

A LabVIEW-Based Remotely Controllable and Accessible Laboratory Platform For Communication Systems II Lecture Experiments

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ABSTRACT

In this study, a remotely accessible and controllable communication systems laboratory model is designed for the undergraduate Electronics and Communication Engineering Education. This laboratory model is designed by using LabVIEW program as real time and virtual for Communication Systems II lecture laboratory applications that contain Convolutional Codes, Viterbi Decoding Algorithm Method, phase shift keying modulated / demodulated schemes and system performance experiments. The student can perform these experiments in the remotely accessible and controllable laboratory platform in campus. This laboratory environment is established by using a server PC with LabVIEW program, Agilent 33220A signal generator, Data Acquisition Card (NIDAQ –PAD 6015). A web site contains the virtual / real time experiments, experiment sheets, and theoretical information documents of all experiments is designed to access this laboratory platform. In addition, a web page is designed for the teacher to observe and communicate with the students simultaneously, while performing their experiments. The students can access laboratory at the web site <http://localhost/Online LabVIEW/default.aspx> in campus. This interactive laboratory platform facilitates to bring in practical skills for students as well as intensify the theoretical studies. The objective of this study is to establish the real-time web-based laboratory platform conduction by accessing the laboratory set-up from a remote location and observe the experimental parameters by generating the control commands at a distant client.

Keywords: *Web-based laboratory; Electronics and Communication undergraduate Education; LabVIEW; Communication Systems Model*

1. INTRODUCTION

The development of engineering education depends on the teaching quality. That's why in recently, various methods having been developed to improve the quality of learning processes [1]. To contribute to the student's success, most of the lecturers in technical education institutions recommend the theoretical knowledge supported by practicing in a properly equipped

laboratory [2]. Computer-based teaching and learning techniques improve the effectiveness and efficiency of the learning process [3]. So, traditional content-based teaching approaches are being replaced by student-based methods. With the rapid developments of internet facilities, new approaches and methods to design virtual and real time laboratory experiments in technical courses have been performed [4-7].

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LabVIEW is one of the primary choices in designing control and analysis solutions virtually and/or remotely in the area of engineering technology and education. In the LabVIEW program, virtual instruments (VI) can be designed and the laboratory equipment (oscilloscope, signal generator, DAQ Card etc.) can be controlled via GPIB, USB, RS232 or VXI interface [8].

Many LabVIEW- based applications that exist in the literature were examined. Reference 9 includes the remotely control of industrial regulators. In Reference 10, some of remotely accessible and configurable applications of Electronics Circuits lecture are explained. In Reference 11, a web based virtual laboratory for Frequency Modulation (FM) experiment is obtained.

In Reference 12, the motion control of a mobile vehicle is done using sensor data from the high end mobile phones with LabVIEW. In Reference 13, Information and Communication Technology (ICT) enabled laboratory is set up.

When the curriculums of Engineering, Vocational and Technical education institutions are examined, it can be seen that the majority of courses are practice-based courses and Communication Systems lecture I-II in engineering education is the one of the main courses. Generally, in Communication Systems lecture II, the students learn the working principles of the transmitter and receiver structures of the communication systems.

In this context, firstly the students will learn how to design various encoder/ decoder and modulator/ demodulator structures theoretically. In the laboratory, experiments are performed by using the experiment sets and devices in groups, because the number of the students is more than the number of the device and experiment sets.

The purpose of this study is to design a new web based laboratory platform by using LabVIEW program that students will perform the laboratory experiments without existing physically in the laboratory. In this web based remotely accessible and controllable laboratory platform, convolutional codes experiments, Viterbi decoding algorithm experiments and error performance analysis experiments of Communication Systems model for various signal to noise ratios can be performed.

In this study, students can access to this laboratory platform and perform the experiments via the developed web site. The designed web site includes not only monitoring and control links, but also theoretical concepts and the laboratory sheets of real time and virtual experiments such as convolutional codes, Quadrature Phase Shift Keying (QPSK), 8-Phase Shift Keying (8PSK) modulators/demodulators, decoding algorithms (hard and soft decision) for Viterbi decoding and also general information about LabVIEW.

In line with this objective, in Section II, some of the prepared experiments using the LabVIEW software on Communication Systems II lecture were explained. The designed web site for remotely accessible and controllable Communication Systems laboratory platform is explained in Section III. Finally in Section IV, some conclusions are drawn.

2. COMMUNICATION SYSTEMS II LECTURE EXPERIMENTS WITH LABVIEW

In the Electronics and Communication Education Department on Technical Education Faculty, the Communication Systems I-II lectures include analog communication systems and digital communication systems, respectively.

During this study, Communication Systems II lecture experiments for supporting the theoretical concepts of the encoding, decoding circuits and the coded modulation techniques are explained. The block diagram of the communication systems structure considered for Communication Systems II lecture experiments is shown in Figure 1.

The Communication System structure in Figure 1 can be summarized briefly as follows: In this structure, messages produced by the source (binary sequences) are encoded by the channel encoder to get minimal impact from the noise and interference in the transmission environment or to improve the safety of message. The binary-coded sequences are converted into the continuous-time signals ($s_i(t)$) by means of the digital modulators in order to get them compatible with the transmission medium. On the receiver side, the signals ($s_i'(t)$) which are affected by noise in the channel are converted into the binary source data.

Within the scope of laboratory experiments on Communication Systems II lecture, the communication systems structure shown in Figure 1 is studied in three main parts. In the first part, the channel encoder experiments are designed as real time and as virtual by using LabVIEW program. In this context, (2,1,2) Convolutional Codes, (3,2,2) Convolutional Codes, (3,1,2) Systematic Convolutional Codes and (2,1,3) Feedback Systematic Convolutional Codes experiments are realized. Firstly, the students perform above experiments in the designed web based laboratory platform as virtual every time and as real time when the system is not used by another.

In the second part, QPSK and 8PSK modulator structures are designed as virtual by using LabVIEW program as modulator experiments. In the designed modulator experiments, the 2-bit channel data at the output of (2,1,2) Convolutional Codes experiment are applied to the input of QPSK modulator and similarly 3-bit channel data at the output of (3,2,2) Convolutional Codes experiment are applied to the input of 8PSK modulator, respectively. Secondly the students perform

the modulator experiments in the designed web based laboratory platform.

The third part of the communication systems model is to design the receiver structure experiments with LabVIEW program. The receiver structure experiments

consist of both demodulator and decoder experiments. In the demodulator experiments, the students observe the conversion of the modulated signals into the binary data sequences and the students perform the decoding experiments by using Viterbi decoding algorithm (soft or hard decision) methods.

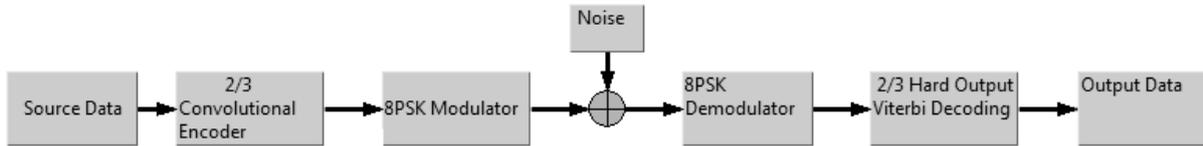


Figure1. Block diagram of Communication Systems Model

In addition, the error performance analysis experiments for (2,1,2) convolutional-coded QPSK modulation scheme and (3,2,2) convolutional-coded 8PSK modulation scheme are designed by using LabVIEW program.

After the students perform the second and third part experiments, the students can perform the error performance analysis experiments over the additive Gaussian noise channel for various SNR's (Signal to Noise Ratio).

The hardware system block diagram and its components of the real time Communication Systems II lecture experiments are shown in Figure 2.

In this block diagram, the lab PC runs as a server PC with LabVIEW program. Connections between signal

generator, Data Acquisition Card and server PC must be full duplex and client PC is connected to lab PC (server PC) via internet/ intranet.

The used hardware resources list is given in Table 1.

Table1. Resources Used For Laboratory

Item	Description
Server PC	Yakumo PC with GPIB interface and LabVIEW 7.1
Operating System	Windows Server 2003
Web Resource	Visual Studio 2005
Devices	1- Agilent 33220A signal generator, 2- Data Acquisition Card (NIDAQ –PAD 6015)

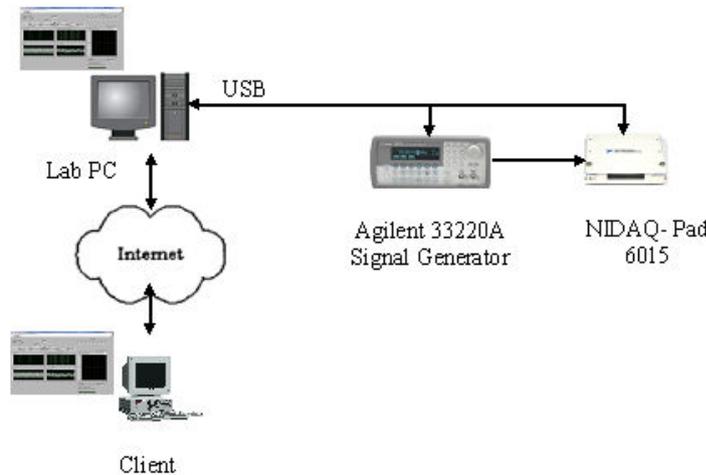


Figure 2. Hardware Block Diagram of the Experiments [16]

The laboratory platform was established to perform the all designed experiments as mentioned in Figure 3.

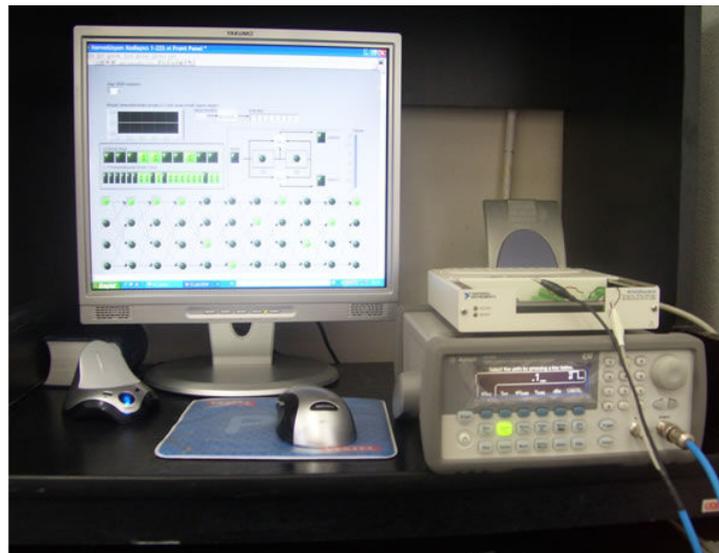


Figure 3. Physical Laboratory Platform [16]

2.1. Convolutional Codes Experiments Front Panel

Due to the fact that the first step in the communication systems model is to design the convolutional encoder as a channel encoder, the students perform this experiment firstly.

As an example, the flow chart of the (3,2,2) convolutional codes experiment (both real time and virtual) prepared by using LabVIEW program is shown in Figure 4.

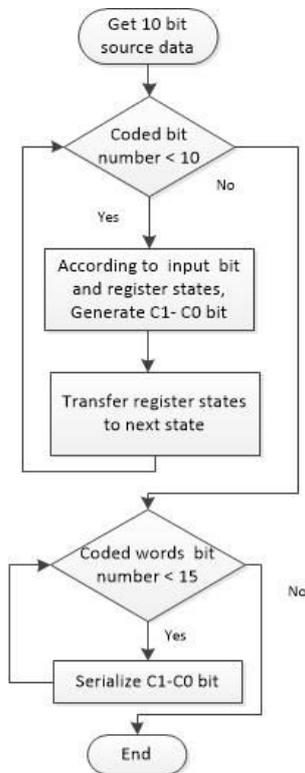


Figure 4. Flowchart of the (3,2,2) Convolutional Codes Experiment

Generally, (n, k, m) convolutional codes is designed as a sequential circuit in which m is shift register, k is input digit of modulo-2 adders and n is output digit. Case studies for both real time and virtual convolutional codes experiments are explained respectively.

Case Study 1: In the real time convolutional codes experiments, the source data between 0-1 V is get from the signal generator as randomized. As an example, the front panel screen of the real time $(3,2,2)$ convolutional codes experiment in a randomize time is shown in Figure 5. In the front panel screen, the output randomized

voltage value get from signal generator is shown as 0,39 V. This 0,39 V voltage is converted to 8 digit message sequence (01100101) by means of ADC which is designed in LabVIEW currently.

On the front panel for each of real time convolutional codes experiments, the student observes the answers of the questions located in the experiment sheets that how the convolutional encoder structure is designed , how many input / output bits of encoder and state transitions of encoder register also what the code words are.

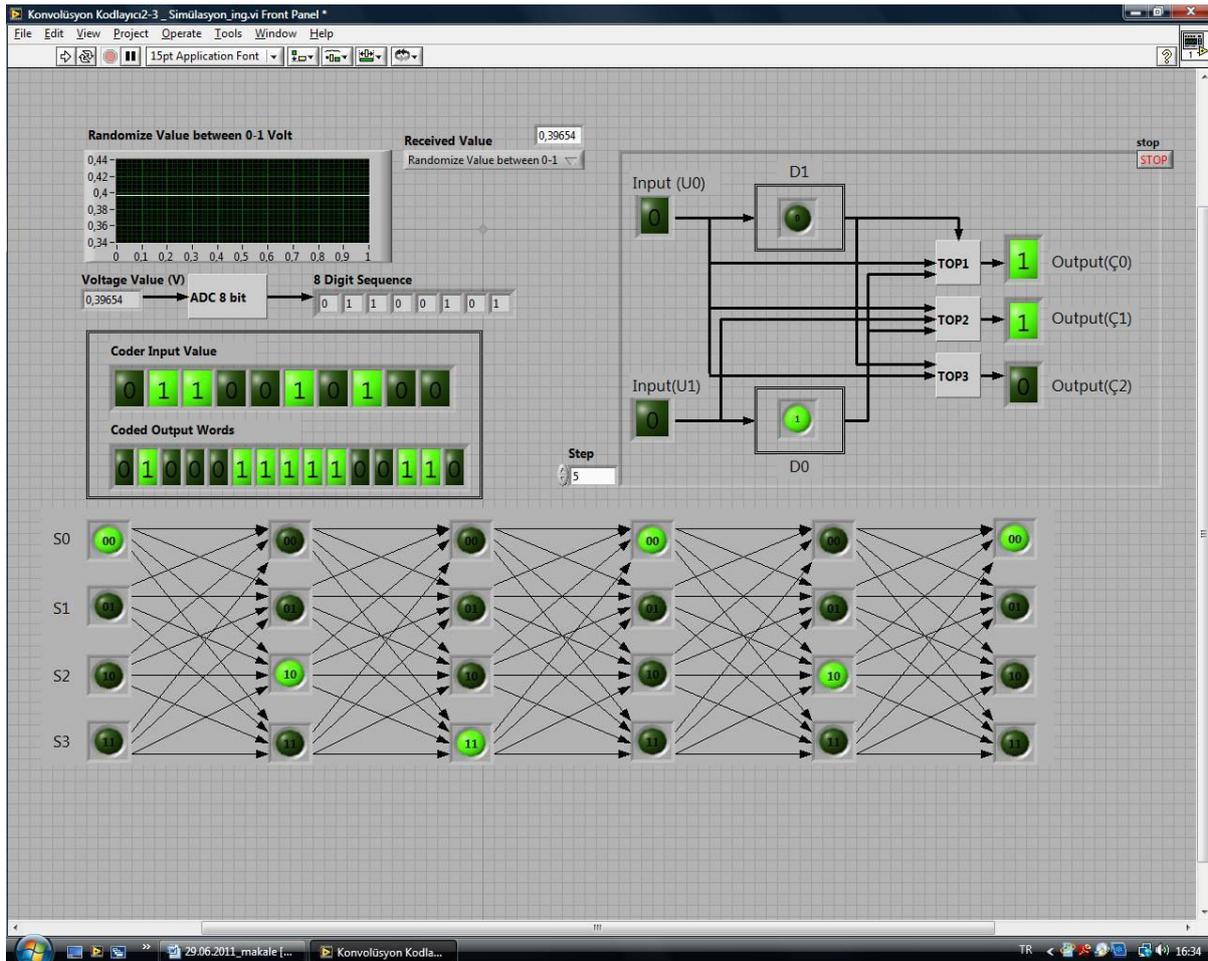


Figure5. $(3,2,2)$ Convolutional Codes Experiment Front Panel

Case Study 2: In simulation convolutional codes experiments, the source data is get from the virtual signal generator designed in LabVIEW program. Similarly, the randomized source data is converted to 8 digit message sequence by means of ADC which is designed in LabVIEW currently.

The student observes the answers of the questions located in the experiment sheets that how the convolutional encoder structure is designed , how many input / output

bits of encoder and state transitions of encoder register also what the code words are on the front panel.

Thus, the student reinforces theoretical knowledge of the convolutional codes with real time and simulation experimental works.

2.2 The Block Diagram Design of Convolutional Codes Experiments

After the front panel is built, by using graphical representations of functions, the connections of front panel objects are built in the block diagram. Block

diagram objects include terminals, subVIs, functions, constants, structures and wires which transfer data among other block diagram objects [8]. In Figure 6, as an example, for real time experiments the designed block diagram of (3,2,2) Convolutional Codes experiment is shown.

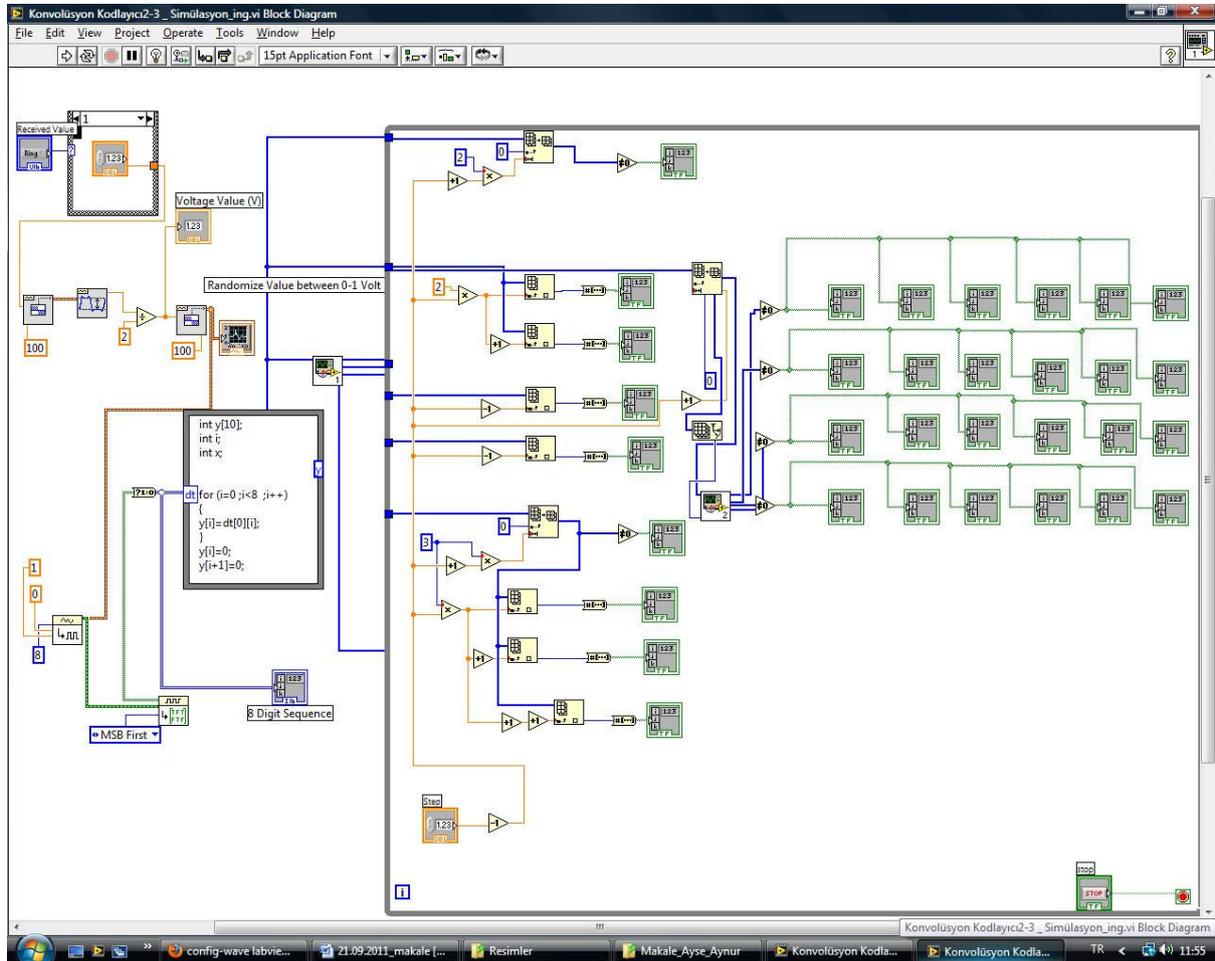


Figure 6. (3,2,2) Convolutional Codes Experiments Block Diagram

Generally, block diagrams of all convolutional codes experiments for both real time and simulation experiments are designed in four main parts.

First Part: The signal generator (Agilent 33220A) is controlled to produce randomized voltage value between 0-1 V by using Config-Wave VI and after that, this randomized value is transferred to LabVIEW software via DAQ assistant (NI-DAQ PAD6015) for real time experiments. For the simulation experiments, the randomized voltage value is get from the LabVIEW random number generator.

The other parts of the block diagram are the same for both real time and simulation experiments.

Second Part: Analog to Digital VI is used to convert the randomized input voltage to 8 digit binary sequences.

Third Part: A program was developed in Formula node to design a convolutional encoder structure which is called as a finite-state machine. For example, (3,2,2) convolutional encoder consists of 2 shift registers and 3 adders which are connected to shift register and a multiplexer that serialize the output of the adders. The convolutional encoder structure programs are called from the main program as Sub VI.

Fourth Part: Icons and wire connections are built on the block diagram to show the codeword output, encoder structure and state transitions on the trellis diagram on the

front panel. The other convolutional codes experiments' block diagrams are designed similarly.

2.3 The Viterbi Decoding Algorithm Experiments

In this study, the students perform the Viterbi decoding algorithm [15] experiments by using soft decision and hard decision methods to convert the received noisy and coded r signals into the source data. The scope of Communication Systems II lecture, Viterbi decoding algorithm experiments are prepared by using LabVIEW program for both hard and soft decision methods. In these

experiments, students observe the source data, convolutional encoder sequence on the trellis diagram and the decoding sequence for all convolutional encoders.

(3,2,2) convolutional encoder produces a 3 bit code word for every 2-bit input data. Therefore, the decoding process is carried out in 5 steps for every frame.

The flow chart of the Viterbi decoding algorithm experiment for (3,2,2) convolutional codes is shown in Figure 7.

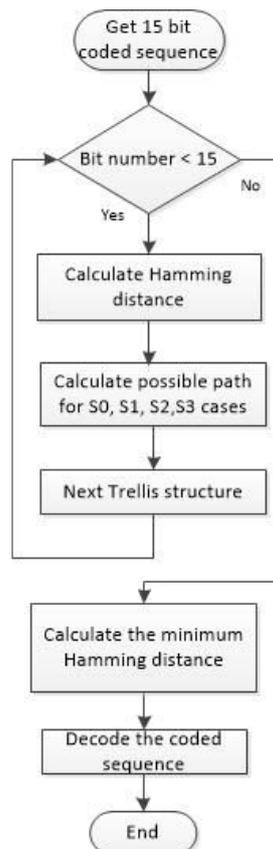


Figure 7. The flow chart of the Viterbi decoding algorithm experiment for (3,2,2) convolutional codes

The Viterbi decoding algorithm experiment for (2,1,2) convolutional codes is designed in LabVIEW as well and is shown in Figure 8.

2.4 Error Performance Analysis Experiments

In this study, a computer simulation model was designed for the error performance analysis experiments using the communication systems block diagram shown in Figure 1. The students perform the computer simulation model

experiments to learn how to transmit the binary information encoded by the source into the channel by using one of the digital modulation methods such as QPSK and 8PSK. And also the students learn how to improve the error performance of communication systems.

The error performance analysis experiment can be explained briefly as follows:

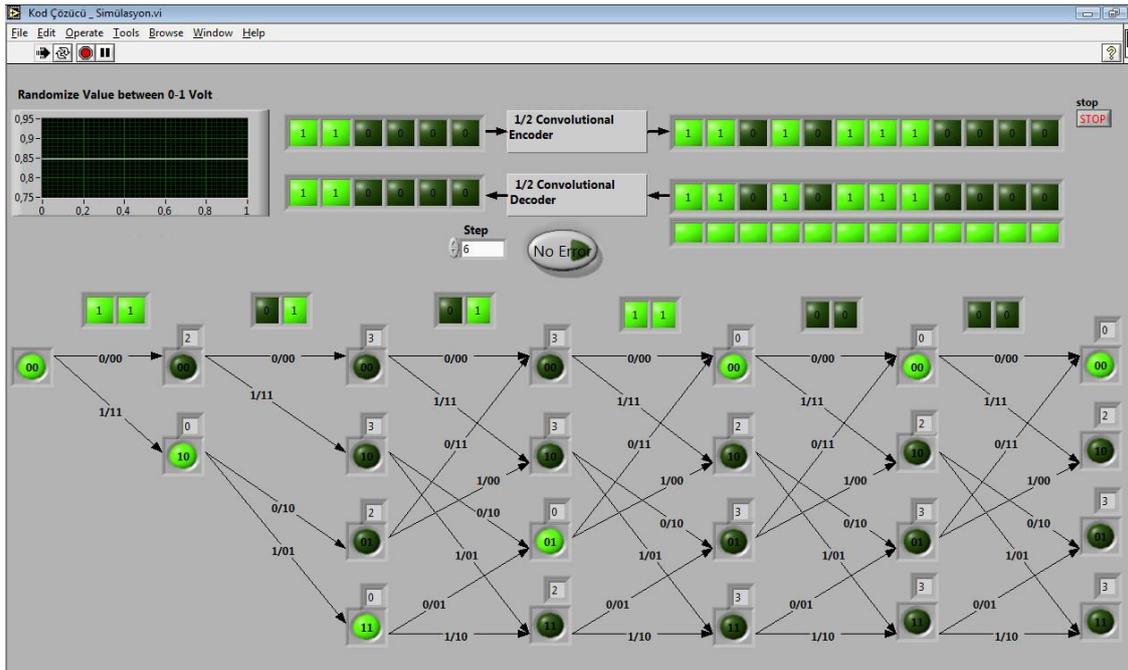


Figure8. (2,1,2) Viterbi Decoding Algorithm Experiment Front Panel

Transmitter Side: 10 bits information is produced by the source. And then, this 10 bits information is converted to the 20-bits and 15-bits encoded sequence by $R = 1/2$ and $R = 2/3$ rated convolutional encoder, respectively. These coded sequences are applied to the input of QPSK and 8PSK modulators whose outputs are sequence of waveforms.

As an example, the transmitter side of the error performance analysis experiment with $R = 1/2$ convolutional encoder and QPSK modulator designed in LabVIEW program is shown in Figure 9.

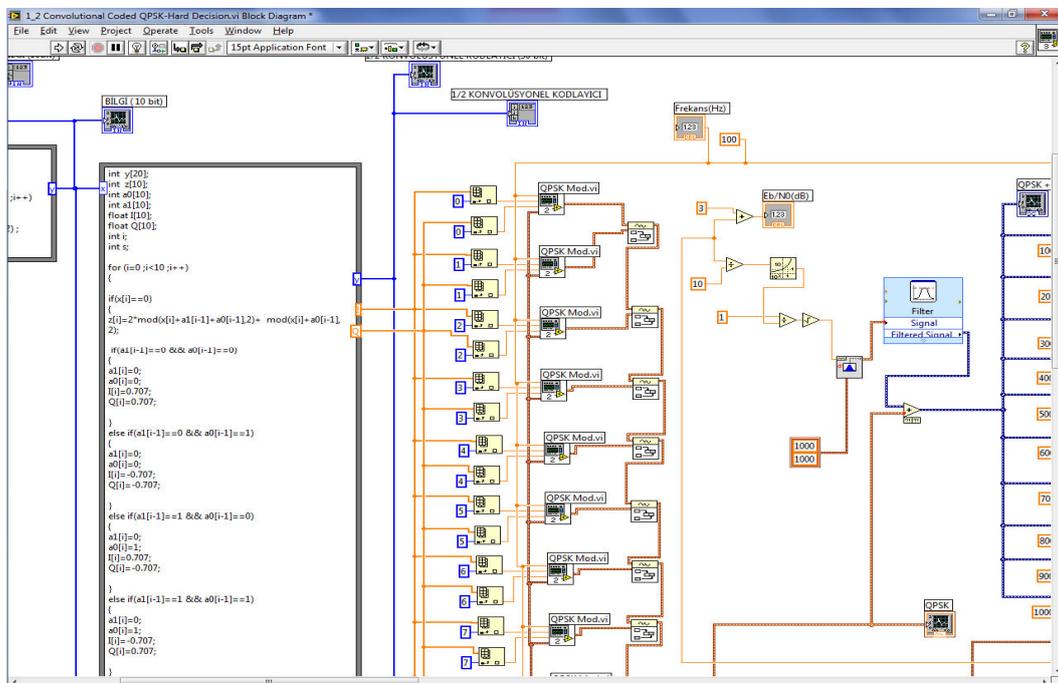


Figure9. LabVIEW Block Diagram of Transmitter Side for Error Performance Analysis Experiment

Receiver Side: A coherent demodulator, in which the received signal is multiplied by the carrier signal, passed through a low pass filter and then converted to binary sequences, is designed in LabVIEW program as QPSK Demodulator Sub VI. For obtaining 10-bits information, the coded binary sequence get from the output of

demodulator is applied to Viterbi decoder (hard decision/soft decision algorithm) which is programmed in LabVIEW program Formula Node. The receiver side of the error performance analysis experiment is shown in Figure 10.

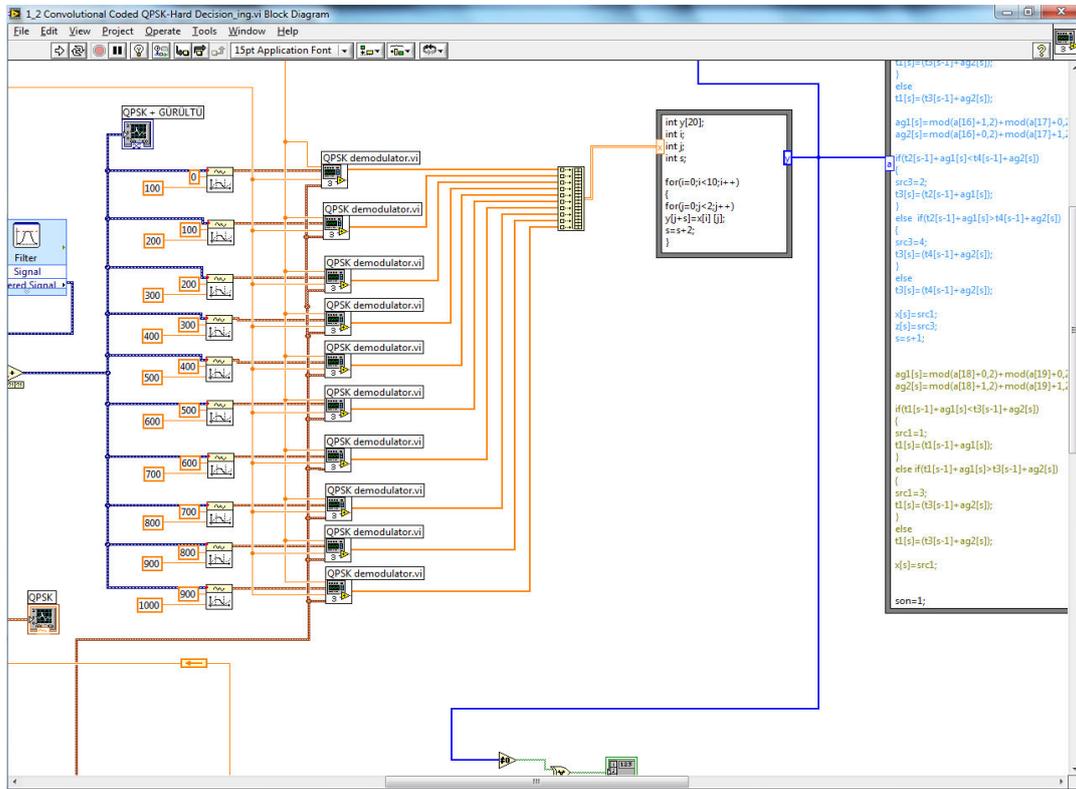


Figure10. LabVIEW Block Diagram of Receiver Side for Error Performance Analysis Experiment

The error performance analysis experiment's steps are as follows respectively.

- I: Student resets the system parameters by the reset button on the front panel.
- II: The student enters the information bit number (For example, as 100,000 bits of information) and runs the system by clicking the start button.
- III: He/she observes 10 bits information and convolutional encoder outputs both as a graphical representation and as a 0-1 LED display on the front panel.
- IV: He/she observes the modulated signals, noisy signals, 0-1 LED display of decoded signal according to selected signals to noise ratios. As an example, error performance

analysis experiment's front panel for R= 1/2 rated convolutional encoder and QPSK modulation is shown in Figure 11. During the experiment, he/she can test the error performance of the designed communication systems model for various signal to noise power ratio $[S/N]_{dB} = [E_b/N_0]_{dB}$ values (0-7dB) where E_b is energy per bit.

And also, the student observes the number of the different bits between the source data and received data called as error bits. The error performance of the system is shown as graph considering the bit error probability in the front panel. So students learn how to measure the error performance of a system in digital communication.

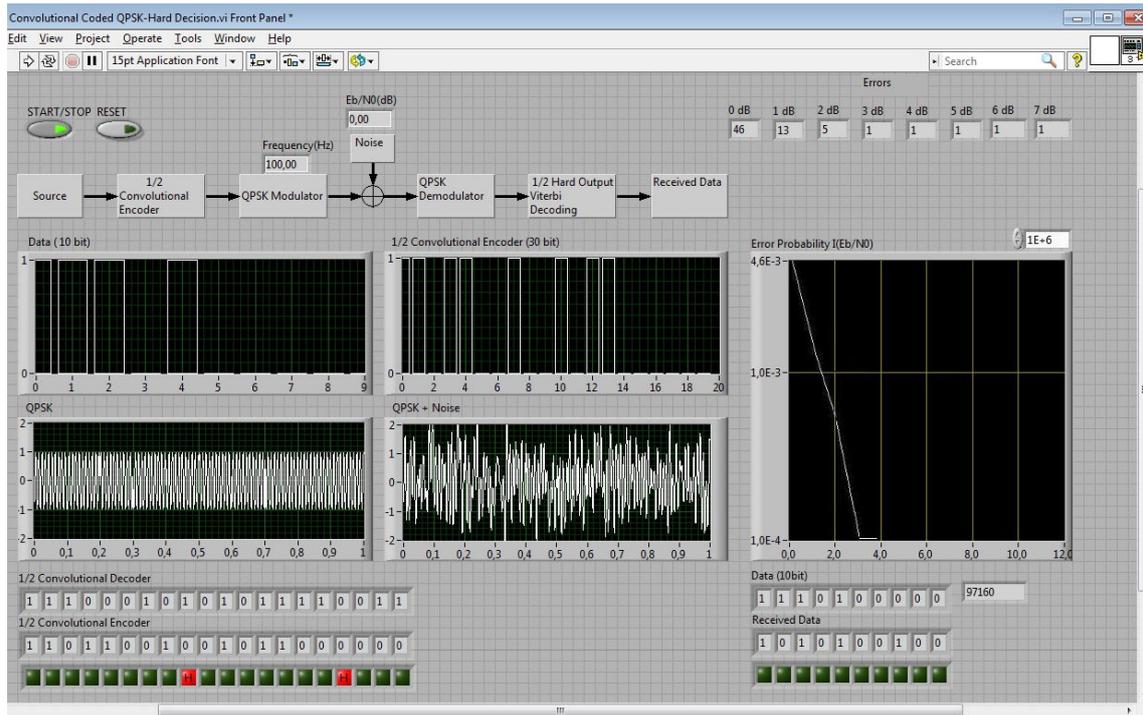


Figure11. Error Performance Experiments Front Panel

3. WEB SITE

In this study, a web site is designed both in Turkish and in English languages to perform Communication Systems II lecture experiments. The web site contains the

theoretical information documents of experiments, virtual / real time experiments and their laboratory manuals. The block diagram of the remotely accessible and controllable laboratory platform is shown in Figure 12.

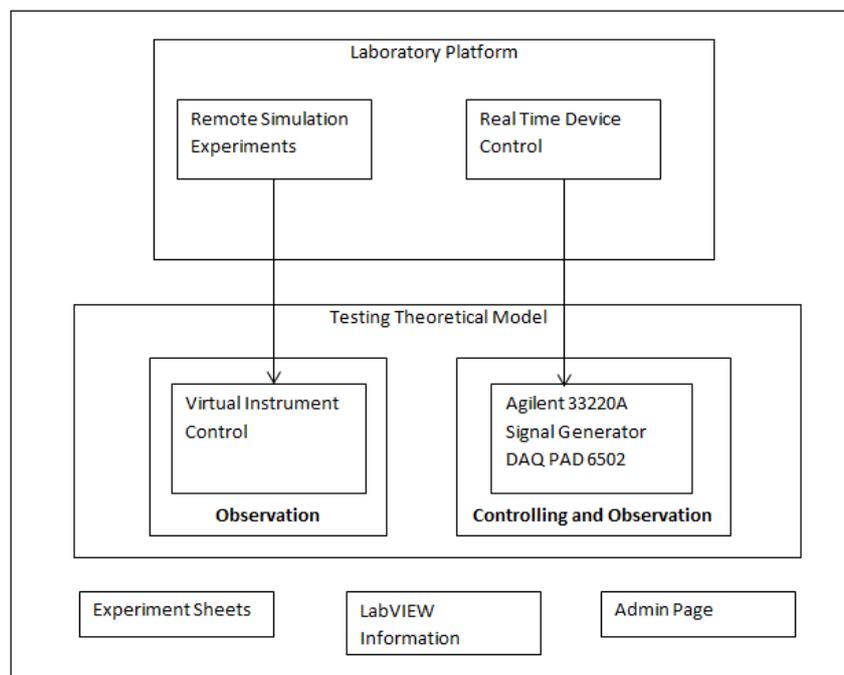


Figure12. The Block Diagram of Remotely Accessible and Controllable Laboratory Platform

The web site is developed in line with Microsoft Internet Explorer. Microsoft Visual Studio 2005 is used for designing the web site and for user account registration Microsoft Access is used. Real time and simulation experiments designed in LabVIEW were integrated into the designed web site by using many functions and methods of Dynamic Link Library (DLL) developed by National Instruments.

Everyone can only access the theoretical information documents freely and download them without logging on

and doesn't interrupt the user doing his/ her experiment. After the students enter the password, they can access the laboratory platform and perform the experiments suitable for online conduction either in campus whenever they want. To conduct and perform the experiment, students don't need to install LabVIEW program in their PC. They only need to have web browser and set up LabVIEW Run Time Engine from the user input page. As an example, the R=1/2 Convolutional Code Experiment home page is shown in Figure 13.

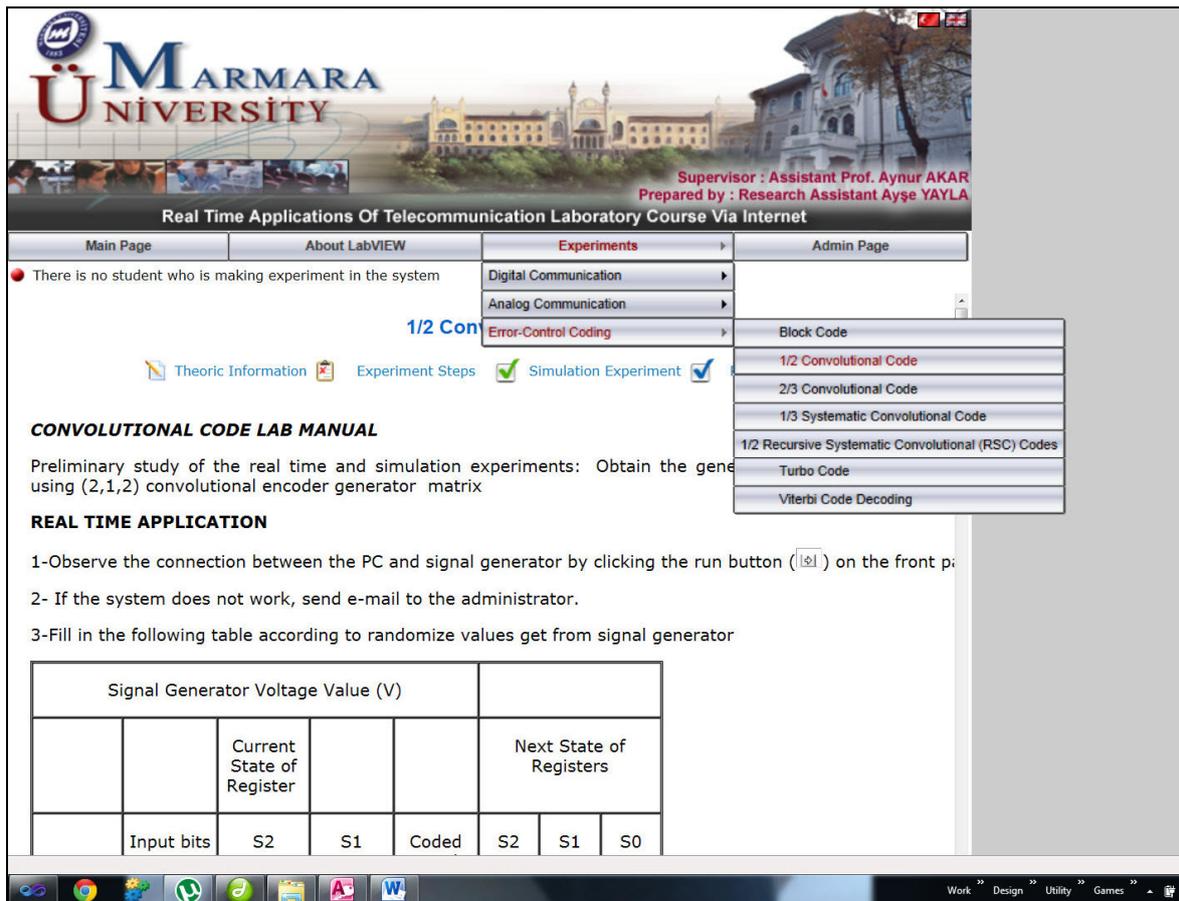


Figure13. Home Page of the Convolutional Code Experiment

The students must follow these following processing steps to perform the experiments on the web page:

1. Choose the experiment from the buttons,
2. Install and set up LabVIEW Runtime Engine if it is not installed before,
3. Input username and password for authentication, Run the experiment and change the parameters,
4. Observe and interpret the experiment results,
5. Ask any questions to the teacher during the session via the chat platform,
6. After 15 minutes, the session is terminated.

In real time experiments, the student must control the devices to observe the results and for this reason, the web site allows to access only one student at the time. In the simulation environment, more than one student can perform the same experiment accessing from different client PC's at the same time. While the student performs the experiment, the teacher can supervise him / her and communicate with him/her via the interface designed for teacher

An administrator page is designed for adding, erasing experiments, updating the current experiments and

disabling / enabling the system. The teacher is authorized as the system manager. When the system is deactivated by the system manager, the students can only access the information such as LabVIEW information, documents about experiments. If they want to access the experiments at this time, "Because of deactivating the system, you cannot access the experiments" message is shown.

4. CONCLUSION

We have designed an original web based remotely accessible and controllable laboratory platform that uses LabVIEW 8.2.1 to present experiments in the domain of Communication Systems II lecture. In this paper, laboratory devices and equipment have been provided with limited budget. Adhering to the theoretical knowledge, experiments were prepared by using the available laboratory devices that are Data Acquisition Card (NIDAQ –PAD 6015) and signal generator (Agilent 33220A).

With the realized laboratory environment, it is thought that the problems occur in the applications such as time limitations; group study etc. may be solved at some level and improved learning process.

Since the laboratory experiments are an important part of the technical education, this real time laboratory platform facilitates to bring in some practical skills for students as well as intensify the theoretical studies. In this paper, a web based remotely accessible and controllable laboratory platform is designed for Communication Systems II lecture experiments. For real time remotely accessible experiments, this laboratory platform was set up by using a PC with LabVIEW, Data Acquisition Card (NIDAQ –PAD 6015) and a controllable signal generator device. In this laboratory platform, (2,1,2) Convolutional Code experiment, (3,2,2) Convolutional Code experiment, (3,1,2) Systematic Convolutional Code experiment and (2,1,3) Feedback Systematic Convolutional Code experiment, Viterbi decoding algorithms both hard and soft decision experiment and error performance analysis experiment are prepared by using LabVIEW program.

These experiments were uploaded to our designed website. When the student wants to perform an experiment, he/she can choose it from the menu items on the home page. If the student selects the real time experiment, he/she can change the parameters of devices with the buttons on front panel. In the simulation experiments, the parameters can be changed via virtual instruments designed in LabVIEW program. So an attractive laboratory platform is offered to the students to perform their experiments easily.

While the student is performing the experiment, teacher may only observe his/her experiment simultaneously and also can ask any question to the student via the developed chat platform. Because of the device control in the real time experiments, the time limitation is required. In this

study, the students can log on to the experiments during 15 minutes.

The teacher is authorized as the system manager to add or erase experiments, update the current experiments and disable / enable the system on the designed administrator page.

In this study, we realized a web based remotely accessible and controllable laboratory platform in campus for the Communication Systems II lecture experiments which cannot be realized in traditional laboratory because of equipment inadequacies. In the future, by increasing the capacity of remotely controllable devices, it is targeted to improve the laboratory platform for other communication systems techniques. And also in the next term, we plan to get feedback from the students for their opinions on issues such as the availability of the experiments, accessibility, flexibility and what affects the motivation to learn and so on with a questionnaire form.

CONFLICT OF INTEREST

No conflict of interest was declared by the authors.

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