Design and development of a remote and virtual environment for experimental training in Electrical and Electronics Engineering

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Abstract

European Remote Radio Laboratory (ERRL) has been developed by the support of European Commission. It intends to provide remote access to high cost devices remotely, and perform experiments in radio frequency (RF), communications and microwave domains of Electrical ad Electronics Engineering. The system has been operational for two years, and been integrated into curriculum of some courses. In this work, the hardware and software structures of the system are presented. Then, experimental content and the motivations in the design of the system are discussed.

1. Introduction

Effective learning in engineering education could be achieved only by those approaches combining theoretical courses with laboratory works which could be repeated as many times as the learners wish. In classical methods, laboratory training may have many limitations both at provider and learner sides. It requires more personnel (teaching assisstant and/or technicians, teachers), high costs for establishment and maintenancefor equipment. Especially, in laboratories such as the ones covering radio frequency (RF), communications and microwaves(MW) domains, it is well-known that fragile and high precision equipment would require highly qualified personnel from the beginning to the end of experiments. Therefore, mostly, it is not possible to allow students to try on equipment, and repeat ean experiment many times. Instead, a qualified teaching assistant makes a demo on how to perform measurements of some parameters for some limited set of experiments. On the other hand, in a basic laboratory, students are restricted to a time schedule and location for a particular course laboratory, and would not be able to repeat the experiment as many times as they wish. In this sense, remote/virtual laboratory applications seem to be an alternative approach to laboratory experience that learners should have acquired in their education.

The literature survey have shown [1-5] that the previously developed remote laboratory platforms have mostly covered introductory and basic electrical and electronics, and control laboratory applications. These studies are generally established on microprocessor, control systems/engineering, power electronics, digital circuits and robotics of electrical, electronics and computer engineering disciplines. None of them have been established in the radio communications, e.i, electromagnetics, RF and microwaves. Theoretical and experimental training in these field may have attraction due to rapidly growing need for technical personnel in wireless systems and defense industry. These fields are usually considered to be important but expensive components of any electrical, electronics, and computer engineering curriculum [6-8].

A team at Atilim University has initiated a project on how experimental training in communications, RF and Microwave can be achieved remotely a few years ago. A remote radio laboratory has been designed and developed by the support of European Commission, since then the ERRL system hosted by Atilim University has been operational in the last two years [9]. The ERRL system has many differences compared with the previous remote laboratory systems. This study presents the design and the development of the ERRL system that have been operational and being used in the last two years at Atilim University. The ERRL system aims to provide theoretical and particularly practical radio communications, RF and Microwaves training to engineering students, graduates and other technical personnel via distant access to high technology equipment through the Internet. As a transnational laboratory, the ERRL intends to allow its users perform web-based experiments and simulations, and follow related course materials.

The paper is structured as follows: in section 2, hardware and software design architecture along with experimental content of the ERRL system are

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discussed. In section 3, the educational use of the system is discussed to show how to better adapt the ERRL system into the classical educational environments. Finally, the results and conclusions are drawn.

2. Structure of the ERRL System

Previous studies have proposed various structures for remote laboratory [1-5,9-11]. With the experiences of previous works, the ERRL system is structured as in Figure 1. Basically, there is a web server on which various components of the ERRL system are runing, and several workbench servers connected to experimental set ups. Workbench servers and experimentals set ups,together, form experimental modules. The main components of the ERRL system, as illustrated in Figure 1, are as follows:

1) Learning Management System(LMS) to maintain authentication and access rights of users, and to keep users/students' logs, backups, courses and their contents, assignments, exercises, exams, grades etc. An open source tool, Moodle, has been chosen as the LMS in the ERRL.
2) Electronic Performance Support System (EPSS) is an integrated electronic environment, it can easily be accessible by each learner, and is structured to provide immediate, individualized on-line access to full range of information, software, guidance, advice and assistance, data, images, tools, assessment and monitoring systems, to permit job performance with minimal support and intervention by others
3) Workbenchservers are usually PCs connected to experimental set ups, via data acquisition cards, and are communicated with the web server for the requests of users.
4) Experimental module is usually a set up containing a bank of experiments in parallel, and controlled by workbench servers.
5) Database Management System (DBMS) to save all data, including course material, EPSS materils, user logs etc.

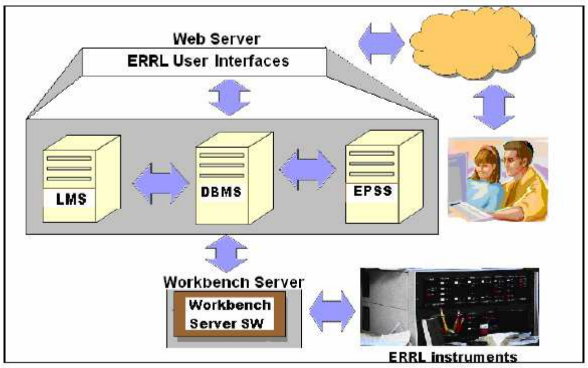


Figure 1. Structure of the ERRL System

2.1. Software Structure

The remote experiments are controlled and executed by the workbench servers (Figure 2). The entry of input and configuration parameters at the user side and presentation of the results to the user is performed by a java applet which resides on the LMS server. LMS handles all user management and tracking, as well as delivering the learning content to the users.

In remote laboratory applications, basically, two approaches have been followed to provide the users an access to the laboratory resources as discussed by the co-authors of this work [12]. In the first approach, users share the laboratory on a scheduling basis and an experiment setup is dedicated to a single user during a time-limited session. This is similar to the traditional way of laboratory practice except that the user does not have to walk into the laboratory and s/he cannot touch the device. In the second approach, there is no session concept and the experiments are in the form of batched jobs where the users receive the experiment results some time after they submit the request for the experiment. In the ERRL, remote experiments have been designed to be consisting of small batched jobs which may be regarded as atomic units. All configuration data for a batched job are automatically submitted as parameters to the workbench server which will perform the experiment. Requests of users to conduct batched jobs are queued and served in a first come first served basis in order to prevent collusion of the requests. The presence of another user attempting to access the same setup simultaneously only delays the response of the system to the request. Such delays are generally small and rarely produce a significant user inconvenience.

In this manner, as illustrated in Figure 2, multiple users can access the experiments almost simultaneously in the ERRL system. The consequent improvement in the utilization efficiency of lab resources is very important since ERRL system is comprised of very expensive equipment.

In ERRL workbench servers web services interfaces has been implemented with Microsoft's .NET framework hosted by a Windows 2003 server. Web services provide an open architecture where diverse server-side and client-side technologies can be used to develop remote laboratory applications.

The same origin policy, which aims to prevent cross-domain scripting fraud, prevents a client application access a remote laboratory server if it originates from a different server. This is a serious obstacle for remote laboratories with multiple servers like ERRL. In ERRL, the 'same origin policy' limitations have been eliminated by using signed java applets. When activated, the applet asks the user whether the source of the applet is a trusted identity. Access to the servers in the remote laboratory is only permitted after the user's confirmation. The software issues and interoperability is discussed in details in another paper of the authors.

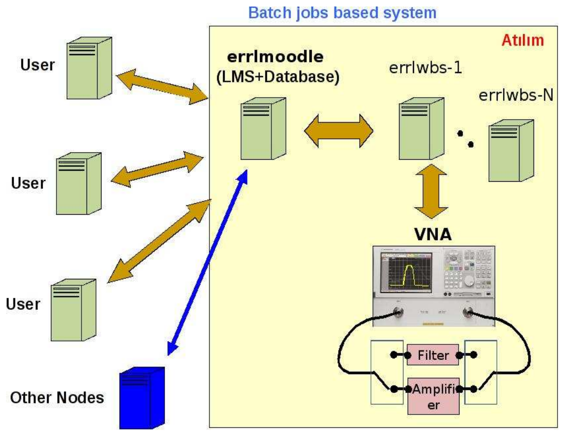


Figure 2. Batch job based ERRL system

2.2. Hardware Structure

There are three hardware modules in the ERRL system. The first module involves the use of Vector Network Analyzer (VNA) in a set of experimental setups to perform experiments on, basic microwaves and antenna concepts. In this module, there are 5 experiments that can be performed with remote access to the ERRL system. The heart of this module is a high capability VNA as the measurement device. The workbench server operates several high precision RF switches through a digital output card so as to connect the measurement ports of VNA to one of the various available experimental setups. In Figure 3, a block diagram of the first module is provided, and details of the experimental setups i.e. the RF devices and their connections to VNA terminals are shown in Figure 4. The arrangement used here is a special case of a generic structure which can be used for various experiments. The generic structure would involve a bank of multiplexed experimental setups, at least two RF switches and a measurement device. In this particular case, a VNA is used to supply signal and measure the outputs of the experimental setups.

The second module contains experiments on temporal and spectral domain signal analysis, and modulation schemes. In this module, a waveform generator, an oscilloscope and a spectrum analyzer are networked, and various experiments can be performed remotely. These two modules are more "device-centric", that is, they are based on the idea that several test and measurement devices and experimental setups can be connected in an appropriate ways via switches to perform different experiments remotely. On the other hand, the last module is designed in a different way. This module was designed specifically for the measurement of intermodulation distortion in RF and communication systems. In this module, various components such as nonlinear amplifier, combiner, signal generator, attenuators and spectrum analyzer were used to design a measurement setup at circuit level. A microcontroller card was developed which communicates with the workbench server via its USB port, and it controls the RF signal generator modules through a serial port based on the commands its receives from the server. In this sense, this setup is more complicated and required a separate circuit design process at the low-level.

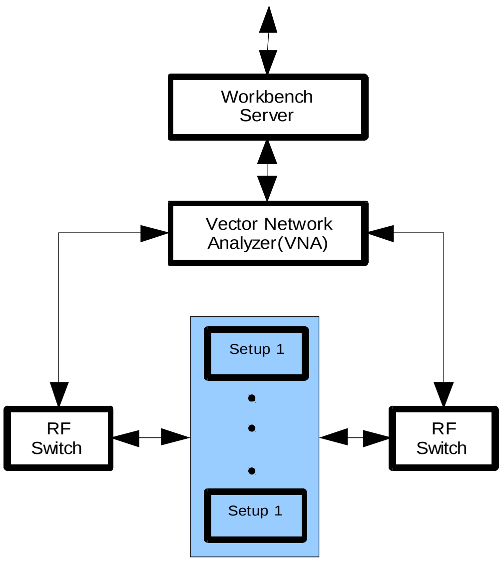


Figure 3. Block diagram of the First Module

2.3. Experimental Content

Since the system has been developed by the support of European Commission, the content and objective of the system has been determined to serve the objectives of mission in improving the education system in Europe. Therefore, the experiments of the ERRL system were determined after a requirement analysis conducted by several institutions [13,14]. Moreover, the target groups that may use the system are determined after the analysis of the data collected. Then the experimental subjects were grouped according to the target user levels. In the ERRL systems, there are, basically, three groups of users/learners or skill levels (basic, intermediate and advanced) determined according to the European Qualifications Framework (EQF) level standards. The list of experiments is listed in Table 1.

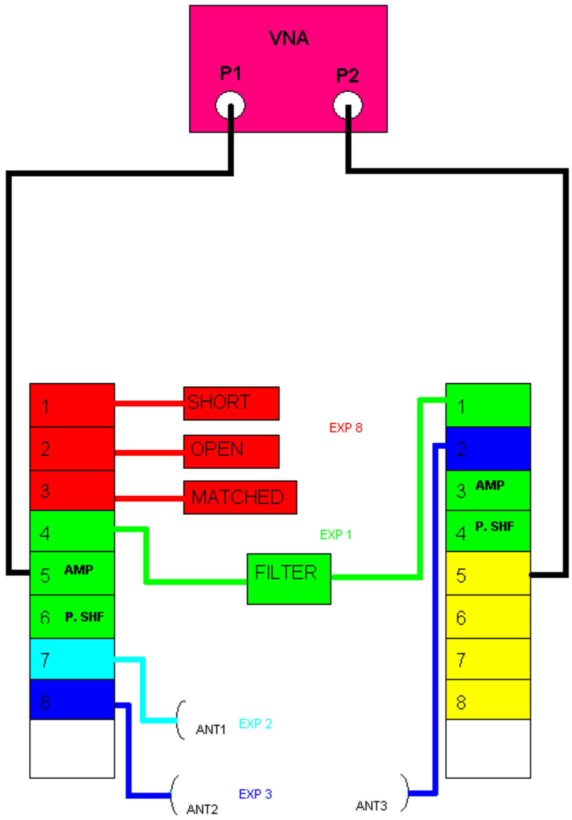


Figure 4. Diagram of the first Module

Table 1. List of Experiments

No	Description
1	Measurement of scattering parameters of short, open load, matched load
2	Spectrum Analysis and Fourier Series
3	Measurement of Scattering Parameters of Devices
4	Extraction of Physical parameters of a Coaxial Medium with Vector Network Measurement
5	RF Amplifier Measurements
6	Noise Figure Measurement of a Spectrum Analyzer
7	Intermodulation measurement in RF systems
8	Analog Modulation (AM)
9	Frequency Modulation (FM)
10	FSK and ASK modulation
12	Analysis of Antennas

With a mixture of experiments, the ERRL system intends to provide several opportunities to the learner groups as

- to learn about RF measurement methodology
- to interact with equipment
- to learn differences between low and high frequency measurements
- to compare analytical and experimental results
- to perform analysis on experimental data
- to asses of the learner's knowledge, skill and competency level

The experiments, instrumentations and theoretical content of the ERRL system are selected to cover all basic subjects, common to most training organisations, from analog and digital communications, electromagnetics, microwaves and antennas along with general RF technology subjects [5-7]. In this regard, the ERRL experiments include the concepts of reflection and transmission (return loss, Standing Wave Ratio, reflection coefficient), transmission lines, loss power, reflected power and transmitted power of the antennas, and the SWR, the input impedance of the antenna at the certain frequency range, multipath, noise, carrier, modulated carrier, modulation, time and frequency analysis of signals (Fourier analysis), electromagnetic compatibility measurements.

The experiment interface, as shown in Figure 5, provides opportunities to set up related parameters and get the results from the related equipment. On top of the experiment interface, an experiment manual is provided specific to each experiment, which provides a step by step guidance on the designed experiment. At the bottom, the setting of the devices and measurement results are provided in various formats. Users may tune the parameters of devices for a particular experiment, press submit button, and complete measurements. Then choose an appropriate format for the output, and display or save the data as s/he wish. In Figure 6, a sample plot of smith chart and an AM signal are shown suggestive one as captured in Figure 6. Plots may have various formats, and this feature of the system is very important for providing interactive learning environment on real equipment.

For example, the first output of Figure 6 shows smith chart for microwave experiments which is very important concept in the analysis of matching networks in microwave circuit design. On the other hand, the ouput at the bottom shows amplitude modulated (AM) signal in time domain. It is a basic modulation scheme of communication systems. The content and format of outputs in the ERRL system is very rich, and a variety of formats of the outputs may be provided as the users request.

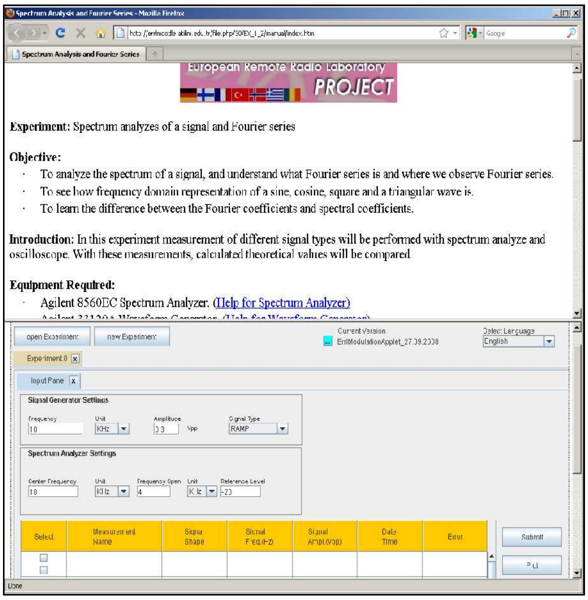
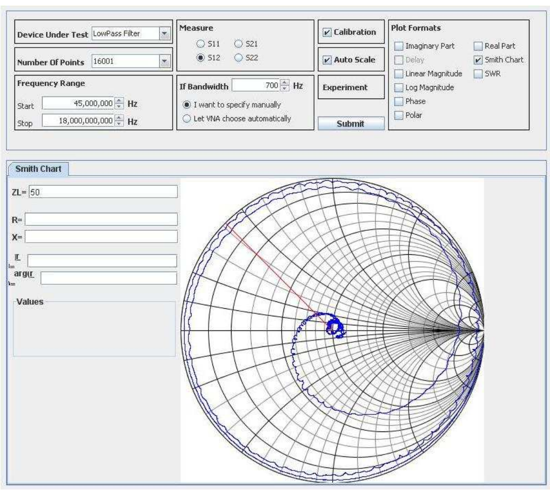
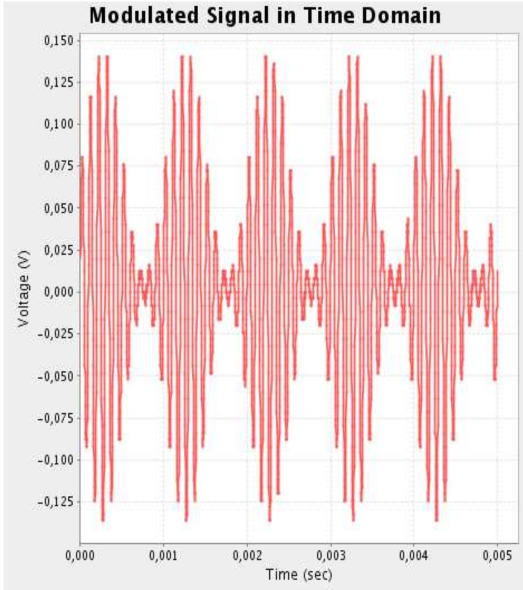


Figure 5. Experiment Interface of the ERRL System



(a)



(b)

Figure 6. Graphical format of the ERRL system

3. Educational use of the ERRL System

When it is compared with previous remote laboratory implementations, ERRL system significantly differs from them in terms of its target users. The experiments and facilities provided in the ERRL aims to serve the following three target groups, each of which corresponds to one skill level of EQF. Since the EQF aims to provide harmony of skill levels between countries in Europe, the subjects and teaching approches used in the ERRL system then should be standardized. The target groups are as follows:

I. Students of electrical, electronics, telecommunications and computer engineering, and those from other engineering level educational and training organisations,
II. Engineers, particularly the new graduates, in the areas of electrical, electronics, telecommunications and computer, and those who have the lack of experimental experience/training in telecom/radio related topics,
III. Students or graduates (technicians) of vocational schools/colleges serving for the electrical, electronics, telecommunications and computers fields, or their equivalents.

To achieve this objective, the subjects are determined after a needs analysis in various countries in Europe, and then they are grouped according to the three skill levels. Simply, the user domain can be considered in horizontal (subject content) and vertical (skill levels) dimensions. Then, the ERRL system has been tested by sample users from three groups, and it has been improved regularly in the development phase of the system. The system has been operational in the last two years, and it has been used regularly in several courses at Atilim University since then.

For users, there are many benefits of the use of the system. Firstly, it serves as an alternative laboratory environment for students who want to access experiments remotely. On the other hand, as having mixture of materials, the ERRL system can serve as a blended learning environments. Because, in additiona to the remote experiments, it has various form of teaching materials including movies, animations and quizzes. It may be considered as complimentary tool for classical educational systems in a technology enhanced learning environment.

On the other hand, authors have attempted to develop a new curriculum for junior level course that integrates the ERRL system into the classical educational environment [6]. From the implementation of this new curriculum in the course, we get very promising results by gaining more time on classroom activities, improving students' learning progress and providing a better experimental environment for the students. From this new implementation, most students provided positive feedbacks on the ERRL System. For example a student stated that, "Since I am performing the experiments, I did not forget what I have learned. For example, in the exams I was still remembering those activities.". Another student has reported that, "I learned by myself. It is very important. I did not wory if I can break a device or other thinks. I used the system from the Internet and this helped me to make more practice and to discover things.". Supporting to these comments, according to the previous year, students' grades improved significantly [15].

4. Conclusions

The ERRL system has been developed by the support of European Commission, and been operational in the last two years. The system basically contains experiment from communications, RF and microwaves. The system is unique in that it provides access very delicate devices which may not be accessible in classical laboratories. However, the experiences acquired by the authors is that the user interface might be improved. The interface might be improved and the experiements may be enriched by adding some subjects from basic electronics and digital systems.

5. References

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