REMOTE RF LABORATORY REQUIREMENTS: Engineers' and Technicians' Perspective

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ABSTRACT

This study aims to find out requirements and needs to be fulfilled in developing remote Radio Frequency (RF) laboratory. Remote laboratories are newly emerging solutions for better supporting of e-learning platforms and for increasing their efficiency and effectiveness in technical education. By this way, modern universities aim to provide lifelong learning environments to extend their education for a wider area and support learners anytime and anywhere when they need help. However, as far as the authors concern, there is no study investigating the requirements and needs of remote laboratories in that particular field in the literature. This study is based on electrical engineers' and technicians' perspectives on the requirements of a remote laboratory in RF domain. Its scope covers investigation of the participants' perceptions toward computer mediated communication and it attempts to answer the questions: which studying strategies are preferred by the learners and what kind of RF laboratory content should be provided. The analysis of the results showed that, geographic independence, finding quickly the elements of past communication and temporal independence are declared as the most important advantages of computer-mediated communication. However, reading significant amount of information is a problem of these environments. In the context of how to show the content, respondents want to see shorter text on the screen. Therefore the instructions should include little amount of text and must be supported with figures and interactive elements. The instructional materials developed for such learner groups should support both linear and non-linear instructions. While analyzing the content to be provided, we have seen that, most of the participants do not have access to high level equipments and traditional experiments are considered as the necessary ones for both engineers and technicians.

Keywords: Remote laboratory; e-learning; Radio Frequency, requirements analyses.

INTRODUCTION

This study is established to better understand the requirements of radio frequency (RF) laboratories based on the electrical engineers' and technicians' perspectives working in this field. In that context, the study is conducted with the electrical engineering (EE) and the technical colleges (TC) graduates. Here, EE covers the Bachelor of Science (BS) and the Master of Science (MS) level of education in

electrical engineering while TC represents the vocational education and training as well as technical and associative educations prior to engineering in this particular field.

Laboratory experience is an important supplement of EE education. As it has been shown in recent Internet based remote and virtual laboratory studies, effective learning in EE education could only be achieved by approaches combining theoretical courses with laboratory works which could be repeated as many times as the learners wish (Wulf, 2000). Laboratory works are provided by means of face-to-face training in particular laboratories as a classical method.

Face-to-face laboratory training may have many limitations both at the provider and at the learner sides (Sanchez et al. 2004). Among the limitations at the provider side, the requirement for more teachers and supporting personnel, high establishment and maintenance costs for some of EE laboratories such as the ones covering radio frequency and microwave techniques are well-known (Ko et al., 2001). At the learner side, 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. Hence, remote laboratory applications seem to be an alternative approach to provide laboratory experience for the learners.

In addition to the listed limitations, recent developments in the Internet opportunities encourage training organizations and institutions/universities to develop e-learning models. Modern universities need to provide lifelong learning environments to extend their education for a wider area and support learners anytime and anywhere when they need help. In order to reach this objective, educational and training organizations, particularly universities, are making increased use of the Internet technologies to enhance and supplement the classical way of face-to-face education. As in the classical education, teaching via Internet should also be partitioned into theoretical lecture hours and complementary laboratory works. Especially in the case of EE education and technical college, in order to better initiate the e-learning programs, the laboratory applications should also be facilitated remotely in order to have a complete e-learning process. A remote laboratory platform enables the learners to access physical instruments at a distant location and to perform experiments remotely via the Internet. In other words, newly emerging remote laboratories can be a solution for better supporting of e-learning platforms as well as increasing their efficiency and effectiveness.

This study focuses on the results of requirement analysis performed in different countries of Europe, in order to establish a remote radio laboratory (RF) for EE education and technical college. We believe that a remote laboratory should provide the potential users what they are not able to access easily and conveniently in classical manner. The requirement analysis in this study is based on the engineers' and technicians' perspectives in the RF domain.

This requirement analysis is, first, aimed to guide further studies in this domain and then, planned to be extended to other domains of EE education. The organization of the paper is as follows: next section introduces the envisioned problems and limitations of practical RF training and describes remote laboratory option to overcome those problems and limitations. Our survey applied to engineers and technicians from various institutions among many countries of Europe, and evaluation of the results are covered in the following sections. The last section is on the discussions and conclusions.

BACKGROUND OF THE STUDY

Widespread public and private services offered by the telecommunications industry compel RF and microwave technology and sciences. Such technology has been recognized as an essential core of EE and computer engineering education over the last decade. This recognition has been supported by studies in the literature (Gupta et al. 2002). In the curriculum of engineering departments and technical colleges, there usually exist many theoretical high-frequency telecommunication or radiocommunication related courses to equip students with the needs of the industry. These courses are usually supported by several laboratory environments. Among them, Remote laboratory on frequency modulation experiment principles (Ko et al. 2001) a face-to-face laboratory implementation in the field of antennas (Mazanek et al. 2005), RF-microwaves (Furse et al. 2004), an RF hardware design laboratory with project oriented approaches (Kuhn, 2000) and wireless information networks (Cassara, 2006) are some recent examples of this environments.

Cassara (2006) have also summarized some of these implementations which generally focus on one of the following topics: wireless networks, radio frequency-microwaves, antennas, radar or optical communications. These implementations prove the recognition of the importance of these topics in the educational arena.

There exist several limitations in establishing those laboratory practices listed above. Expensive physical experimental setups both in implementation and maintenance are only few of them. It is hard to acquire enough laboratory equipment and to establish experimentation facility to support and demonstrate the application of the theory (Menzel,2003; Righi et al. 1998; Iskander 2002). The lack of laboratory equipments exist particularly for telecommunication 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 equipments required in high-frequency telecom/radio 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 telecommunication 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.

Another factor that should be considered is that practicing in telecommunications industry has rapidly been changing. Hence, technicians, engineers and managers working in this field should continuously improve their skills and technical background according to the most recent requirements of the industry, in order to remain competitive in the field. It should be noted that supporting those personnel merely with updated theoretical information is insufficient. Improvement of the practical skills is vital for the aforementioned field. Engineering departments of universities are the best places to offer lifelong learning (LL) opportunities by complementing theoretical education with practical training (Wulf, 2000).

Different approaches to solve the problems discussed above have been proposed in the literature. For example, an open laboratory where students can work at any time during normal business hours has been established (Kuhn, 2000). As an advantage, this allowed a class of ten or more to share single equipment such as spectrum or network analyser. In this approach, the problem of time limitations and maintenance of expensive instruments still exist. Simulation of physical experiments is another

alternative solution (Menzel,2003; Righi et.al 1998; Iskander, 2002). However, a laboratory experience is essential for the students to develop troubleshooting skills for dealing with instrumentation and physical processes (Gustavsson, 2002).

Learning process differs among individuals. It is an important need of students to receive the most effective education where they have the chance to choose and follow their own learning style and pace. Remote laboratory platform offers a more flexible practice environment to the users, and provides more efficient use of the laboratory equipment. Users can configure circuits and get results very quickly, which encourages them to change variables for example input signal frequency or amplitude in order to observe the differences between several situation more easily than they would in a physical laboratory. Remote laboratory applications are considered to be a feasible way of supporting lifelong learning, since they can offer training at flexible hours.

It is well known that the instruments used in basic courses are generally easy to control remotely (Gustavsson, 2002). Accordingly, a number of remote laboratory applications related to basic EE courses have been implemented successfully (Aktan et al. 1996; Etxebarria et al. 2001; Sanchez et al. 2004; Miele et al. 2004; Gomes & Costa, 2005; Fujii & Koike, 2005; Tzafestas, et al. 2006).

Early remote laboratory applications in the EE domain have generally been established on microprocessor, control systems, power electronics, digital circuits and robotics. There are not many examples of remote laboratory applications established in the RF domain. On the other hand, the rapid growth of telecommunications industry and widespread deployment of wireless network services boomed the opportunities in careers related to high frequency technology for graduating seniors and seniors. This rapid growth also forces practicing engineers, computer specialists, and managers to re-educate themselves in the area of telecom/radio-communications technology (Weller et al., 1998; Cassara, 2006). Such education is generally offered by electromagnetic, RF, antenna and microwave courses, which are important components of any EE and computer related educational curriculum. Finally, the requirements and lacks of workforce on RF specialists has been indicated recently in (Sloan, 2005) where an industry/education partnership (Global Wireless Education Consortium-GWEC) involving more than 30 universities and 9 large companies in wireless sector in the USA has been reported. Hence, a remote laboratory application in the RF domain seems to be a very critical issue in order to improve and support current educational environments.

III. Research Methodology

This study investigates the requirements of remote RF laboratory based on engineers' and technicians' perspectives working in this field. The research question is as follows:

- **Which requirements and needs should be fulfilled while developing a remote RF laboratory?**

In order to answer this main research question, we examined the following sub-questions in this study.

- **What are the participants' perceptions on computer-mediated communication?**
- **Which studying strategies are preferred by the participants?**

- **What kind of RF laboratory based content should be provided?**

Data-collection Process

In order to better understand the needs and requirements of remote RF laboratories we have prepared a questionnaire for sample groups of engineers and technicians in RF domain. Since highly specialized people work in RF domain, the number of the participants is limited with 53 people (15 technicians, 38 engineers) from Germany, Romania, Turkey, Greece and France.

The engineers are selected from target industry and have at least Engineering Bachelor degree, where as the technicians are selected from target industry and have at least vocational school, +2 or +4 years of vocational education degree. Table 1 shows the profile of the engineers and technicians (multiple selections are considered).

Table: 1
Composition of Engineers and Technicians

	Technicians	Engineer
Vocational High School	2	
BS engineer		26
MS		10
Ph. D.		2
4 years of vocational education	3	
2 years of vocational education after high school	10	
Total	15	38

All of the participants are male. Table: 2 shows the participants' years of experience in the field.

Table: 2
Experiences of the participants in the field

Year	Technicians %	Engineer %	Total %
0-5	6	53	40
6-10	27	29	28
11-15	47	11	21
16-	20	8	11

Majority of participants (68%) are having 0-10 years of experience in the field. This shows us that, the participants have a learning potential in this field. This ratio is

82% for the engineers and 31% for the technicians. Most of the technicians have (74%) 6-15 years of experience in the field.

EVALUATION OF QUESTIONNAIRE RESULTS

In order to better understand how a remote radio laboratory should be established and what the engineers and technicians need in this education, we have prepared a questionnaire.

In this questionnaire we have organized the questions in the following dimensions:

The participants' perceptions toward computer mediated communication, forms and ways of showing content and the scope of the content to be provided.

Perceived Advantages and Disadvantages of Computer Mediated Learning

In this dimension, we have asked to the participants to select the advantages of computer mediated communication.

As summarized in Table 3, the participants find the geographic independence (28%), easily accessing the past communication (28%) and temporal independence (27%) as the most important advantages of computer-mediated communication.

The results showed that distractions (14%) and the embracing teacher's presence (3%) are not seen as main advantages of computer-mediated communication (CMC). The results are similar for both engineers and technicians.

Table: 3
Advantages in Computer-mediated Communication

Item	Technicians %	Engineers %	Total %
Geographic independence	29	28	28
You can find quickly elements of all past communication	23	30	28
Temporal independence	30	25	27
Silent (nobody disturb you)	10	16	14
You are not embarrassing for teacher's presence	8	1	3

As summarized in Table: 4, according to the participants, reading significant amount of information online is the most important disadvantage (39%) of the CMC.

It was found that, absence of immediate feedback is another disadvantage (24%) of CMC. The problems with CMC follow these items (17%).

They think that they have sufficient experience on the web-based applications and they do not worry much if the participants receive their message or not.

Table: 4.
Disadvantages in Computer-mediated Communication

Item	Technicians %	Engineers %	Total %
Reading online especially if the amount of information to be read is significantly large	40	39	39
Absence of immediate feedback	15	29	24
Imperfect technology	15	18	17
Not yet sufficient experience with the web and Internet	15	7	10
You may not be certain whether other participants have received your message	15	7	10

Instructional Strategies

Table 5 shows the participants' preferred way of studying a new subject (in groups or individually). When learning a new concept, most of the participants (75%) prefer to study with someone who knows the concept well, or within a group. 25% of the participants prefer studying on their own.

When we analyzed the technicians and engineers separately, we see that, 87% of the technicians and 71% of the engineers need a person or a group while studying a new subject.

Both engineers and technicians in the first place prefer to study with someone who knows the concept well. In the second place, while engineers prefer to study on their own, technicians prefer to study within group.

Table: 5
Preferred way of Studying (in groups or individually)

	Technicians %	Engineers %	All %
Studying with someone who knows the concept well	47	50	49
Studying with a group	40	21	26
Studying on their own	13	29	25

Under this dimension, we also asked participants' preferred way of studying a new subject in the sense of linear or non-linear way. Table 6 summarized results of the participants' responses on this question. 66% of the participants prefer studying a

concept by starting from the beginning and go through the chapters one by one in the given order (linear way of studying). On the other hand, 34% prefers to search on a keyword and than study on that specific topic only or reading the chapter(s) that they are interested in and never read rest of the content (non-linear way of studying). It should also be reported that, none of the technicians prefer the keyword search, where as 24% of the engineers prefer keyword search. None of the participants have chosen to study on the examples and exercises, and never read the rest of the chapters.

Table: 6
Preferred way of Studying (in linear or non-linear order)

	Technicians %	Engineers %	All %
Starting a concept from the beginning and go through the chapters one by one in a given order	73	63	66
Prefers reading the chapter(s) that they are interested in and never read rest of the content	27	13	17
Search on a keyword and than study on that specific topic only	0	24	17

Most of the participants declared that they prefer to study the concepts in a linear manner. We have asked the participants to order their preferred way of studying a new concept by using a web site. We have multiplied the total number of first place choices by 3 and total number of second place choices by 2 in order to calculate the total scores. The calculated total scores are reported in Table 7.

Table: 7
Preferred way of Studying on the web (linear or non-linear order)

	Technicians Score	Engineers Score	All Score
Reach the information by means of keywords and read only the chapters you need	34	71	105
Go through the chapters in a given order one by one	26	53	79
By means of questions and answers between the system and you	17	29	46

As seen from Table 7, most of the participants have reported that, they prefer to reach a subject by means of a keyword and read only the concept related with that keyword (score=105). Next, they prefer to go through the chapters in a given order (score = 79). Lastly they prefer to ask questions and get answers of that questions from the system (score=46).

Table: 8 shows the participants' preferences while performing experiments on a computer. The score here is also calculated in a similar way as in Table 7.

As shown in this table, they mostly prefer interactive content, animations and figures. Batch jobs and sound-based instructions are not their preferred way of doing experiments.

Table: 8
Participants' Preferences while performing an Experiment on Computer

Preferred way	Technicians Score	Engineers Score	All Score
Interactive	104	195	299
Animations on the subject	101	192	293
Figures on the subjects	112	170	282
Several problems and exercises	84	176	260
Text-based instructions	88	65	153
Story based	33	94	127
Games related with the subject	34	91	125
Batch jobs	22	97	119
Sound-based instructions	32	43	75

Content to be Provided

We have asked the participants to select the devices from the following list that they have been using for hands-on experiments and their real-life projects in low end, standard or high level.

Table: 9
Currently used RF Instruments and technologies

	Technicians (%)				Engineers (%)			
	No answer	Low Level	Std.	High End	No Answer	Low Level	Std.	High End
Power meter	67	0	26	7	29	10	32	29
Oscilloscope	13	7	60	20	13	11	39	37
Spectrum Analyzer	53	0	40	7	26	14	18	42
Vector network analyzer (VNA)	86	0	7	7	55	11	8	26
RF signal generator	53	0	40	7	24	13	37	26

Modulation generator (FSK, PSK, ASK, FM, AM)	20	13	60	7	24	21	26	29

As seen from Table: 9, engineers use high level equipments (SA and VNA) while technicians use generally standart equipments (oscilloscope and modulation generator). Both groups use VNA rarely.

Only 7% of the technicians have high level experience on VNA and 7% of the technicians have standard level experience on the same device. Where as most technicians (85%) have not used VNA yet. For the same equipment, the situation is a little better for the engineers (26% have high end experience, 8% standard and 11% low level).

However, 55% of the engineers have no experience with that equipment. These results show that, most of the participants do not have access to high level equipments.

From the same list, we also asked to select the devices which are not available at the moment, but would be necessary for significant quality improvement in hands-on experiments and measurement capacity.

Their responses on this question is summarized in Table: 10.

Table: 10

Currently not available technologies/instruments

	Technicians (%)		Engineers (%)	
	No answer	Necessary	No Answer	Necessary
Power meter	47	53	63	37
Oscilloscope	20	80	58	42
Spectrum analyzer	67	33	50	50
Vector network analyzer	60	40	39	61
RF signal generator	27	73	61	39
Modulation generator (FSK, PSK, ASK, FM, AM)	20	80	58	42

In this question no answer means either they have these devices or they do not know the devices at all. Since technicians use generally standart equipments, they report that these devices are more necessary ones.

Table: 11
Required HF Devices for improvement of experiments

	Technician (%)			Engineer (%)		
	No Answer	Yes	No	No Answer	Yes	No
Up to 50 GHz Spectrum Analyzer	**67**	**33**	**0**	**47**	**34**	**19**
Up to 26.5 GHz Spectrum Analyzer	**13**	**80**	**7**	**53**	**34**	**13**
Up to 40 GHz Vector Network Analyzer	**13**	**80**	**7**	**42**	**42**	**16**
EMC Analyzer	**27**	**73**	**0**	**42**	**47**	**11**
RF Signal Generator	**20**	**54**	**26**	**32**	**53**	**15**
Modulation Generator (FSK, PSK, ASK, FM, AM)	**60**	**27**	**13**	**29**	**62**	**9**
Up to 4 GHz Oscilloscope	**53**	**40**	**7**	**29**	**61**	**10**

On the other hand, engineers report that Spectrum Analyzer and VNA are more necessary ones.

Table 11 summarizes the interest in usage of a chosen set of high-end devices which are relatively expensive and can possibly be served through a remote laboratory. In this question "Yes" means, the participants think that the equipment is required.

This table shows that, engineers want to use spectrum analyzer and VNA while technicians want the use 4 GHz oscilloscope and complex modulation generator in the first place. We have also asked some questions about major experiments in the field. Table: 12 shows if these experiment are necessary or not for the participants.

Table: 12
Necessary Experiments

		Technicians (%)	Engineers (%)
Vector Network Analyser			
1	**Measurement of scattering parameters (such as short, open load, matched load)**	**73**	**71**

2	**Measurement of scattering parameters: waveguide and filter (such as bandpass, lowpass), amplifier, phase shifter, directional coupler**	**40**	**61**
3	**Analysis of basic and practical antennas (such as wire, patch and microstrip)**	**93**	**61**
4	**Impulse Response and Multipath (multipath effects in a real radio environment/channel)**	**13**	**47**
5	**Time and Frequency domain analysis of radio channel response and multipath**	**3**	**42**
Spectrum Analyser, RF signal generator			
6	**Basic RF signal noise and distortion measurements**	**73**	**68**
Spectrum Analyser, Modulation Generator, Oscilloscope			
7	**Analog Modulation (time and frequency analysis)**	**66**	**68**
8	**Frequency Modulation (time and frequency analysis)**	**66**	**76**
Spectrum Analyser, Signal Generator			
9	**Signal analysis, Spectrum Analysis (Fourier Analysis)**	**7**	**50**
EMC Analyser			
10	**Basic EMC Measurements**	**80**	**53**
Spectrum Analyser, RF Signal Generator			
11	**Frequency Transfer Characteristics of Active Devices (Amplifier)**	**13**	**47**
12	**Frequency Transfer Characteristics of Passive Devices (Filter)**	**7**	**55**
Spectrum Analyser, Modulation Generator, Oscilloscope			
13	**Shift Keying techniques (FSK, ASK and PSK modulation)**	**87**	**68**

According to the results, the experiments 1, 3, 6, 7, 8 and 13 are necessary ones for both the engineers and technicians. However, while the experiment 2 is considered as necessary (61%) one for the engineers, the technicians (40%) do not consider it as necessary as the engineers.

Similarly, experiment 10 is considered more necessary by the technicians (80%) than the engineers (53%).

We asked the participants from the following list to select the necessary ones for their system knowledge. According to the both engineers and technicians electronic, telecommunication, and RF information are of approximately the same importance

for their system knowledge, as shown in the Table 13.

However, the level is higher for the technicians. They prefer microwave and electromagnetic as least important level. Antennas and propagation is more necessary for the technicians (73%) than the engineers (34%).

Table: 13
Necessary System Knowledge (%)

Item	Technicians	Engineers	All
Electronics	73	58	62
Telecommunication	73	58	62
RF	60	50	52
Antennas and propagation	73	34	45
Microwave	33	11	17
Electromagnetics	7	16	13

CONCLUSIONS AND DISCUSSIONS

In this study we have analyzed the participants' perspectives on three dimensions. Participants find the geographic independence, finding quickly the elements of past communication and temporal independence as the most important advantages of computer-mediated communication. On the other hand, they find the reading significant amount of information online as the most important disadvantage of the computer mediated communication.

When learning a new concept, most of the participants prefer to study with someone who knows the concept well, or within a group. The participants in this study are from different age groups and different skill levels. The results show that, the participants' preferences on linear or non-linear instructions also vary. Cagiltay et al. (2006) have also showed that the learners' preferred learning path (linear or non-linear) depends on their personal characteristics such as their age, perceptions on problem solving, teacher or self study preferences, familiarity with the windows based computer applications, gender and preferred way of learning. Accordingly, the instructional materials developed for such learner groups should support both linear and non-linear instructions.

The participants mostly prefer interactive content, animations and figures. Batch jobs and sound-based instructions are not their preferred way of doing experiments. Respondents want to see shorter text on the screen. Therefore the instructions should include little amount of text and must be supported with figures and interactive elements.

Most of the participants do not have access to high level equipments. Since technicians use generally standart equipments, they report that these devices are more necessary ones. On the other hand, engineers report that Spectrum Analyzer and VNA are more necessary ones. Engineers want to use spectrum analyzer and VNA while technicians want the use 4 GHz oscilloscope and complex modulation

generator in the first place. We have seen from this study that, traditional experiments are considered as the necessary ones for both engineers and technicians. Engineers use high level equipment while technicians use generally standard equipments. Technicians use oscilloscope and modulation generator with standard level.

Both groups rarely use VNA. Majority of the respondents select electronic, telecommunication, RF and Antenna propagation as necessary areas for their system knowledge. Microwave and electromagnetic related subjects are less preferable.

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