modulation are described.

4.1. LABORATORY SEMINAR FOR EXAMINING THE AMPLITUDE MODULATION
4.1.1. THEORETICAL SETTING FOR EXAMINING THE AMPLITUDE MODULATION

In this lab exercise, create an amplitude-modulated signal, calculate the modulation index, and determine the frequency spectrum of this type of signal.

Using amplitude modulation (AM), the useful speech signal is converted into an electrical signal using an electronic device such as a microphone. This electrical signal is called a message. The message is then used to vary the amplitude of a high-frequency signal called a carrier or carrier signal. The carrier frequency is much higher than the message frequency.

4.1.2. EXPERIMENTAL SETTING FOR EXAMINING THE AMPLITUDE MODULATION

The block scheme for examining AM is presented on Figure 60.

Figure.60: Block scheme for studying AM

4.1.3. HARDWARE REALIZATION OF THE DISTANT LAB FOR EXAMINING AM

The hardware implementation of the remote laboratory for amplitude modulation research consists of two parts: **measuring equipment** and a **laboratory model**. Figure 61 shows the block diagram of the remote AM research laboratory.

The measuring equipment of the remote laboratory for amplitude modulation research consists of a GDS-2000A GW Instek digital oscilloscope. The communication between the laboratory mock-up, the measuring equipment and the laboratory server is carried out via a USB interface.
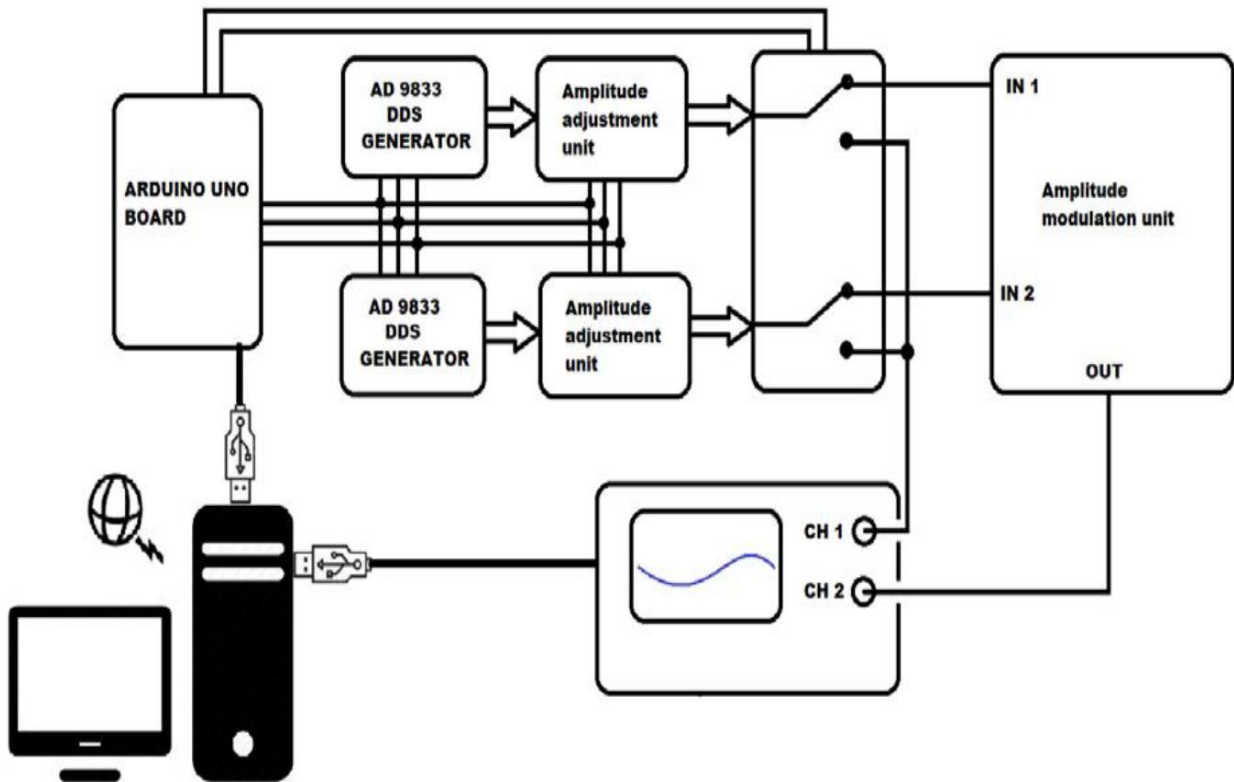
Figure 61: Block scheme of the distant lab for studying AM

The laboratory model of the remote laboratory for the study of amplitude modulation consists of the following components:

- ➢ Arduino Uno – It is a microcontroller board based on ATmega328P. ArduinoIDE is used to create applications and program Arduino boards. Arduino is an open source platform that offers a large set of libraries for working with peripheral devices (sensors, modules, actuators, Arduino Shields, etc.).
- ➢ Two function digital generators AD9833 (DDS generators for short - Direct Digital Synthesized) – are used to generate carrier and modulating signal.
- ➢ Digital potentiometer MCP42010 – used to change the amplitude of the generated signals.
- ➢ Dual op amp lm13700 – used to implement AM.

4.1.4. MANUAL FOR WORK WITH THE SYSTEM FOR REMOTE ACCESS TO TRAINING RESOURCES IN EXAMINING AM

Students to use the remote lab for AM research must complete the following steps:

1) Enter the system for remote access to laboratory exercises by opening the link http://194.141.37.133/LabSystem/.

2) To make a request for access to the AM research laboratory exercise by filling out a standard web form in the system. After the instructor reviews and approves the request, a schedule entry is created for access to the remote lab. The student should receive an e-mail from the system e-mail, which contains the following information: a link to the remote laboratory; name and password for access and time interval for using the remote laboratory.

3) To download from the theoretical materials section in the system everything that is necessary to conduct the laboratory exercise for the study of amplitude modulation.

4) To open the chat application of the system for communication with the teacher during the laboratory measurements. Through the chat application, the student can receive consultation from the teacher and additional instructions for performing the laboratory exercise.

5) To open the link http://194.141.37.133:8088/upr1 to the AM research exercise and authorize themselves with the name and password they received in the e-mail from the system. After the student opens the link to upr1 on the remote lab, he can set various parameters of the carrier and modulating signal.

6) To configure the connection to the lab mock-up through the user interface by selecting the serial interface and connection speed to the lab mock-up.

7) Start the video server to the remote laboratory and monitor the oscilloscope screen in real time. To do this, they should use the Video Lab button from the user interface, which opens a link to the video server of the remote lab. The web interface of the video server allows recording a video or photo of the lab exercise.

8) To configure the oscilloscope through the remote lab.

9) Make graphs of the measured signals and save them as pictures.

10) To complete the protocol for the conducted laboratory exercise for studying amplitude modulation.

CHAPTER FIVE. STUDYING THE IMPULSE-CODE MODULATION VIA THE DISTANT LAB

In the fifth chapter, pulse-code modulation (PCM) is presented; the block diagram of a PCM system; the concepts of discretization, perturbation, noise, distortion, quantization and quantum error and a laboratory exercise to explore PCM.

5.1. LABORATORY SEMINAR FOR EXAMINING THE IMPULSE-CODE MODULATION
5.1.1. THEORETICAL SETTING FOR EXAMINING THE IMPULSE-CODE MODULATION

In this lab exercise, pulse-code modulation is implemented by observing the analog signal before modulation and the values obtained at the decoder output. Through the digital generator of the lab model, an analog signal is produced at the Out_DC output of the AD 9833 module. The Out_DC output is connected to one channel of the amplifier module, thereby obtaining a signal with certain parameters (amplitude and frequency). The received signal is fed to one of the analog inputs of the Arduino Uno board, where the sampling process is implemented - this is the first stage of converting the continuous analog signal into digital.

The value of one discrete corresponds to the amplitude of the signal at a specific moment, and these values are obtained at equal time intervals. In figure 82 graphs from the user interface of the exercise are presented that illustrate the discretization process.
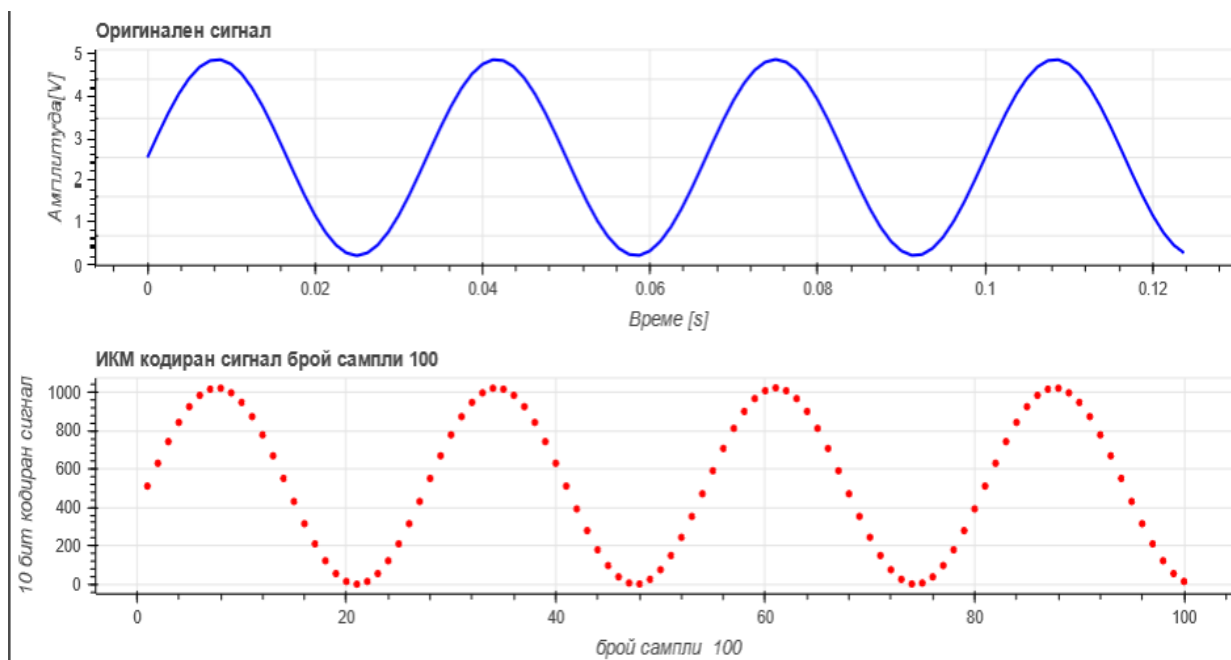

Figure 82: Graphics from the user`s interface of the analogue and encoded signal

For the development of the specific exercise, the conversion of the digital code of each discrete into analog voltage is used a specially developed software algorithm. The obtained values are displayed graphically on the computer screen, as shown in Figure 83.
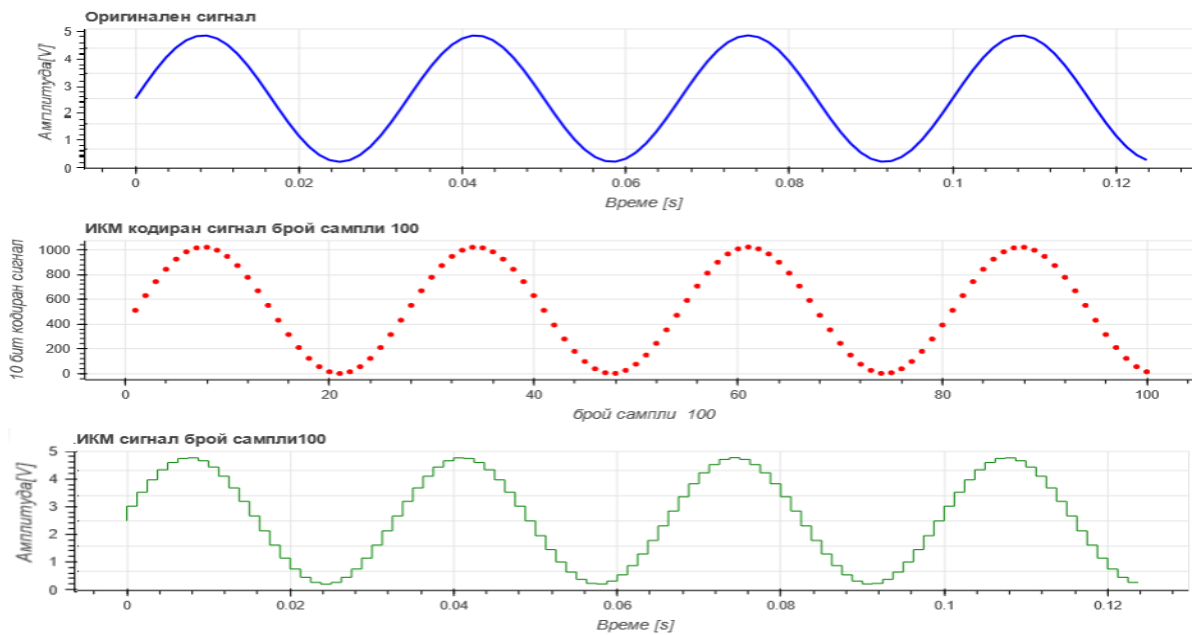

Figure 83: Graphics of the signals form the user`s interface

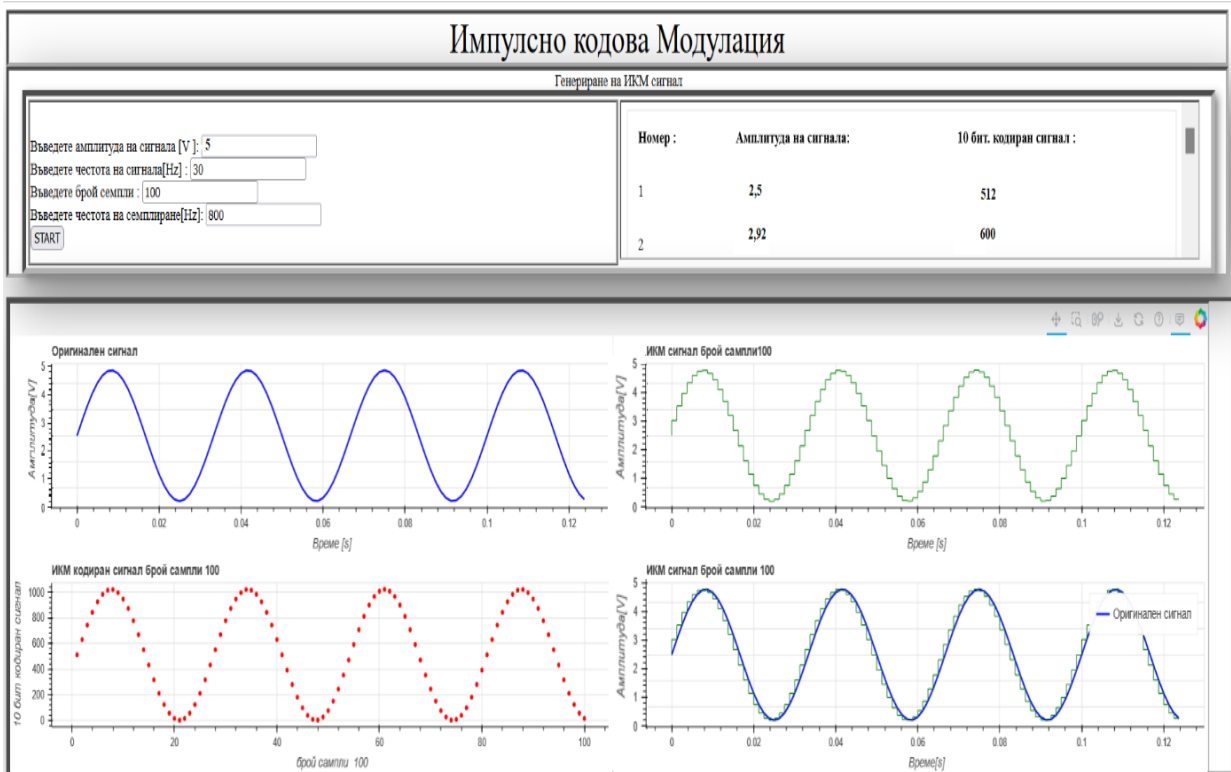The general view of the user`s interface in class is presented on Figure 84.

Figure 84: General view of the user`s interface

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5.1.2. EXPERIMENT OF THE IMPULSE-CODE MODULATION

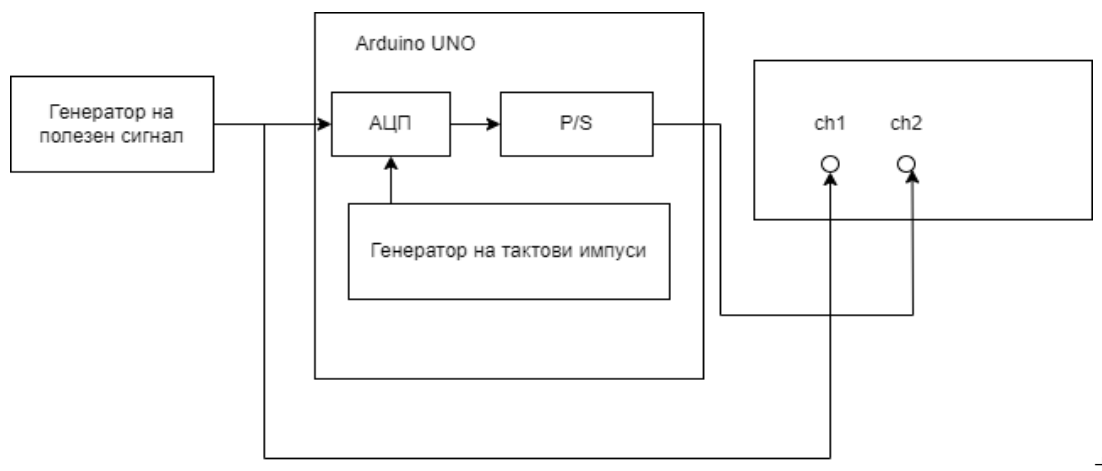The block scheme for examining ICM is presented on Figure 85.

Figure 85: Block scheme for studying ICM

5.1.3. A MANUAL FOR WORK WITH THE SYSTEM FOR REMOTE ACCESS TO TRAINING RESOURCES IN STUDYING THE IMPULSE-CODE MODULATION

In order to use the remote computer lab for research, students must complete the following steps:

1) Enter the system for remote access to laboratory exercises by opening the link http://194.141.37.133/LabSystem/.

2) To make a request for access to the laboratory exercise for PCM research, by filling out a standard web form in the system. After the request is fulfilled, the student receives an e-mail from the e-mail of the system, which contains the following information: a link to the remote laboratory; name and password for access and time interval for using the remote laboratory.

3) To remove from the theoretical materials section in the system everything that is necessary for conducting a laboratory exercise for the study of PCM.

4) To open the chat application of the system for communication with the teacher during the laboratory measurements. Through the chat application, the student can receive consultation from the teacher and additional instructions for performing the laboratory exercise.

5) Open the link http://194.141.37.133:8090/upr2 to the PCM study exercise and log in with the name and password they received in the e-mail from the system. After the student opens the link to upr2 on the remote lab, he can set various parameters (frequency and amplitude) of the useful signal generator, number of samples and sampling rate.

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6) Start the video server to the remote laboratory and monitor the oscilloscope screen in real time. To do this, they must open the link http://194.141.37.133:8089/ to the video server of the remote laboratory. The web interface of the video server allows recording a video or photo of the lab exercise.

7) Adjust the frequency and amplitude of the useful sinusoidal signal generator, the sampling frequency and the number of samples (diskettes) depending on the tasks.

8) Make graphs of the measured signals and save them as pictures. This can be done from the user interface of the lab exercise by having the student press the save button from the graphics tools.

9) To complete the protocol for the conducted laboratory exercise for the study of pulse-code modulation.

CHAPTER SIX. EVALUATION OF THE SYSTEM FOR REMOTE ACCESS TO TRAINING RESOURCES

6.1. METHODOLOGY FOR OVERALL EVALUATION OF THE SYSTEM FOR REMOTE ACCESS TO TRAINING RESOURCES

The system evaluation methodology includes various methods and techniques for data collection and subsequent quantitative and qualitative data analysis (interviews, questionnaires and tests of student learning achievements).

The purpose of the evaluation is to identify problems with the system before it is used in training courses. The following two approaches to testing the usability of the system are envisaged, which are included in a pilot experiment:

A. **General review of the system**. Students perform laboratory exercises with the system individually, but with the support of a teacher. While performing each of the exercises, participants were observed and then asked to share their experiences with the system.

B. **Students' success**. The purpose of the evaluation is to measure the effect of the system on the students' achievements in the implementation of the relevant laboratory exercises. The students are randomly divided into two groups, and the work tasks during the laboratory exercises of both groups are the same. In order to draw adequate conclusions, at least 15 students were included in each of the groups.

The pilot experiment of the system for remote access to learning resources took place during the academic year 2020-2021. with students from the "Telecommunications and Information Systems" and "Telecommunications with Management" majors, 4th year of the OCS "Bachelor" in the "Fundamentals of Telecommunications" course. Two laboratory exercises were conducted through the remote laboratory: an amplitude modulation study and a pulse-code modulation study. At the end of the experiment, 4 teachers and 15 students were asked to evaluate the quality and pedagogical effectiveness of the remote laboratory. Three specific instruments were used to collect information on system performance indicators, namely:

➢ Questionnaire (survey) about the attitude towards computer-based learning.
➢ Questionnaire (survey) about the usability of the system.
➢ Achievement of participants.

As a diagnostic method, a survey of teachers and students is used to establish their opinion and attitude towards computer-based learning and the usability of the system. The survey was carried out with the help of a questionnaire (survey card), which is a system of statements carrying information about the opinion and attitude of the surveyed persons.

6.2. EVALUATION OF THE STUDENT`S ATTITUDE TOWARDS COMPUTER LEARNING

The Computer Learning Attitude Questionnaire applies a Likert scale [99], rating each item from 1 to 5, minimum to maximum agreement with a specific statement in the questionnaire. The responses are usually averaged to determine the overall attitude of the participants towards the particular statement.

Attitude toward computer-based learning is considered a variable that needs to be controlled for as it may influence system evaluation. Participants were asked to answer a short questionnaire about their attitudes towards computer-based learning. The questionnaire consists of 15 statements and the participants have to answer by choosing a value between 1 and 5 depending on whether he/she strongly disagrees ("1") or strongly agrees ("5") with the statements.

The items in the questionnaire that receive a score above 4.50 are: 1, 3, 7 and 13, which refer to the use of the "Internet as a learning medium". All other items in the questionnaire were scored above four, indicating high agreement with the statements in the questionnaire and generally indicating a positive attitude towards computer-based learning.

The results of the "Questionnaire about the attitude towards computer-based learning" have the following synthesized form:

1) The questionnaire consists of 15 items using the Likert scale, 15 participants answered the questionnaire.
2) Attitude is a valuable factor to control because it can affect system evaluation.
3) The item with the highest score is (4.67) "I like working in an Internet environment".
4) The global average value in the questionnaire is 4.25 and shows a high positive attitude of the participants towards computer learning.

The histogram (Figure 86) shows the values of the items in the questionnaire on the Likert scale "Attitude to learning by computer" from 1 – minimum, to 5 – maximum. The range of responses ranged from 2.1 to 5, with a mean value of 4.25, which could be interpreted as a high positive attitude of the participants towards computer-based learning.
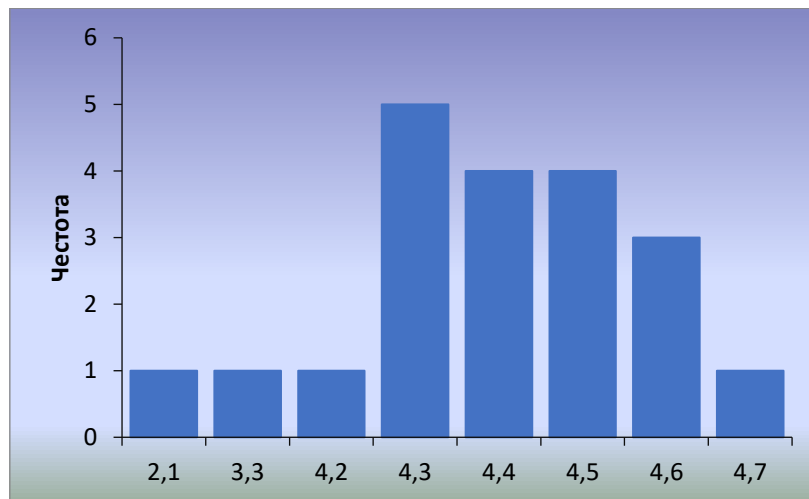
Figure 86: Histogram of the results from the Questionnaire related to the
attitude towards computer learning
(Mean=4.25, Std. Dev.=0.6, N=15)

6.3. EVALUATION OF THE USEFULNESS AND FUNCTIONALITY OF THE DEVELOPED SYSTEM FOR REMOTE ACCESS TO TRAINING RESOURCES

The evaluation of the usability and functionality of the remote access to learning resources system refers to how well the system meets the needs and requirements of the users. This assessment serves as a contextual variable that needs to be controlled for, because in an online course with remote lab access, the way the system works can affect the entire learning process and also the final results.

6.3.1. ANALYSIS OF THE STUDENTS` RESULTS FROM THE QUESTIONNAIRE RELATED TO THE USEFULNESS AND FUNCTIONALITY OF THE SYSTEM

The Remote Access System Evaluation Tool is a survey ("Questionnaire on Usability and Functionality of the Developed System"). Students studying the "Fundamentals of Telecommunications" course at Plovdiv University were asked to answer the "Questionnaire on the Usability and Functionality of the System"). The questionnaire contains a total of 19 statements, applying the Likert scale, from 1 (strongly disagree) to 7 (strongly agree).

Most students find the system stable and easy to use. Over 60% of them agree with the statement that the response time of the system is good. The variation in the answers to this question is due to the fact that students connect to the system from different devices and their Internet connection speed is different.

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Most of the students found the study materials uploaded to the system to be good and clear, but at the same time, only 61.8% of them felt that these materials were completely sufficient for them to perform remote experiments. All students found remote laboratory experiments to be an effective learning experience. All items scored above 5.50, with a mean of 6.25 and a standard deviation of 0.26, indicating almost complete agreement in user evaluation of the system.

At the end of the questionnaire, the students were asked the following two open-ended questions: *"What are the positive characteristics of remote laboratory exercises?"* and *"What are the negative characteristics of remote laboratory exercises?"*. The students' responses can be summarized as follows:

Positive features:

➢ Possibility of carrying out the attempts at a convenient date and time.

➢ Possibility of conducting the experiments in conditions of social distance.

➢ Remote labs increase students' technological literacy.

Negative features:

➢ Lack of opportunity for collaboration – at a time only one student can perform a given remote experiment.

➢ Lack of immediate help from the teacher during the experiments.

➢ Some students feel more confident working with the lab equipment in groups.

The histogram (Figure 87) shows the statistics from the "Questionnaire on the usability and functionality of the system" applied to students.
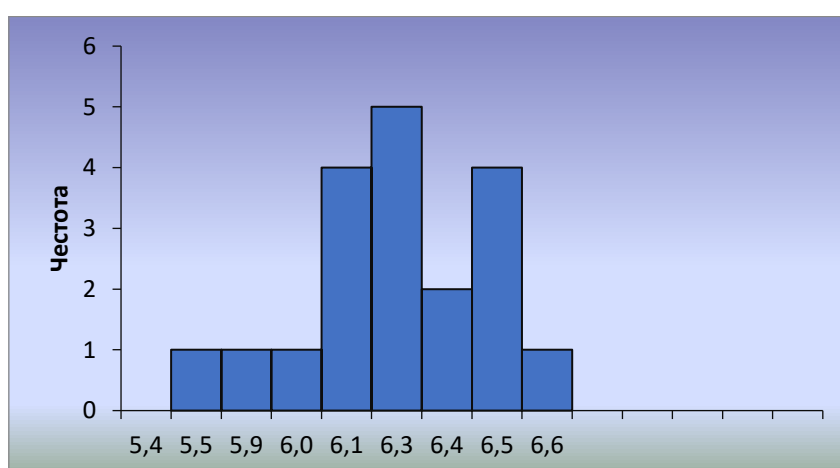

Figure 87: Histogram or the results from the Questionnaire about
the usefulness and functionality of the system
(Mean=6.25, Std. Dev.=0.26, N=15)

The results of the "Questionnaire on the usability and functionality of a system" have the following synthesized form:

1) The questionnaire consists of 19 items (questions), the Likert scale is applied, from 1 (completely disagree) to 7 (completely agree).

2) The following items were most highly rated: "It was easy to learn to use the system" (6.60); "System response time is good" (6.50); "I can finish my work quickly with the help of the system" (6.50); "I can complete my work effectively using the system" (6.50); "The training materials uploaded to the system and the chat module of my system were quite sufficient to carry out the remote experiments" (6.50).

3) The global average value in the questionnaire is 6.25, which indicates a positive assessment and agreement among the participants to the usability and functionality of the developed system for remote access to educational resources.

6.3.2. ANALYSIS OF THE LECTURERS` RESULTS FROM THE QUESTIONNAIRE RELATED TO THE USEFULNESS AND FUNCTIONALITY OF THE SYSTEM

Teachers' perceptions were collected in interview form. According to them, the system works very well. It is easy to use and has all the capabilities of resource reservation and user monitoring. The results of the students' laboratory protocols confirmed the reliability and accuracy of the measurements carried out.

The main disadvantage of the system is that in a given time interval only one student can perform a given remote experiment. Thus, instructors must spend much more time observing student work than in a traditional lab where students work in groups.

6.4. EVALUATION OF STUDENTS` ACHIEVEMENTS

In order to verify that the system of remote access to learning resources is effective, an analysis should be carried out to what extent the learning objectives have been achieved. This is done by evaluating the knowledge gained by the students through the evaluation of the protocols submitted by them from the conducted laboratory exercises.

Two groups of students are evaluated:

➢ **Tested group** - students who conduct remote laboratory exercises using the developed system for remote access to educational resources;

➢ **Control group** – students who carry out face-to-face exercises in a laboratory.

Both groups consist of 15 students each. There are two lab exercises that are assessed: *"Exploration of Amplitude Modulation"* and *"Exploration of Pulse Code Modulation"*. Each protocol is graded from 1 to 10. After students complete each laboratory exercise, instructors assign the appropriate number of points to the protocols. The correspondence between number of points and grade according to the six-point system is as follows: from 6p. up to 6.99p. - Middle 3); from 7p. up to 7.99p. – Good (4); from 8p. up to 8.99p. – Very good (5); from 9p. up to 10p. - Excellent 6).

The average results of the students from the **test** and **control** groups in "Research of amplitude modulation" and "Research of pulse-code modulation" are indicated in Table 19 and in Figure 91.

Table 19: Average results of the tested and control student groups

Students	AVERAGE RESULTS		
	Average number of points, Received after examining AM and ИКМ	Mark	
		words	numbers
Control group	9,18	**Excellent**	5,73
Tested group	8,68	**Very good**	5,33

From the obtained results, it can be seen that in the control group, the average score is **Excellent (5.73)**, and in the test group it is **Very good (5.33)**. This means that the performance of students in the test group does not change as a result of using the remote access to learning resources system.
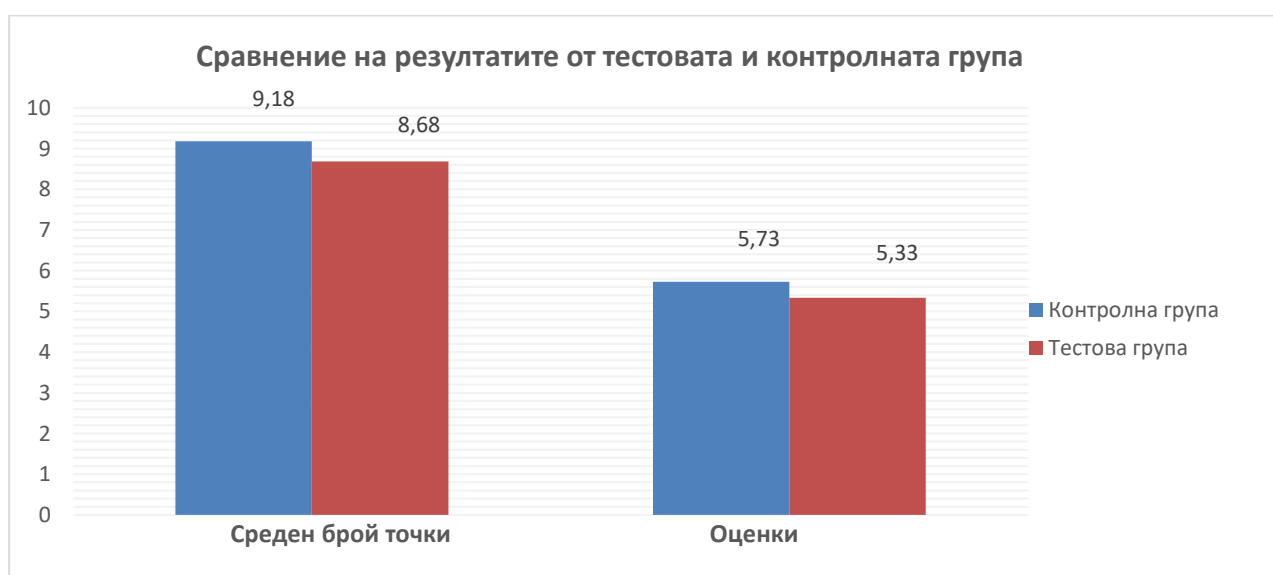

Figure 91: Comparison of the average results of the students from the tested and the control groups

CONCLUSION

The dissertation analyzes the existing systems for managing remote laboratories, as well as the requirements they must meet. The stages through which the design and implementation of the system goes are defined. Based on the analysis, the main characteristics and parameters of the system for remote access to real laboratory equipment to be used for the needs of students studying in the field of technical sciences have been formulated.

A software system has been implemented that provides remote access to a series of laboratory exercises in the field of telecommunications. Such a system can be very useful for training in various fields where it is necessary to carry out experiments and practical exercises to complement theoretical knowledge.

CONTRIBUTIONS OF THE DISSERTATION WORK

The basis of the dissertation work is the design and development of a new system for access to educational resources (remote laboratories). This system is an innovative and practical solution that can be used for educational purposes and access to laboratory equipment for scientific research.

A detailed analysis and overview of the existing systems and platforms for access to remote laboratories has been made within the framework of the dissertation work. In order to evaluate the effectiveness and applicability of the developed system, two remote laboratories have been developed – for the study of amplitude modulation and for the study of pulse-code modulation.

The main contributions of the dissertation work can be characterized as scientific-applied and applied. The **scientific and applied contributions** are the following:

➢ An approach to implement a web-based system for access to educational resources is proposed.

➢ An architecture of a system for remote access to learning resources is presented.

The **applied contributions** of the dissertation research are as follows:

➢ The software of the system for accessing learning resources has been implemented.

➢ The software and hardware for the remote laboratories integrated in the system have been implemented.

➢ A method for remote access to laboratory equipment through a web interface was designed and implemented.

➢ An analysis of the opinions of the users (students and teachers) has been made and the results of the use of the system have been presented.

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