

A Remote RF Laboratory in Electrical Engineering Education

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Abstract. This paper describes the use of a hardware and software environment that allows distant access to RF electronics measurement devices called Remote RF Laboratory. This access only requires conventional Internet browser and corresponding plug-in, both available for free, and low speed Internet connexion. Remote users may perform web-based RF measurements at any time, from any place, which is particularly interesting for applications in distant learning, enhancement of traditional lectures and from a financial point of view. General architecture of the remote laboratory is presented and multiple accesses to it discussed. Pedagogical approach is described and advantages compared to traditional lab are outlined. Users feedback is given and discussed.

1 Introduction

It is now well known and indisputable that both teachers and students can take advantage of new communication technology in education [1]. The way we view teaching and learning is changing and the educational institutions are entering into a new era. Teachers can greatly improve information management, quality of class preparation and class presentation. New communication technology has also positive influence on pedagogical considerations and contributes to develop the competence and skills of the students. From the student point of view, instant access to high quality class material from anywhere at any time is one of the major improvement compared to traditional learning. But this is not the single one. Engineering students are generally highly computer-literate and they can easily benefit from availability of many other resources, improved communication with teachers, competences acquirement and better results. They also will be more responsible for their learning. However, this new communication technology is today limited to traditional class when software, hardware and networks technologies are now sufficiently mature to allow their use in experimental lab class.

Thereafter, infrastructure used to provide distant access to RF measurement devices will be called Remote RF Laboratory. It is designed from a control PC used as a gateway between distant users and measurement devices.

- For communication with distant users, a web server and HTTP protocol is used to transmit requests from distant user to measurement devices and to transmit measurement results from measurement device to distant user.
- Communicating with the measurement device is done with virtual instruments. They are designed with LabVIEW [2] (no Java code or CGI script is required) and use GPIB bus to remotely control elementary functions of the measurement equipment

Remote laboratory concept ([3], [4], [5]) is of particular interest for many reasons:

- Researchers can share costly equipment and collaborate more efficiently on research
- Lectures may be enhanced with live demonstration
- Quasi multiple access to a single equipment is possible
- Additional software resources can extend calculation capabilities of the measurement device itself. A scientific environment including numeric computation, advanced graphics and visualization, and a high-level programming language or a simulation environment are of great interest because they allow real time observation of phenomenon not directly observables with the measurement device itself.
- Students can access laboratories after hours
- Maintenance costs are decreased

2 General Architecture of the Remote RF Laboratory

Functional scheme shows the central role of HTTP protocol [6] used by distant user for communication with the Remote Laboratory but also for possible access to an e-learning platform used to provide additional documentation, on line evaluation, and communication tools. So, Remote RF Laboratory is easily accessible with the URL of the control PC hosting the web server [7].



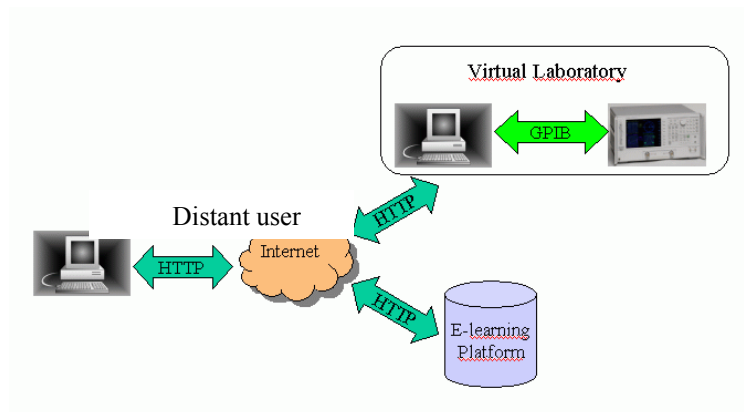


Fig. 1. Remote laboratory access

From the distant user side, only a common PC connected to Internet and a classical web browser (like Microsoft Internet Explorer or Mozilla) associated with corresponding plugin is required. The web server includes security and access control features and is able to manage multiple access (for obvious reasons, only one distant user may have control at a time).

Requests to the measurement device are inserted in HTTP protocol, sent to the control PC that transmits them to the measurement device through GPIB bus with virtual instruments. As shown on Fig. 2, GPIB connexion may be local (with physical cable link between control PC and measurement device), or distant (through a LAN).

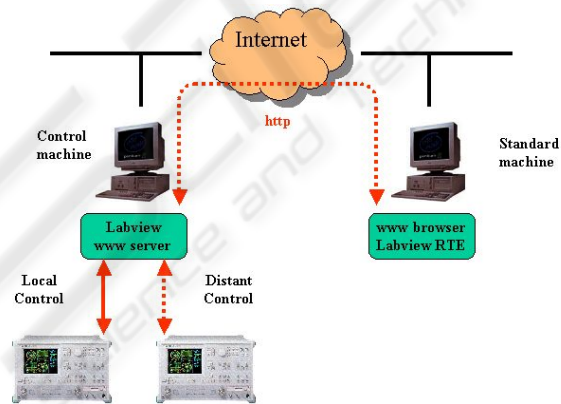


Fig. 2. Local or distant control

The response (a set of data) follows the reverse way.

3 Human Machine Interface

Human Machine Interface is of great importance and must be as intuitive as possible in order to facilitate access to complex measurement equipment. Providing a front panel as close as possible of that of the real instrument lowers getting started time. Corresponding graphical object is loaded only at the first access of the web page to minimize network load.

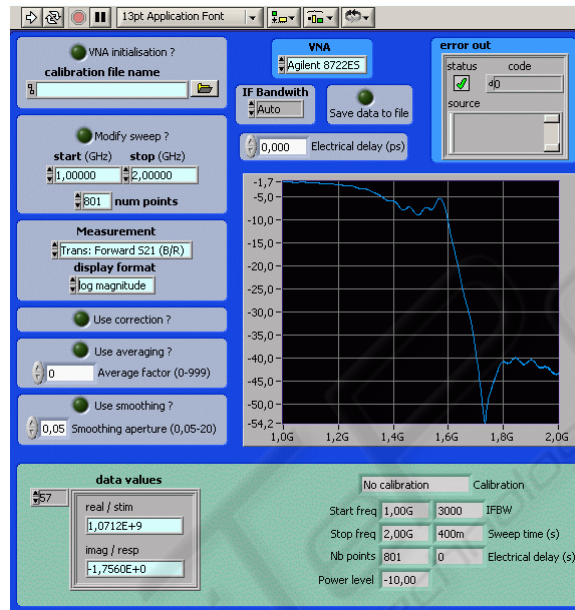


Fig. 3. Front panel

Then, only request and responses are transmitted to limit network load to the minimum. LabVIEW is used to design virtual instruments and front panel shown on Fig 3 is its graphical representation. The virtual instrument can be viewed as a main program composed of many subroutines [8]. They are linked together to exchange data as shown on Fig 4.

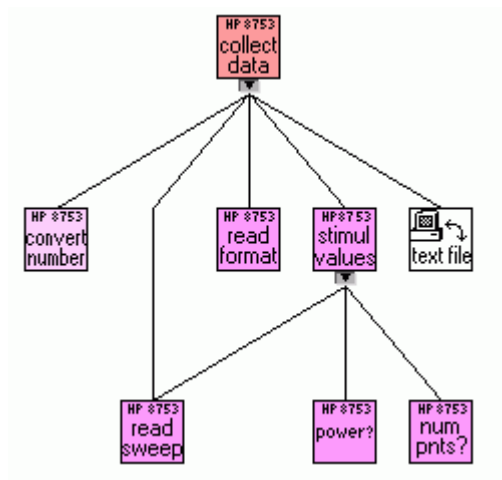


Fig. 4. Virtual instruments hierarchy

LabVIEW allows data flow graphical programming and debugging for reduced development time. A piece of graphical code is shown on Fig 5. It corresponds to highest-level virtual instrument.

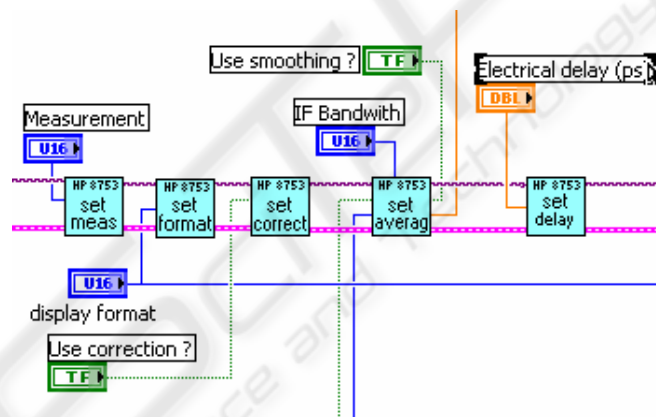


Fig. 5. Graphical programming

4 Distant Control

Once the front panel (embedded on the access web page) loaded, distant user can request the control of the virtual instrument. If control is granted (Fig. 6), measurement requests are transferred to the control PC that sends them to the measurement device through GPIB bus.

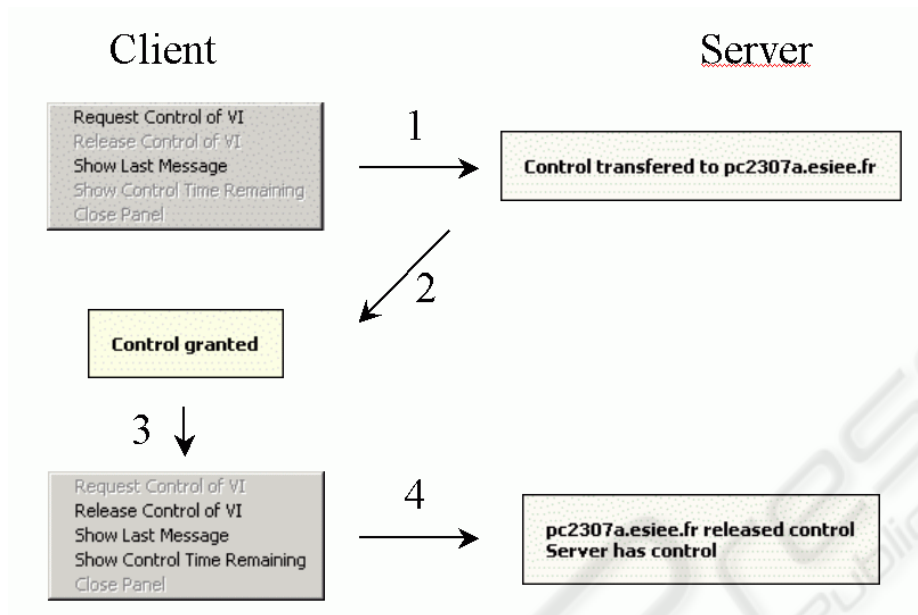


Fig. 6. Distant control request

In step 1, distant client request control of the server hosting virtual instruments in its memory. If it is possible, server transfer control to the distant client (step 2). Instrumentation device can be initialized for measurements. Control may be released by the distant client (step 3) or by the server that have ability to manage connexions. Step 4 informs distant client that he have no longer control on the distant instrumentation.

5 Lab Example

To illustrate Remote Laboratory capabilities a lab used with electronic engineering students is presented ([9], [10]). It consists to measure electrical parameters of a very high frequency filter, in the gigahertz range. Measurements are made both for amplitude and phase and need a very expensive and unique measurement device. Students concerned already have a basic experimental knowledge and "physical" contact with the measurement device is not of great importance.

5.1 Teaching Goals

The main goals of the course were to:

- Familiarize students with the practice of microwave measurement
- Illustrate high frequency electronics features: incident, reflected and dissipated power in passive circuits

- Explain internal architecture and working of a vector network analyser in order to understand measurement uncertainty
- Give an order of magnitude of measurement errors for high frequency electronics
- Show calibration influence on measurement results

5.2 Device Under Test

Device under test is a microwave filter designed with surface mounted components on a microstrip substrate as shown on Fig 7.

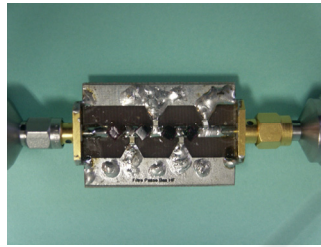


Fig. 7. Microwave filter

Distant measurement associated with scientific environment like Matlab allows advanced real time data analysis not available with the measurement device itself. Three kinds of parameters may be observed:

1. Classical electrical parameters that can be obtained directly from the measurement device (without additional powerful calculation tool). For a microwave filter these parameters are transfer function, return loss and group delay.
2. Phenomenon that is not accessible from the measurement device because they are complex function of many classical electrical parameters (belonging to the first category). Dissipated power in the filter is an example.
3. Statistical analysis of measurement errors that implies processing of a great number of data. Obviously a scientific environment is essential.

5.3 Vector Network Analyzer

Vector network analyzer is used to measure high frequency electrical parameters of a two port device.



Fig. 8. Vector network analyzer

When wavelength is of the same order of magnitude as circuit size, quasi optical approach is required and S parameters are used. Compared to low and medium frequency electronics, internal structure of measurement equipment is more complex (Fig. 9).

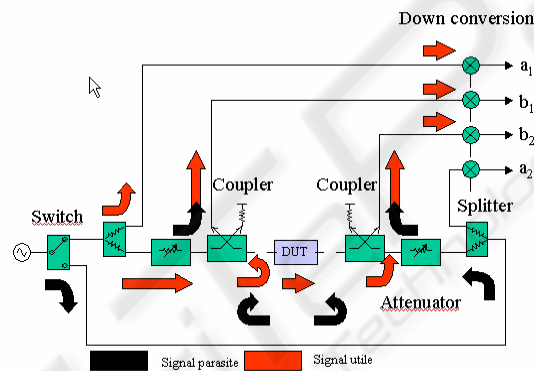


Fig. 9. Internal structure of a vector network analyzer

Active and passive circuits inside introduce frequency dependency, losses and mismatching that must be evaluated and compensated [11]. Error correction is an accuracy enhancement procedure that removes systematic errors (repeatable measurement variations) in the test setup. The analyzer measures known standard devices, and uses the results of these measurements to characterize the system.

5.4 Multiple Accesses to a Single Measurement Device

24 students attend this lab. They are divided in 12 groups of 2 students. Measurement sequence includes two parts:

1. Measurement device initialization have to be done (frequency range, correction method, parameter to measure, format, ...)

2. Measurement request to the measurement device and measurement data must be transferred

First part may be performed off line and measurement device is available for the others. Second part needs effective control of the measurement device and it is not available for the others. Duration of this part of the measurement process is about few seconds.

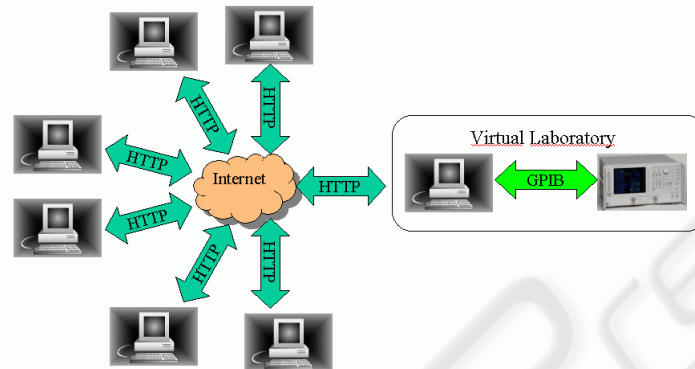


Fig. 10. Multiple accesses

Instant access is really possible for a single distant PC. Simultaneous use of the measurement device is however possible with the following observations:

- Effective utilization of measurement equipment is generally below 50% of the total lab class duration. Remaining time is dedicated to theoretical calculations or experiment preparation.
- Short duration of the measurement process itself induces a statistical multiplex effect as encountered in communication networks.

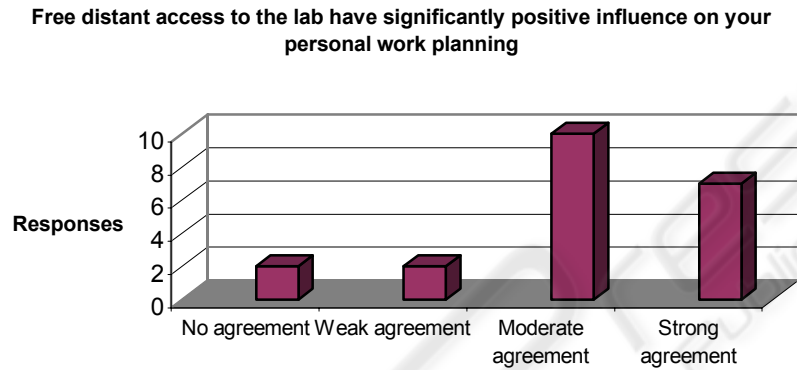
Above items have been experimented and validated with 12 distant PC during a lab class.

6 Students Feedback

Real time distant measurement associated with a scientific or simulation environment is an innovative teaching process, possible now with existing software, hardware and networks technologies. It allows new way of teaching scientific domains like physics or electronics and it is interesting to observe student feedback. Essential conclusions are given below:

6.1 Asynchronism

Individualism and asynchronism (in time and/or space) are now made possible by the use of new technology. Main benefit is freedom in self-work planning with less compulsory presence, and more play and less effort in the learning work. Hence, learning process is now student centred instead of being teacher centred. Results of the student opinion poll are given below:

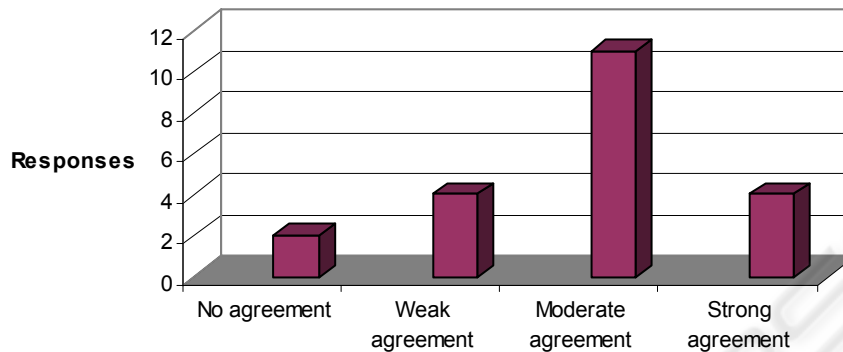


81 % of the students have positive view of asynchronism in experimental studies

6.2 Apprenticeship

Developing the competence and skills of the student in order to facilitate their integration to the workplace is the main challenge of universities. Adding experimental lab class to traditional academic teaching is of great interest.

Free distant access to the Remote Laboratory significantly improves academic apprenticeship



71 % of the students think that free distant access to the remote Laboratory have positive influence on the academic apprenticeship

These responses not only suggest that students are becoming familiar with microwave measurement content, but they also suggest a fairly high level of student interest and engagement.

7 CONCLUSION

Today measurement devices are based on computer platform and their manipulation needs a human machine interface that can be a desktop one in traditional laboratories or a software one in remote laboratories. The single difference between the two approaches is the “physical” contact with device under test, connectors and probes. For students with a basic experimental knowledge and hands-on practice (acquired from traditional lab or practical projects), the lack of physical contact is not boring, and they can conduct electronics experiments remotely from their home or elsewhere. The quality of student work, as well as the positive feedback about the lab class, indicates that these postgraduate students were not only motivated by the subject matter but were also capable of complex measurement. Additional use of a commercial ([12], [13]) or open source [14] e-learning platform may be interesting to provide technical documentation, labs, theoretical background and communication tools (chat, forum, whiteboard).

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