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DEVELOPMENT OF A DIGITAL EDUCATIONAL PLATFORM
FOR STUDYING RADIO ENGINEERING COURSES

The main tasks solved with the help of a digital educational platform with interactive learning opportunities are a remote process of obtaining knowledge, providing permanent access to educational materials, and monitoring the level of students' performance. This paper considers the development of a digital educational platform for the remote study of modern Ultra high frequency (UHF) and Extremely high frequency (EHF) radio systems. The architecture of the developed platform is a client-server. The server part includes a database of collected laboratory results, and the client part is responsible for displaying and outputting the necessary information. The list of virtual labs that are part of the educational platform, as well as devices and measuring instruments used in the virtual laboratory is presented. An example of a lab with remote access implemented using the Unity 3D application development tool is given. This digital educational platform will be used by students of the «Radio Engineering, Electronics and Telecommunications» educational program to study radio engineering courses. It is shown that the use of virtual laboratory work in the educational process can replace real expensive equipment, as well as consolidate practical skills in training.

Keywords: digital educational platform, virtual laboratory, satellite radio monitoring, remote access, client-server architecture, Unity3D, Leap Motion.

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Радиотехникалық пәндерді зерттеуге арналған цифрлық
білім беру платформасын әзірлеу

Интерактивті оқыту мүмкіндіктері бар цифрлық білім беру платформасының көмегімен шешілетін негізгі міндеттер білім алудың қашықтан процесі, оқу материалдарына тұрақты қолжетімділікті қамтамасыз ету және оқушылардың үлгерім деңгейін бақылау болып табылады. Бұл жұмыста аса жоғары жиілікті (АЖЖ) және өте жоғары жиілікті (ӨЖЖ) диапазондарының заманауи радиожүйелерін қашықтықтан зерттеуге арналған цифрлық білім беру платформасын әзірлеу қарастырылған. Әзірленген платформаның архитектурасы – клиент-сервер. Сервер бөлігі жиналған зертханалық нәтижелер туралы мәліметтер базасын қамтиды, ал клиент бөлігі қажетті ақпаратты көрсетуге және шығаруға жауап береді. Білім беру платформасының құрамына кіретін виртуалды зертханалық жұмыстардың тізімі, сондай-ақ виртуалды зертханада қолданылатын құрылғылар мен өлшеу құралдары ұсынылған. Unity 3D қосымшаларын әзірлеу құралын қолдана отырып, қашықтан қол жетімділікпен зертханалық жұмысты жүзеге асырудың мысалы келтірілген. Бұл цифрлық білім беру платформасын Халықаралық ақпараттық технологиялар университетінің радиотехникалық пәндерді оқу процесінде «Радиотехника, электроника және телекоммуникациялар» білім беру бағдарламасының студенттері пайдаланады. Оқу процесінде виртуалды зертханалық жұмыстарды қолдану нақты қымбат жабдықты ауыстыруға, сондай-ақ оқытудағы практикалық дағдыларды бекітуге мүмкіндік беретіні көрсетілген.

Түйін сөздер: цифрлық білім беру платформасы, виртуалды зертхана, спутниктік радиомониторинг, қашықтан қол жеткізу, клиент-сервер архитектурасы, Unity3D, Leap Motion.

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Разработка цифровой образовательной платформы для изучения радиотехнических дисциплин

Основными задачами, решаемыми с помощью цифровой образовательной платформы с интерактивными возможностями обучения, являются дистанционный процесс получения знаний, обеспечение постоянного доступа к учебным материалам, контроль уровня успеваемости обучающихся. В данной работе рассмотрена разработка цифровой образовательной платформы для дистанционного изучения современных радиосистем сверхвысоких частотных (СВЧ) и крайне высоких частотных (КВЧ) диапазонов. Архитектура разрабатываемой платформы – клиент-сервер. Серверная часть включает в себя базу данных собранных результатов лабораторных работ, а клиентская часть отвечает за отображение и вывод необходимой информации. Представлен перечень виртуальных лабораторных работ, входящих в состав образовательной платформы, а также устройства и измерительные приборы, используемые в виртуальной лаборатории. Приведен пример реализации лабораторной работы с удаленным доступом, выполненной с помощью инструмента разработки 3D приложений Unity 3D. Данная цифровая образовательная платформа будет использована студентами образовательной программы «Радиотехника, электроника и телекоммуникации» в процессе изучения радиотехнических дисциплин. Показано, что использование виртуальных лабораторных работ в учебном процессе позволит заменить реальное дорогостоящее оборудование, а также закрепить практические навыки в обучении.

Ключевые слова: цифровая образовательная платформа, виртуальная лаборатория, спутниковый радиоманиторинг, удаленный доступ, архитектура клиент-сервер, Unity3D, Leap Motion.

Introduction

Today, we witness the active introduction of modern digital technologies in the field of education, one of the main reasons for which is the transition to distance learning due to the global COVID 19 pandemic. Virtual laboratory work, virtual textbooks, online courses, as well as digital educational platforms that allow students to acquire the necessary skills and abilities remotely via the Internet are increasingly used in the educational process.

The main tasks solved with the help of a digital educational platform with interactive learning opportunities are a remote process of obtaining knowledge, providing permanent access to educational materials, and monitoring the level of students' performance. The most popular free educational platforms or learning management systems (LMS) for organizing the learning process are Moodle and Google Classroom.

The Moodle platform is used in many higher education institutions. The main advantages of this platform include its convenience, open-source code for creating additional extensions, access to a mobile application, the ability to conduct performance analytics, and others. Among its shortcomings, one can single out the use of large computing resources by the platform, which leads to additional costs.

The Google Classroom platform is also one of the most popular LMS. The advantages of Google Classroom are the easy registration and the user-friendly interface, but the disadvantage is that only Google tools are used within the platform.

From the distance learning perspective, virtual work performed remotely is of practical interest. Such virtual labs can be implemented both as a web application and as a client-server architecture using the thin client approach on the user side, in which a small application that is not demanding on computing resources is installed and executed on the user side. At the same time, if the simulated instruments and devices have an "appearance" similar to their "real" counterparts and provide access to "real" controls, this will be an undoubted advantage of these systems.

Virtual labs created using various graphical integrated development environments allow students to fully master the studied material and consolidate practical skills in the studied area, as well as replace real expensive equipment. Interactive laboratories are widely used in universities of different countries [1-4].

Comprehensive laboratory work, including the implementation of remote and real experiments,

experiments with a computer-aided design system, as well as further work on the design and manufacture of high-frequency filters, is presented in the paper [5]. Remote labs for the study of radio frequency experiments are carried out in the European Remote Radio Laboratory (ERRL). These experiments allow you to measure parameters such as return loss, standing wave ratio, signal power, and impedances. With the help of remote experiments, students gain knowledge in the field of electromagnetic wave propagation, analytical and graphical methods used in the derivation of formulas for microwaves and develop the ability to establish correlations between physical phenomena and handle highly complex measuring instruments (for example, a vector analyzer).

The authors in the article [6] present a virtual tutorial on the calculation of radio-electronic coverage "RADIOGIS". The program contains various practical exercises that allow students to acquire knowledge related to the planning of radio communication systems. Such types of calculations as radio link budget calculation, network coverage calculation, network coverage optimization in radio communication systems, etc. are given. A feature of the program is that it is based on GIS technology, which allows students to familiarize themselves and strengthen their knowledge in this area. Radio signal propagation models for calculating network coverage were implemented in C++.

The development of a virtual lab for the study of Fresnel zones and radio wave diffraction is described in the work [7]. It was made using the Moodle platform and the Labrick virtual lab framework.

The implementation of training within a virtual laboratory, which includes the use of video games, multimedia content and virtual simulations, is presented in [8]. The virtual laboratory work is intended to study the problem of planning wireless networks and improve students' knowledge in the field of key concepts of wireless networks.

Method and methodology

The educational platform for studying radio engineering courses

The purpose of this work is to develop a digital educational platform for the study of radio engineering courses.

The development of an educational platform implies the implementation of many different functions: registration, authorization, uploading and downloading data, displaying information, performing virtual labs, etc. All this implies data

management, which is impossible without a database. Therefore, when designing the application, much attention was paid to the development of data storage logic, determining the necessary entities, relationships between them, and access control. The types of user roles are also defined: an administrator, a teacher, and a student. The access levels and the number of available functions change depending on the user role.

For the platform to be available on the local network, it is planned to deploy it on a server and define access depending on the user role. The architecture of the project is client-server. This means that, depending on the functions, the load is distributed between two types of devices: a client requesting services and a server providing services. After placing the platform on the local network, it is planned to test it, fix weaknesses, and improve functionality. This approach allows checking the implementation of the project without high risks. As a result, it is planned to deploy the system on the global Internet. Figure 1 shows a screenshot of the educational platform for studying radio engineering courses.

The educational platform contains such types of virtual labs on the study of SHF and EHF devices as:
− study of a reflector antenna for a satellite communication system;
− study of the waveguide filter;
− study of microstrip resonator;
− study of coaxial-waveguide transition;
− study of the transistor amplifier;
− study of the radio monitoring process of the radio emission source;
− study of the main parameters of the Earth station of satellite communications.
The parameters in the virtual labs are measured using such instruments as:
− vector network analyzer ZVA-40;
− vector network analyzer E8363B PNA Network Analyzer;
− digital oscilloscope RTC1000;
− spectrum analyzer FPC1500.
Also, the signal generator SMC 100A can be used in virtual laboratory work.

When constructing models of SHF devices, analytical calculations were used or their computer models were created, which were built based on numerical results obtained using the CST Microwave Studio software. A distinctive feature of the development is the interface of virtual instruments, which exactly copies the appearance of real devices.
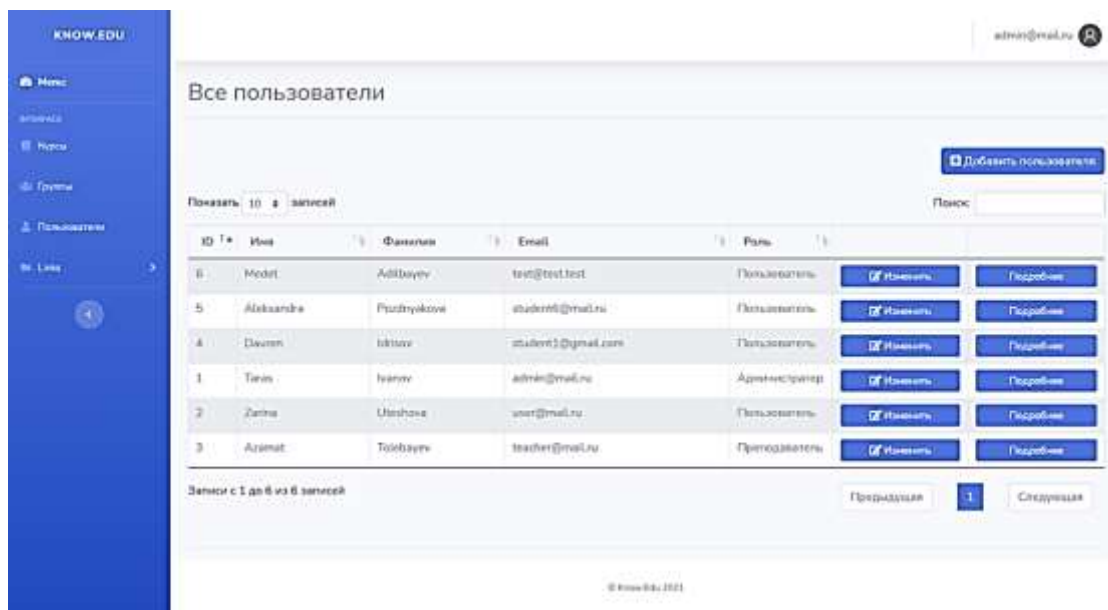
Figure 1 – Screenshot of the educational platform for studying radio engineering courses

*Mirror antenna for a satellite communication system*

This device consists of a mirror and a waveguide horn of a rectangular or circular cross-section that irradiates the mirror. The calculation of the electrodynamic characteristics (modulus of reflection coefficient |S11| and voltage standing wave ratio (VSWR)) of reflector antennas with different feeds was carried out using numerical simulation programs. The user interface of the reflector antenna model is shown in Figure 2. It can be seen from the figure that the user can select the type of feeds (horns) and frequency range. Such a construction of the model makes it possible to add, for example, the possibility of changing the geometric dimensions of the antenna itself without any special modifications to the software.
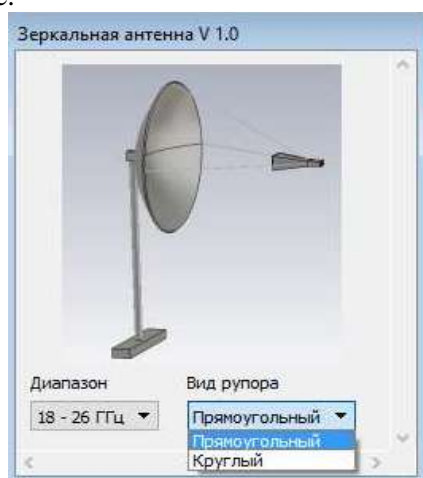
Figure 2 – The user interface of a reflector antenna model

Waveguide filter

In the modern UHF and EHF technology, various waveguide filters are widely used. These devices are manufactured not only based on classical rectangular waveguides but also using waveguides of complex cross-sections, which have a number of advantages. In this work, two different filter models were created: a filter on a rectangular waveguide and a filter on an H-waveguide. The user interface of the bandpass filter model is shown in Figure 3.
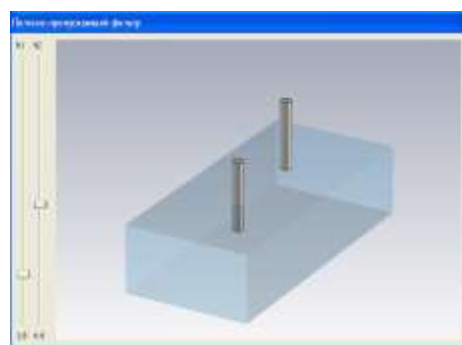

Figure 3 – The user interface of a rectangular waveguide filter model

The user can change the depth of immersion of the pins in the waveguide. In this case, the corresponding values are selected from the binary data set in real-time, the necessary approximating polynomials are constructed, and the obtained amplitude-frequency characteristic of the filter is displayed on the screen of the cathode-ray tube of the indicator unit. After that, the user can make all the necessary measurements (bandwidth, loss, etc.).

Microstrip resonator

A microstrip resonator is a segment of a waveguide with a dielectric substrate on which three metal conductors are located. The user interface of the microstrip resonator (Figure 4) allows you to change the length and width of the middle conductor. After the user changes the dimensions of the resonator, the required set of S-parameters is selected from the binary file, which is processed accordingly and transferred to the measuring device for display.
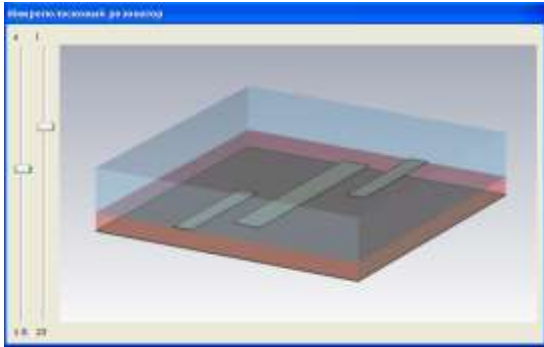
Figure 4 – The user interface of the microstrip resonator model

Satellite radio monitoring of the source of radio emission

The development of a model for the process of radio monitoring of a radio emission source was carried out on the basis of such publications of the International Telecommunication Union (ITU) as the Radio Regulations, radio monitoring handbooks, ITU-R recommendations, reports on regulating the use of the radio frequency spectrum and satellite orbits. To develop this laboratory work, the most important points were identified to understand the principle of operation of a radio monitoring system based on a small spacecraft (SSC). In addition to the computational part, visualization also turned out to be an important component, since it is a demonstration of the radio monitoring process that allows you to determine the radio emission sources (RES) [9].
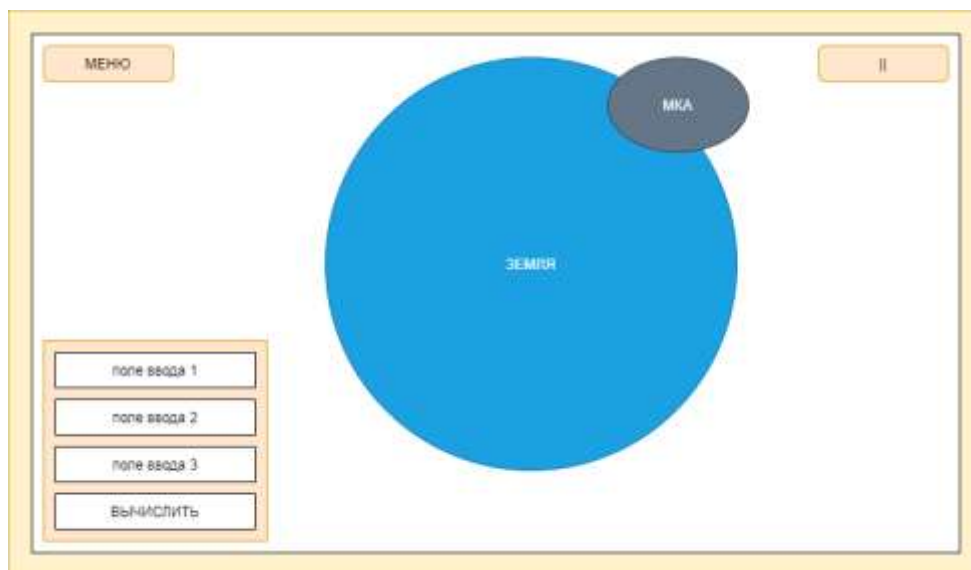
As a result, a scene template was created (Figure 5), consistent with the lab procedure.

Thus, the work consists of two elements that are important for the user and his understanding of the operation of the system: observation of ground-based RES and SSC, and performing calculations. The first was implemented using 3D models of the SSC and the Earth, corresponding to reality. And the second one is implemented thanks to the calculation algorithm inside the virtual lab. It was divided into three stages:

- power calculation;
- latitude calculation;
- longitude calculation.

The application logic was written in C#. There are three main classes inside the scene: UIController, SceneLogicController and CalculationsController. The first script UIController is responsible for controlling the user interface, the second – CalculationsController implements all the required calculations; the third – SceneLogicController controls the behaviour of the scene elements: the Earth, the SSC, the RES system, as well as the interaction between them and the UI.

Thus, the lab was carried out, which made it possible to study the principles of operation of the radio monitoring system. The process of developing the virtual lab for studying the operation of a radio monitoring system is given.

Figure 5 – The scene template

The execution of these calculations is consistent and follows the order of the lab. This approach allows focusing the user's attention because the transition to each subsequent step implies the implementation of the previous one: the longitude calculation is impossible without power and latitude calculation at the program level [10].

The application logic was written in C#. There are three main classes inside the scene: UIController, SceneLogicController and CalculationsController. The first script UIController is responsible for controlling the user interface, the second – CalculationsController implements all the required calculations; the third – SceneLogicController controls the behaviour of the scene elements: the Earth, the SSC, the RES system, as well as the interaction between them and the UI.

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Figure 6 – The lab scene

A virtual model of the measuring device

Let us consider the simulation of a measuring device with remote access using the ZVA 40 vector network analyzer as an example of one of the market leaders in measuring equipment from Rohde & Schwarz. All its functionality is implemented by two methods: with and without redrawing the characteristics of the device being studied on the device screen, i.e. with or without requesting data from the connected device. The process of interaction of various parts of the device models included in the lab "Filter on a rectangular waveguide" is schematically shown in Figure 7.
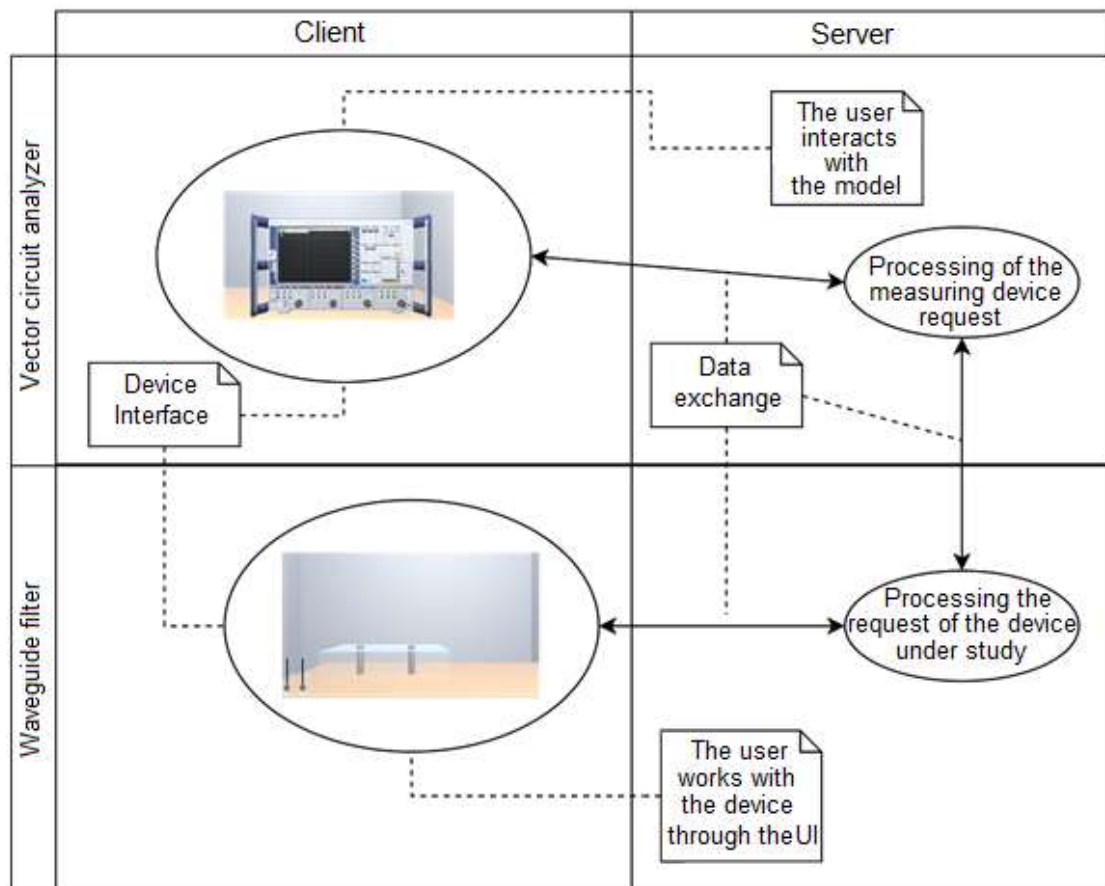
Figure 7 – The interaction of the models of the devices in the virtual lab

It can be seen from the figure that if it is necessary to redraw the characteristics of the device being studied (for example, the user has changed the displayed frequency range or the displayed parameters), the server is requested for the required data, i.e. the database is accessed, which stores the necessary S-parameters of the device under study. In this case, we adhere to certain rules: the client sends a request to the server and waits for a response, which contains a set of necessary S-parameters to build the frequency response of the device. After receiving and processing it, a special array is created, the index of which is the frequency value belonging to the specified sweep range. It is this array that is used further by all internal methods of the created class "Vector Network Analyzer".

It can be seen that only the module that implements the user interface should be located on the client side, i.e. which handles pressing buttons, determines which one is pressed and, if necessary, sends a request to the server. And the server component, at the request of the client, must return the data it needs for processing.

Obviously, data exchange between different parts of devices (between client and server) is possible only within a strictly defined interaction protocol.

An example of the remote access lab

Let us consider an example of the remote lab implementation. The Unity 3D package was chosen as a development tool, which is distinguished by easy integration of various libraries, the ability to develop applications for any platform (mobile devices, PC, web), a user-friendly interface and a wide range of tools. There are also many additional modules that allow you to implement a variety of systems and facilitate the work on the project and its further use. With the help of this package, modules of the client and server parts, data management and interaction of instruments and devices with each other were implemented.

The client part consists of a user interface (Figure 8) and displays the information on the device screen, including redrawing the frequency response of the device and the operating modes of the vector network analyzer. The server stores data about users and the main part of the software package. On the user's device, after authorization, a copy of the module he or she needs is created, which avoids code duplication.
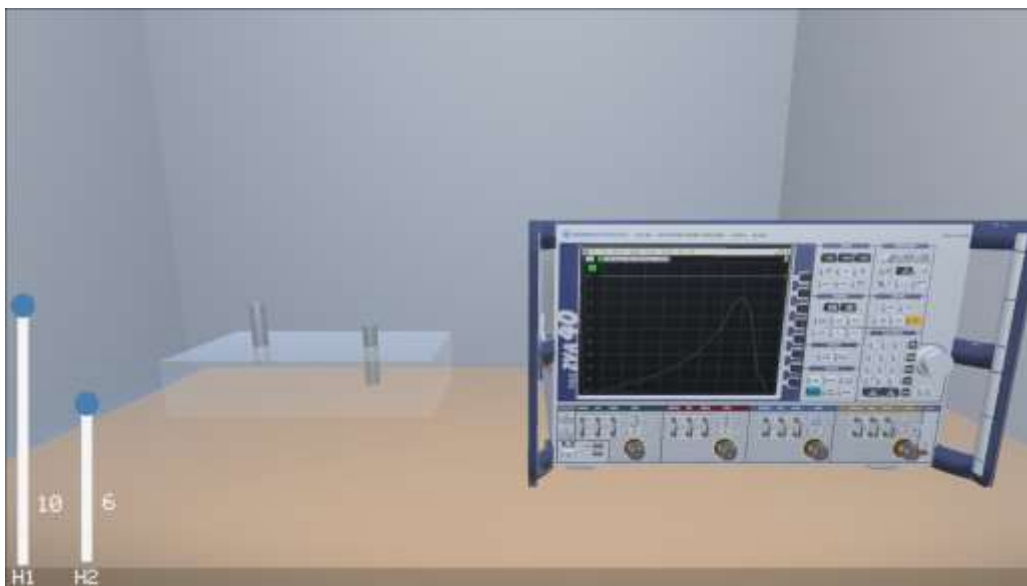
Figure 8 – The computer 3D interface of the virtual lab

The user menu and the control of the device in the developed digital educational platform are available in virtual reality mode using the Leap Motion controller, and Oculus Rift virtual reality helmet. Oculus Rift immerses the user in a virtual environment and, together with the Leap Motion controller, implements a "real" operation mode on devices. The Oculus and Leap Motion modules are fully compatible with the selected Unity engine and

with each other, so they can be easily imported into the project being developed, which greatly reduces and facilitates the work on the cross-platform application.

Conclusion

Thus, in this work, the digital educational platform for the study of radio engineering courses

has been developed. Models of devices and measuring instruments are presented. In the future, it is planned to increase the number of topics on which new labs will be performed. The functionality of the lab given in the article will also be expanded to provide users with a deeper understanding of radio engineering processes.

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