Development of Computer Models of Measuring Devices for the Study of Radio Engineering Disciplines

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Abstract

This article discusses the process of creating virtual computer models of measuring devices, such as an oscilloscope and a spectrum analyzer, as well as a computer model of a signal generator device. To create the models, devices from the manufacturer Rohde & Schwarz were used, such as the FPC1500 spectrum analyzer, SMC100A signal generator and RTC1000 oscilloscope. As well the article presents the results of the literature review conducted in order to define the current situation of the signal processing and measurement devices simulation.
The approach of the models development was shown and described as well the implementation process.

Keywords:

Computer model, 3D modeling, radio engineering, virtual laboratory, measuring instruments

1. Introduction

Today, there is a rapid spread of digital technologies. Digital transformation occupies a leading place in almost all spheres of human activity. This process was especially actively observed in the context of the global COVID-19 pandemic, which contributed to the transition to the digitalization stage. The introduction of digital technologies leads to significant qualitative changes. For example, the use of digital technologies in education has largely made the learning process more exciting, interactive and mobile. Students show great interest in learning and become more involved and motivated, compared to traditional teaching methods.

As noted earlier, the current situation with the global COVID-19 pandemic has significantly accelerated the transition to distance education. In this regard, there is an active use in the educational process of virtual laboratories, virtual tools, as well as digital educational platforms that allow students to fully acquire the necessary knowledge.

This article is dedicated to the development of computer models of measuring devices for students of the specialty of Radio engineering, electronics and telecommunications. Device models are used when performing virtual laboratory work.

The works [1-2] present the process of developing a digital educational platform, as well as computer modeling of devices for studying radio engineering disciplines. It is revealed that one of the significant advantages of using virtual laboratories in the learning process is that with the help of devices included in the laboratory, it is possible to replace expensive equipment. Indeed, the appearance of such virtual laboratories and simulators solve such a problem as the lack of material resources for the purchase of

Proceedings of the 7th International Conference on Digital Technologies in Education, Science and Industry (DTESI 2022), October 20–21, 2022, Almaty, Kazakhstan
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expensive and bulky equipment, and also, on the other hand, minimize the number of industrial injuries that can be obtained during laboratory.

In works [3-4], modeling of various radio engineering devices for their inclusion in a virtual laboratory is presented. A computer model of the measuring device of the ZVA 40 vector circuit analyzer from Rohde & Schwarz is presented. The interface of the computer model is an interactive photo of a real device with all the buttons on the panel and available for controlling a computer mouse.

Computer simulation of a spectrum analyzer based on the Unity game engine is presented in [5]. The paper presents the implementation of the model, describes the main elements and logic of the work.

In [6], the authors consider the problem of creating and using virtual measuring instruments in teaching modeling of physical processes. It is revealed that the use of virtual laboratory complexes improves the quality of teaching and assimilation of educational materials by students.

This work describes the process of creating computer models, such devices as:

- spectrum analyzer FPC1500;
- oscilloscope RTC1000;
- signal generator SMC100A.

The manufacturer of these radio engineering devices is Rohde & Schwarz, which is one of the leaders in the field of electronic test equipment, broadcasting and mass media, cybersecurity, radio monitoring, radiolocation and radiocommunications [7].

2. Literature review

The authors of the currently available works mainly pay attention to the issues of training specialists with the help of computer laboratory work, consider the development of educational and laboratory stands and virtual laboratory work [8]. The created educational and laboratory workshops and virtual laboratory works are used in the study of robotics, biochemical engineering, thermodynamics and multiprocessor systems [9]. The proposed works are intended to fully or partially replace real laboratory work.

Many authors note the important role of virtual laboratories in engineering education [10]. At the same time, it should be noted that computer modeling is increasingly used in the study of physics, including in technical universities, where this subject is the main one [11].

Laboratory work that is currently available in the field of study of RET disciplines can be divided into the following groups:

- development of virtual measuring instruments;
- signal processing and the study of modulation types;
- research of wireless networks;
- design of antenna systems;
- electromagnetic compatibility of radio electronic devices and electromagnetic waves,
- virtual work in the field of electronic devices.

In order to assess the situation in the industry, a literature analysis was carried out during which the experience of implementing work with laboratory devices based on LabVIEW was studied. The authors developed a course on basic electronics, where students, using augmented reality technology, were able to learn the principles of working with various laboratory devices [13, 14].

Articles [15,16] have developed a learning environment with augmented reality in the field of electronics. In the work, the proposed system allows to automatically identify the integrated circuit using a smartphone and a breadboard, and virtual 3D models of the oscilloscope and signal generator were developed. Interaction with 3D models of laboratory equipment in an augmented reality environment has improved the practical possibilities of students.

Works [17,18] are devoted to the study of signal processing and digital modulation methods using the MATLAB modeling environment, which in turn increases students' understanding of digital modulation and signal processing methods used for the communication systems course.

There are works devoted to the study of the field of electromagnetism [19, 20]. For example, in [21], virtual works on electromagnetism include lessons on vectors and coordinate systems, electrostatics, Maxwell's equations, electromagnetic waves, dielectric materials, and transmission lines.

At present time to develop practical skills and strengthen theoretical knowledge of students in this area, many virtual works have been developed. One of them is a virtual web laboratory for processing and analyzing satellite images VSIPAL developed by Indian scientists [22]. VSIPAL is e-learning system, and therefore it is designed to be accessed via the Internet. The user only needs an Internet connection to access the portal. There are absolutely no requirements to install any special hardware or software on the user's computer. On the basis of VSIPAL, 17 works can be made, which are accompanied by video lectures, theoretical materials that are aimed at familiarizing the student with various concepts of image processing and analysis. There is also an experimental part, which gives students practical skills, and at the end of each work there are control questions and interpretation of experiments for comparison with the data obtained during the experiment.

The VSIPAL evaluation was attended by students from the Indian Institute of Technology Bombay and from other universities and colleges. The students noted that they enjoyed experimenting with virtual labs, and also agree that virtual labs helped them understand the ongoing processes. Received reviews were only positive.

Modeling of measuring equipment and various devices is practically applicable and applicable. A special place is occupied by the modeling of measuring equipment, which practically does not differ from its "real" productions.

It is also advisable to create laboratories in which all measuring equipment is found, as well as the studied elements and devices associated with the use of computer models and the corresponding mathematical apparatus. Such works have considerable flexibility, throughput and can be used in the educational process. Virtual labs can be used as complements or replacements for large labs offered by a range of scientific publications.

3. Virtual device model implementation

A large number of works are devoted to the issues of modeling microwave devices, in which the authors have shown that various computer-aided design systems can be used to adequately describe the electrodynamic characteristics of microwave devices, for example, CST Microwave Studio, Ansoft HFSS, AWR Microwave Office, EMSS FEKO or strict numerical-analytical methods providing a high speed of calculation of the necessary parameters. At the same time, the authors noted the advantages of the CST Microwave Studio computer simulation software package in building models of various microwave devices.

Thus, using the results of calculations obtained using the CST Microwave Studio software product as initial data, it is possible to create a large number of different models of microwave devices and instruments.

The use of computer models and simulations is being introduced everywhere: in the study of engineering specialties, due to the high cost of equipment and the constant need to update it due to the development and updating of technology. The problem is relevant for students of Kazakhstani universities due to the not always sufficient number of devices and the availability of access to the necessary devices. The problem became especially acute during strict covid restrictions, when students were physically unable to work with real equipment.

Working with devices usually takes place as part of laboratory workshops. Inside them, students have a certain procedure, which as a result of gaining knowledge and experience with the equipment. To make the student's experience comparable to the real one, the following device parameters were determined:

- Realistic appearance;
- Realistic operation of the simulated device.
- Possibility of interaction of the user with the equipment.

Figure 1 shows a spectrum analyzer precedent diagram. It shows that the user can set the necessary frequencies inside the device, change the modulation mode, set markers to study the distribution of vibration energy.

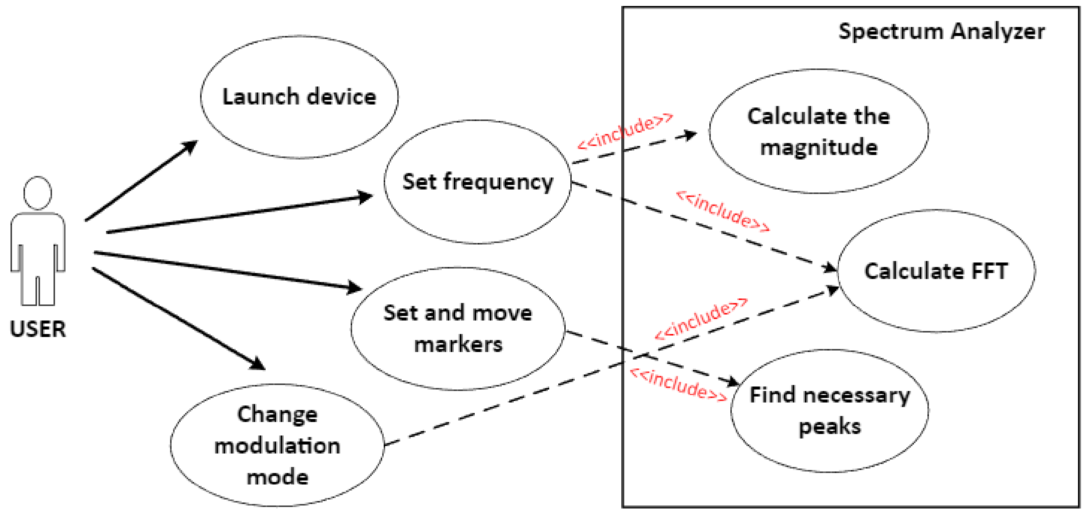

Figure 1: Spectrum Analyzer Precedent Diagram

Then, when planning the development of the device, it was decided that each of them would be independent. To accomplish this task, the device logic is divided into input and output functions, and therefore they can be used in various labs.

4. Tools

The conducted work was done using Unity 3D game engine since it allows to work with many different target platforms and eases the general development process thanks to simple and native user interface, has rich functionality and suitable for virtual reality, augmented reality and mixed reality.

The models of the equipment were created within Autodesk Maya and then exported in .fbx format. All the scripts defining the model's behavior and interaction were written in C# using Visual Studio 2020 supporting Unity plugin simplifying project work.

5. Results

Real physical laboratory work is, in fact, a set of devices connected to each other in accordance with the necessary task. Each installation has its own set of functions, which has its own input and output, so that data is exchanged between them, and the user sees the results of his work.

As a result of the work on the project, the models of the FPC1500 spectrum analyzer, the RTC1002 oscilloscope, and the SMC100A signal generator were developed.

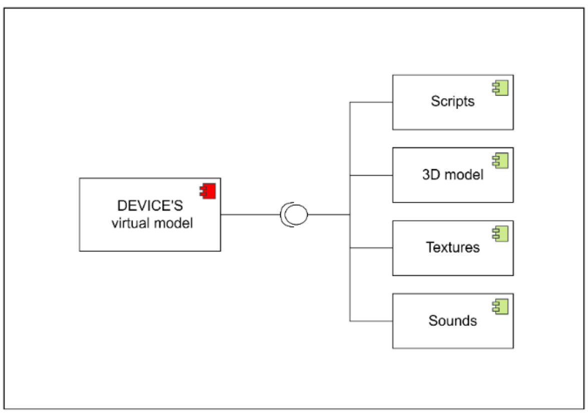

Figure 2: Component Diagram

The internal structure of each device consists of components: scripts that define the behavior of the device, a 3D model of the equipment itself, and the necessary textures and sounds that make the user experience more realistic. Figure 2 describes the common structure of each model.

The visual appearance of the devices completely repeats the real equipment and allows the user to press buttons and perform the necessary operations. Depending on the device itself, corresponding functions have been developed that calculate the data. That is, the functionality implemented in the scripts corresponds to the operations on the device buttons. The created devices are separate modules, the interface of which is dynamically updated depending on the input values. The graphical interface also completely repeats the screens of the simulated equipment.

Simulated measuring devices can have a fairly rich functionality, almost without boundaries. However, during its actual operation, the number of frequently used functions is insignificant and they are quite enough to carry out all the necessary measurements. Therefore, for the initial training of users in the basics of work, it is quite enough to implement a limited number of functions. The user also has a choice of various descriptions and methodological recommendations. Which will further simplify the student's work with the device being studied.

For the correct simulation of the processes demonstrated to the user, there was a need for numerical and mathematical modeling. On the basis of the created models, further work and behavior of the system, the development of scenes of virtual laboratory work are built. This made it possible to recreate the operation of radio engineering devices in virtual space.

One of the characteristics of the project is scalability, that is, the ability to change the number of devices in the lab. Therefore, the entire functionality of the devices is described as a set of input and output signals and functions. This also allows us to represent each of the devices as an independent unit that has a set of input and output signals, as well as functions that convert them.

The computer model of the FPC1500 spectrum analyzer, shown in Figure 3, allows to study and measure signal fluctuations in both time and frequency form. To work with the device, the user is given the opportunity to switch the signal display mode, enter the value of the required frequency, and place markers in the signal spectrum. From the figure 4 it seems that the view of the computer model is very close to the real model.

Figure 3: Computer model of the FPC1500 spectrum analyzer

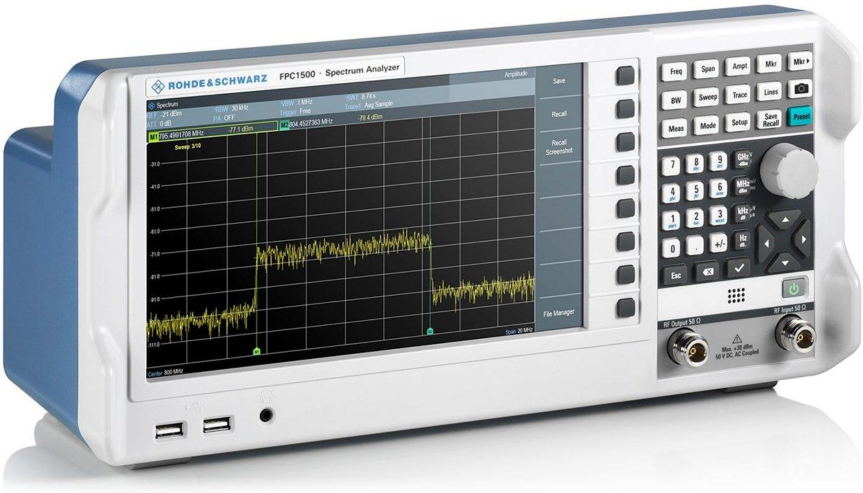

Figure 4: Physical model of the FPC1500 spectrum analyzer

From the device logic side, all these functions imply preliminary data preparation in the form of a fast Fourier transform. Which was implemented in the program code along with the functions of switching the mode between frequency and amplitude.

As a result, the virtual model of the spectrum analyzer implements:

- selection of frequency sweep range (Start/Center and Stop/Span);
- selection mode of measured parameters (Meas) S-matrix;
- mode of formatting the output results on the instrument screen (Scale);
- modes of operation with markers placed on curves and used for the convenience of performing measurements (Marker, Search, Marker Funct);
- selection of some menu display modes on the device screen (Display Config);
- some functions for data entry, selection of units of measurement, etc.

Figure 4: AM signal spectrum on the spectrum analyzer model screen

The Figure 4 demonstrates the screen of the device after changing of the measurement mode and entering necessary frequency value.

The oscilloscope and spectrum generator models, as well as the spectrum analyzer, have an interface similar to the realistic interface of a real device. The user has the ability to change the necessary parameters, depending on which the information displayed on the screen also changes.

Figure 5: Computer model of an oscilloscope RTC 1002

The oscilloscope on the figure 5 allows to get the amplitude and time parameters of the electrical signal for its further. Within the framework of the presented project, the computer simulation of the oscilloscope has the following functionality:

- fast fourier transform;
- the ability to display key measurement results;
- the mode of formatting the output results on the instrument screen;
- sine wave output
- selection of some menu display modes on the screen;
- functions for data entry, selection of units of measure, etc.

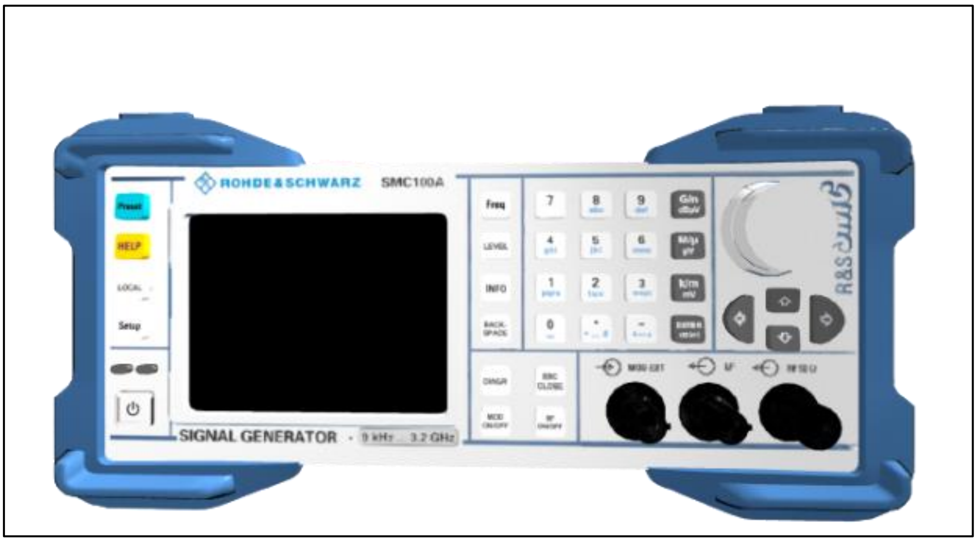

Figure 6: Computer model of the SMC 100 A signal generator

Figure 6 shows the simulation result of the SMC 100 A signal generator. The signal generator is an integral device of any laboratory. It allows to generate signals of a certain nature, for its further study. This model of the device allows to change the frequency of the signal, work in various signal setting modes, and also operates in two main modes: operational and measuring. The same set of functions is implemented in the virtual model of the device.

6. Discussion

This paper presents and discusses the experience of developing virtual models of computing devices for a computer model of an oscilloscope, a spectrum analyzer, and a signal generator. The computer model - simulation makes it easier for students to access the necessary devices to study them and gain experience in interacting with them.

Even though the behavior of devices is quite close to real equipment, virtual labs still remain an additional educational tool, and not a complete replacement for real devices. It was also shown in the work of Sypsas and Kalles [23]. They also propose virtual laboratory works as a supplemental material. And they can improve educational process in a combined or hybrid sessions.

In future works authors plan to investigate the user experience after interaction with these models in terms of virtual laboratory work within web-platform as a tool to investigate signals phenomena and parameters. Some works demonstrates comparing of results between two groups of students: one using virtual labs another studying using classical approach. The results show positive impact on students' perception of the new technology introduction though the academic results do not demonstrate significant improvements [24].

7. Conclusion

This article describes the work on the development of virtual models. The general approach to the model's implementation was developed and implemented.

During work on the project numerical and mathematical modeling of modern microwave and EHF devices was carried out, a concept was developed for creating models for their inclusion in virtual laboratory work.

Models of measuring instruments and devices have been created:

- spectrum analyzer FPC1500;
- oscilloscope RTC1000;
- signal generator SMC100A.

A digital database of the electrodynamic characteristics of devices has been formed. The created database will be used in the construction of virtual laboratory work, including those with remote access.

Future research devoted to the development of virtual laboratory works using discussed models of measuring instruments and devices for the study of radio engineering disciplines and further including them on digital educational platform.

8. Acknowledgments

The work was carried out with the financial support of the Committee of Science of the Ministry of Education and Science of the Republic of Kazakhstan under the program of grant financing of scientific research for 2020-2022 years, grant No. AP08857146.

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