A REMOTE LABORATORY FOR TRAINING IN RADIO COMMUNICATIONS: ERRL*

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ABSTRACT

This paper presents, first, a short survey of remote laboratory initiatives in electrical and computer engineering, and then discusses design and development phases of remote laboratory environment on radio communications, the ERRL (European Remote Radio Laboratory). As being the first attempt in establishing of such a large scale remote laboratory on radio communications, ERRL enables access to high technology RF equipments and setups through the Internet. The software structure, target groups and experimental set ups of ERRL are shortly discussed. First attempts on implementation of pilot experiments are discussed.

I. INTRODUCTION

Radio communications related courses include topics that form the backbone of techniques used in industries such as telecommunications, security systems, automative and defense systems. It is highly important for those industries that technical personnel such as engineers and technicians have the practical experience as well as the theoretical background for radio communications. Laboratory works are important suplement of theory in training of engineers and technicians. In most of vocational training schools, there are many radio communications related courses for teaching the theory but not enough laboratory equipment/experiments to support and demonstrate the application of the theory. The main reason is that the equipment required in high-frequency telecom/radio laboratories are of high technology, very expensive, as a result most of the schools cannot afford to have such equipment, and establish those labs [1].

On the other hand, access to Internet became a routine for almost everyone in daily life, online education opportunities started to explode. Researchers started to develop new ideas for improving the quality of training by web based education systems [2,3]. Web based laboratory applications use two different approaches: virtual lab initiatives involve the simulation of a system on a computer, and does not require a physical lab environment but allows the user feel like s/he is performing an experiment. Although being educative, such an experience lacks acquaintance with real data which will improve troubleshooting capability of the user. Remote laboratory platforms, on the other hand, enable the user to control physical lab equipment from a distance via the Internet. Initial attempts to developing remote laboratory environments were mainly focused on control engineering, chemical and mechanical (robots) applications and basic electronic circuits [1-4]. The use of Labview (Laboratory Virtual Instrument Engineering Workbench) is usually chosen for ease of data acquisition process and control of instruments. However, it requires tools to be installed on the user side that does not provide desired flexibility for the user. Therefore, the need for accessing physical set-ups brings up many problems to be solved when more flexible and extendible solutions are preferred.

The first successful remote lab in EE domain [2] is based on the client /server architecture. It has used platform independent, flexible and simple java applets on the user side while Visual C++ is used on the server side because of instrument drivers mostly written in C++. The server software provides two-way communication separately with the set up and the web-server and it also has a GUI for the instructor to monitor the whole process on the web-server side. This lab, however, uses a simple experimental setup, and is very limited in terms of content. In [3], an upgraded version "lab on web" for CMOS device characterization is presented. The architecture developed for "Lab on web" incorporates web services interface based on XML, and a UDDI service directory for allowing educators to offer and select experiments from different locations. For such an application, a layered security framework has been developed. A group of about twenty Italian universities and specialized instrumentation, e-learning, and publishing companies have presented a remote didactic laboratory called L.A.D.I.R.E "G.Savastano" [4-6]. The designed experiments are listed in [5], which enable access to Digital Oscilloscope, Digital Multi-Meter, and Waveform Generator. The user is also allowed to set up predefined circuits at the client side and to use

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measurement devices remotely, where a set of hardware modules and a bread-box for circuit assembling is provided to the student on demand. The three-tier LADIRE architecture, software layers and delivered services are introduced in [6]. Measurement modules distributed geographically in Italy are interfaced to Measurements Servers (MS) via GPIB cards. Each laboratory uses a Laboratory Server (LS), which connects to multiple MSs through LAN. LS is the only machine directly accessible through the internet. The software technologies, low-level programming, how data are flowing between the nodes, and constraints are partially discussed in [7-9]. It seems that this didactic lab serves as a centre for collection of many experiments structured independently, where set ups can be extended independently and main centre can only monitor the users and the overall system. The system seems to aim at local users only, and the architecture seems to support the specific aim of exchanging didactic activities related to basic EE courses among Italian universities. Since the web module and referenced links in the papers are all in native language, papers would be expected to appear to clarify the implementation details of LADIRE “G. Savastano”.

II. REMOTE LABORATORY IN RADIO COMMUNICATIONS

In the curriculum of engineering departments and colleges, there usually exist many theoretical high-frequency (HF) radio communications related courses to equip students with the needs of the industry. These courses are usually supported by several laboratory environments. However, there exist several limitations in establishing of those laboratories. Expensive physical experimental setups (an experiment setup of basic electronic circuit would cost just one tenth of a HF device such as network analyzer) and their implementation and maintenance should be considered. It is hard to acquire enough laboratory equipment and to establish experimentation facility to support and demonstrate the application of the theory [10-13]. The lack of laboratory equipments exist particularly for radio communications experimentations in high-frequency ranges, which are used in various consumer devices (mobile phone, CD player/radio, car remote etc.) at present. That is because, the equipment required in HF radio communications laboratories are very expensive and delicate, and accordingly, most of the schools cannot afford to have such equipments and the trained personnel. Even at the presence of high frequency radio communications laboratories, trainees may not have the opportunity to fully exploit them due to the lack of supervising personnel and restricted time allocation. Unattended conduction of experiments is risky since the cost of any damage to equipments is very high. Then, remote implementation of radio communications experiments would be a good choice, and have many advantages. The literature survey shows that, the previously developed remote laboratory platforms mostly covered introductory and basic electrical and electronics, and control laboratory applications [2-8]. In literature, several radio communications related remote and virtual laboratory attempts were explored. Among them, a few important implementations are the followings: remote implementation of frequency modulation (FM) experiment-VLAB [14], a virtual spectrum analysis via digital oscilloscope [15] and virtual digital oscilloscope [16]. An extended version of VLAB in [14] was proposed in [17], where a remote laboratory structure based on client/server architecture was developed to access six experiments on modulation techniques implemented on the same board via switching of low frequency signals. The application server is connected through TCP/IP to both client and the experiment module with appropriate GUI modules. Frequency and time domain analysis of “low frequency” signals related to AM, FM, PSK and FSK schemes can be demonstrated by receiving data from and sending data to the client. The picture of experimental setup can also be transmitted to the client with an integrated webcam. These implementations show the recognition of the importance of these topics in the educational arena, ad also initial attempts to demonstrate its remote access. Radio related applications can also be generalized and collected under wireless technology concept. Then, a interesting initiative should be considered: Global Wireless Education Consortium (GWEC) [18] mostly formed by the US universities and industry. GWEC aims to develop an international curriculum in order to provide training individuals to have required qualifications of wireless industry. With many industrial and educational partners, GWEC has proposed different course modules, called Points of Knowledge (POK) on wireless technology with wide range of topics from radio transmission to health issues.

In Europe, on the other hand, European Commission (EC) states a mission, with the declaration of Lisbon, to improve education system in Europe. One of the objectives of this mission was to promote of life-long (LL) learning system in order to update competences and to encourage new specializations of adults and to increase capability of finding or changing their jobs [4]. E-learning based on emerging Information and Communication Technologies (ICT) could be used to achieve this objectives. Therefore, in this sense, remote laboratories are complementary part of such an e-learning system to be developed for ICT training in engineering and colleges.

European Remote Radio Laboratory (ERRL) is an initiative addresses an advanced field compared with predecessors, radio communications, and enables access to high technology RF equipments and experimental setups through the Internet. Although the target groups of ERRL, a subgroup of ICT students and personnel, is not as broad as that of basic laboratory applications discussed previously, their access to such equipments are more limited. Yet, the qualifications which ERRL objectives aim to provide are highly demanded by the RF industry. The reason for limited access to RF equipments is that they are not available at most laboratories due to their very high cost and lack of trained personnel. Another issue specific to ERRL is that access to equipments requires specific solutions different from previous remote laboratory applications. ERRL will provide not only education to university or college students, but also training and improvement of skills for the graduates, and even individuals. An illustration of ERRL domain is shown in Figure 1 where horizontal axis represents subjects in Electrical, Electronics and Computer technologies (part of ICT) while vertical axis represents skill levels from college degree up to graduate degree.

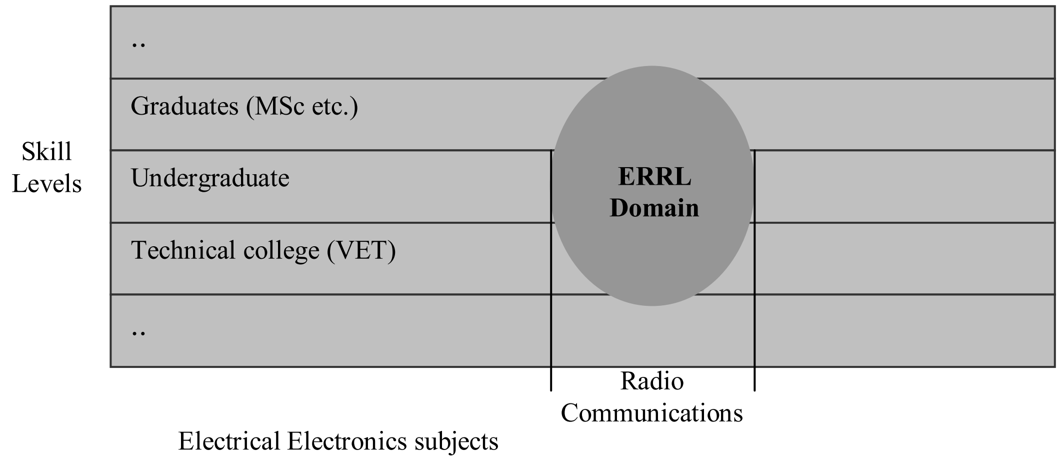

Figure 1. Area of ERRL content in educational subjects and skills

With the ERRL target domain in Fig. 1, when compared with previous remote laboratory implementations, ERRL significantly differs from them in terms of its target user groups. The experiments and facilities to be provided in the ERRL are planned to serve the following three target groups:

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.

The target groups profile shows that ERRL not only aims to support EE education by practical training, but also emphasizes improvement of skills of engineers and technicians in the field according to the advancing needs of the technology. Hence, additionally, the engineers and technicians who are unemployed, and/or looking for a job, among those engineers and technicians women staying at home while improving their competences, female radio communications trainers who have to stay out of high frequency range instruments due to pregnancy, as well as people having disabilities and difficulties in reaching the place of the laboratory in these domains. The final users of the remote laboratory will be vocational schools, colleges, universities and/or other educational institutes, employer or training organisations in Telecommunications or related fields, through which their students, graduates, members, or employees will benefit. This wide range of target user groups suggests a modular structure of laboratory content. Then, experiments and supporting contents are planned to cover a wide range subjects in radio related courses including electromagnetic, communication systems, microwave and antennas. These subjects should also be partitioned according to the needs of target groups.

Table 1. List of Experiments

No	Equipment and subject Description
	Vector Network Analyzer (VNA)
1	Measurement of scattering parameters of short, open load, matched load
2	Measurement of scattering parameters of waveguide, filter (such as bandpass, lowpass), amplifier, phase shifter, directional coupler
3	Analysis of antennas such as patch, wire antennas
4	Impulse Response and Multipath (To gain understanding of the relation between time and frequency domain response of a radio channel)
5	Extraction of physical parameters of a coaxial medium with vector network measurement.
	Spectrum Analyser, RF signal generator
6	Noise figure measurement of a spectrum analyzer
7	Intermodulation measurement in RF systems
	Spectrum Analyser, Waveform Generator, Oscilloscope
8	Analog Modulation (AM)
9	Frequency Modulation (FM)
10	FSK, ASK and PSK modulation
11	PLL in time domain
	Spectrum Analyser, Signal Generator
12	Spectrum Analysis and Fourier Series
	EMC Analyser
13	EMC Analyser

Curriculum of several European universities and the needs and requirements of telecommunication industry are considered [1] when the experiments and subjects are determined. As the knowledge of authors, ERRL is unique in its integration of RF and telecommunication systems. As shown in Table 1, 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. While providing a broad exposure to the telecom and radio communications area, students also gain hands-on experience with state-of-the-art instrumentation including spectrum analyzer, vector network analyzer (VNA) and a digital oscilloscope at high frequencies.

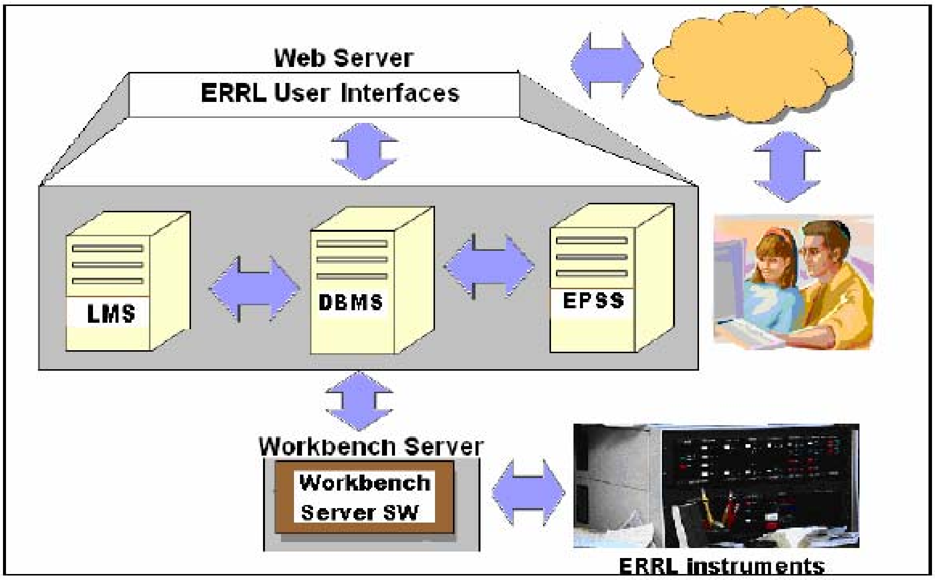

Figure 2. General structure of ERRL

ERRL software structure is shown in Fig.2 where the following components are considered

ERRL User Interfaces

The user interfaces of the ERRL mainly serve the instructors and the learners. The instructors are able to set-up new experiments and related instructions. They are also able to search in the system database for the current instruments, experiments related instructions and statistical information from the system. The learners are able to do experiments, see the results of experiments.

The Workbench Server Software

It is the lowest layer of the system. This software establishes the communication between instruments and the user interfaces through the ERRL database.

Electronic Performance Support System (EPSS)

The EPSS is developed to prepare the learners to be ready for doing experiments with the specific instruments. The EPSS part of the ERRL project has specific instructions for each instrument in the system. The EPSS also covers some initial experiments to help the learner better understand each instrument. However, these initial experiments are designed as simulation of actual experiments and do not work remotely. It uses real data which is previously prepared for that experiment and stored in the database.

Learning Management System (LMS)

Moodle is an open source LMS used in the ERRL project. The content about the experiments is defined in the LMS. The LMS database and the ERRL information system database are linked together in order to support integration.

When the hardware structure is considered, ERRL is unique in the sense that experiments at high frequencies (up to 18 GHz) can be performed thanks to HF switches by Agilent. This high precision coaxial switch is able to provide fast switching between experimental modules. Figure 3 shows block diagram of experimental setup for frequency characteristics of active and passive devices, or frequency analysis of signals.

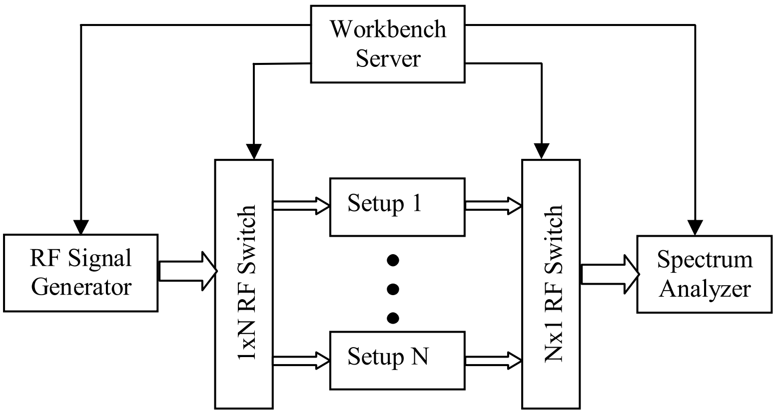

Figure 3. Sample experimentation set up for frequency analysis of circuits and/or devices.

III. CONCLUSION

Remote laboratory approaches are reviewed and discussed. The needs of a large scale remote laboratory on radio communications and target requirements are discussed. Design and development of a remote radio communications laboratory, ERRL, are described. ERRL structure is considered on three components: software, hardware and content. Many approaches have been studied for software design of ERRL. Hardware facilities to be provided under ERRL concept are unique with high cost, precise RF equipments. The content of the experiments have been determined according to a) skill levels of users (horizontal) b) importance of subjects in radio communication fields.

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