

MICROWAVE AND RADIO COMMUNICATION VIRTUAL LABORATORIES

Vicent Miquel Rodrigo-Peñarrocha¹ and Miguel Ferrando-Bataller²

Abstract) Virtual laboratories may mean simulation or remote control. In our case we have implemented a remote control laboratory. It needs different systems in order to be managed efficiently: not only measuring instruments but also switching matrices, web servers, video servers and data bases. For a successful virtual laboratory the users need to be as comfortable as if they were in the real laboratory. A reference model for high performance virtual laboratories is outlined using standards from three fields: OSI levels for interconnecting computers, instrumentation and measurement hardware and software (control drivers) and web server management. A performance improvement in virtual laboratories is introduced using time domain multiplex for user control of the laboratory: different users can access the same instrument at the same time as if they were the only user for that instrument. Finally an implementation of a microwave virtual laboratory is presented.

Index Terms) Multiple user access, reference model, remote control, virtual laboratories.

INTRODUCTION

The big growth of internet technologies is changing the way of learning. The concept of distance learning is gaining space to traditional learning every day. Engineering schools are joining this new way of teaching and learning, but they found one big problem: performing laboratory experiments without being present physically in the lab. This problem is the biggest obstacle for the distance learning, which has implied a lower quality level in comparison with the traditional learning.

Many solutions rely on simulations [1]. This is a good solution, because students can use and practice with a system very close to the real system. Here the concept of virtual instrument [2, 3, 4] is in many of the systems implemented, but it would be better if students could really make their measurements using the real instruments in the laboratory: controlling remotely the instruments and getting the results of the measurements done.

This is the solution we offer and explain in this paper: a virtual laboratory, but not with simulated but with real measurements behind. Any student, wherever he is, with an internet connection and a web browser, can make the experiments as he is in the laboratory. The keys are tele-control and an intelligent instrument manager.

Using this way of measuring, instruments not affordable for all students can be offered in a remote use basis, i.e.: network analysers, spectrum analysers or any other instruments that, due to their expensive prices, cannot be in any laboratory bench. Such instruments can be therefore remotely used and practices done by all the students, distant or near.

Many options can be used to offer a virtual laboratory. Solutions adopted at the Radiocommunications Laboratory of

the Communications Department of UPV are presented [5]. Some experiences are explained and future developments are discussed.

VIRTUAL INSTRUMENTS

Prior to think about e-learning and remote laboratories, one problem common to all laboratories is the use of expensive or single instruments [6]. In a student laboratory, it is economically difficult to have different instruments, one for each bench. So if it is possible, at least one instrument should be available. Offering this single instrument to all the students is complicated. One possible solution is having a virtual instrument in each bench: The software is in the computer in each bench and that program controls the real instrument, which in practice implies having the instrument in each bench. These solutions need two different signal distribution systems: one for the instrument control and the other for the signal being measured. These signal distribution networks can be easily implemented with switches: a switch for the GPIB control bus and another switch for the signal to be measured. An example of the real and the virtual instrument for a network analyser can be seen in figures 1 and 2.

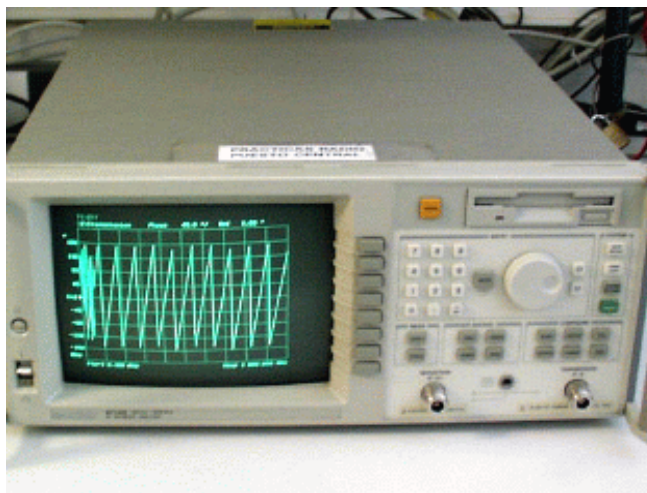


FIGURE 1. REAL INSTRUMENT

There are some other cases where virtual instruments are required. Some old instruments, due to their intensive use and/or the ending of their expected life, must be replaced.

A typical standing wave ratio meter is based on a voltmeter measuring voltage ratios. This instrument can be replaced using a PC with an acquisition card, or simply by a cheap sound card (because it is not needed an exact voltage

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value but a voltage ratio)
 The old and new SWR meter are shown in figures 3 and 4.

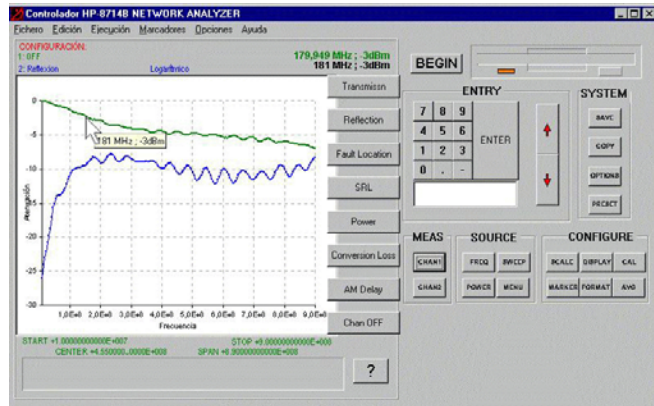


FIGURE 2. VIRTUAL INSTRUMENT.

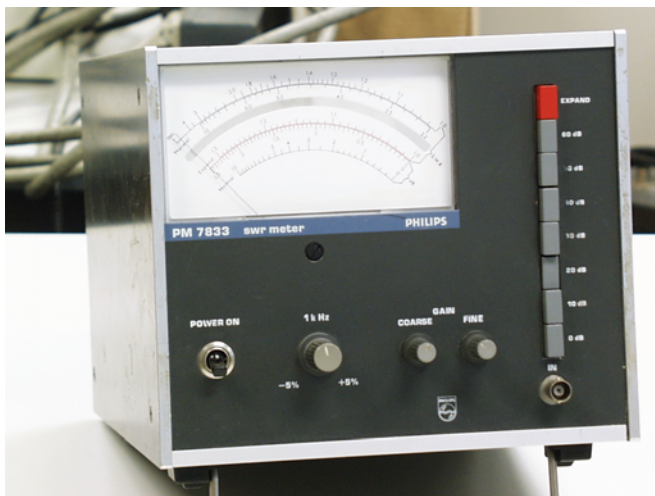


FIGURE 3. OLD SWR METER.

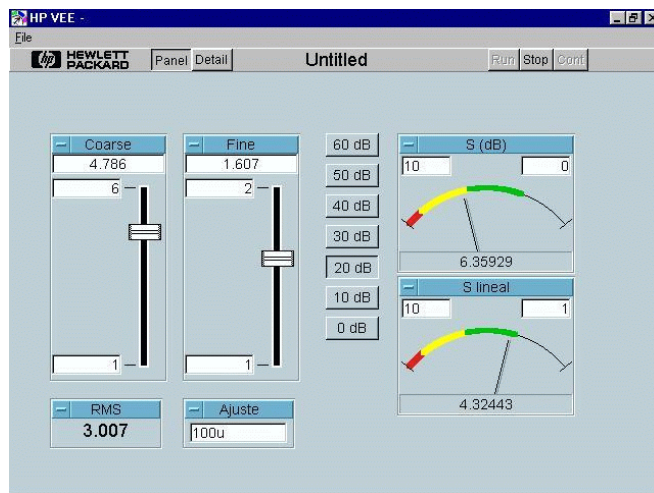


FIGURE 4. VIRTUAL INSTRUMENT. FOR SWR METER.

VIRTUAL LABORATORY

The next step in instrument optimization is offering it to everybody, everyday, every time. With this philosophy in mind the next action is to create a virtual laboratory [7]: a set of elements (measuring instruments, hardware, software) placed in one or more sites, offered to users, placed everywhere, in order to work with them. This can be described in figure 5.

Different technologies can be used to implement this remote access or tele-control of the measuring instruments [8, 9]. The accepted basis is that the user has a computer with internet access and a web browser. Through the navigator, the web pages are loaded and the programs needed to control the laboratory are executed.

But new problems appear due to the user absence from the laboratory:

- **Instrument access:** Before making a measurement or using an instrument, the user needs to know if the instrument can be used or not. In the traditional laboratory is clear that if one person is sat in front of the instrument, you can not sit in his chair. A management system for assigning resources is needed. The experiment can be used by only one user at a time or shared by multiple users.
- **Setup assembling:** If you see a setup in the laboratory bench, you know you can use it. In the virtual laboratory a setup management must be implemented to inform the user of the device measurement possibilities.
- **Multiple D.U.T. measurement:** In the laboratory it is easy to connect different devices. But in front of the computer, this can not be done so easily. If different devices have to be measured, a multiplexer is needed. And a system for managing this multiplexer is also necessary.

To face these and other problems, a global solution must be implemented. Here a complete solution for a virtual laboratory is presented in the form of a reference model for a virtual laboratory.

A REFERENCE MODEL FOR A VIRTUAL LABORATORY

As can be seen in figure 6, the model consists of four different big blocks: the client (or user), the laboratory server, the measurement server *i* and the instruments with the devices under test and other setup connected. It is a layered model joining the OSI model [10] with instrument model and client server architecture.

Client

The user needs a computer with internet connection and a web browser. The layer structure defined by OSI, with the modification of Arpanet [10] network, applies to the model. There are different possibilities in the transport layer [9, 11]: TCP, UDP, Datasocket,..

The only application needed for the client is a web browser.

Laboratory server

A laboratory server is needed in each laboratory. It consists of a computer with a web server, a data base and management

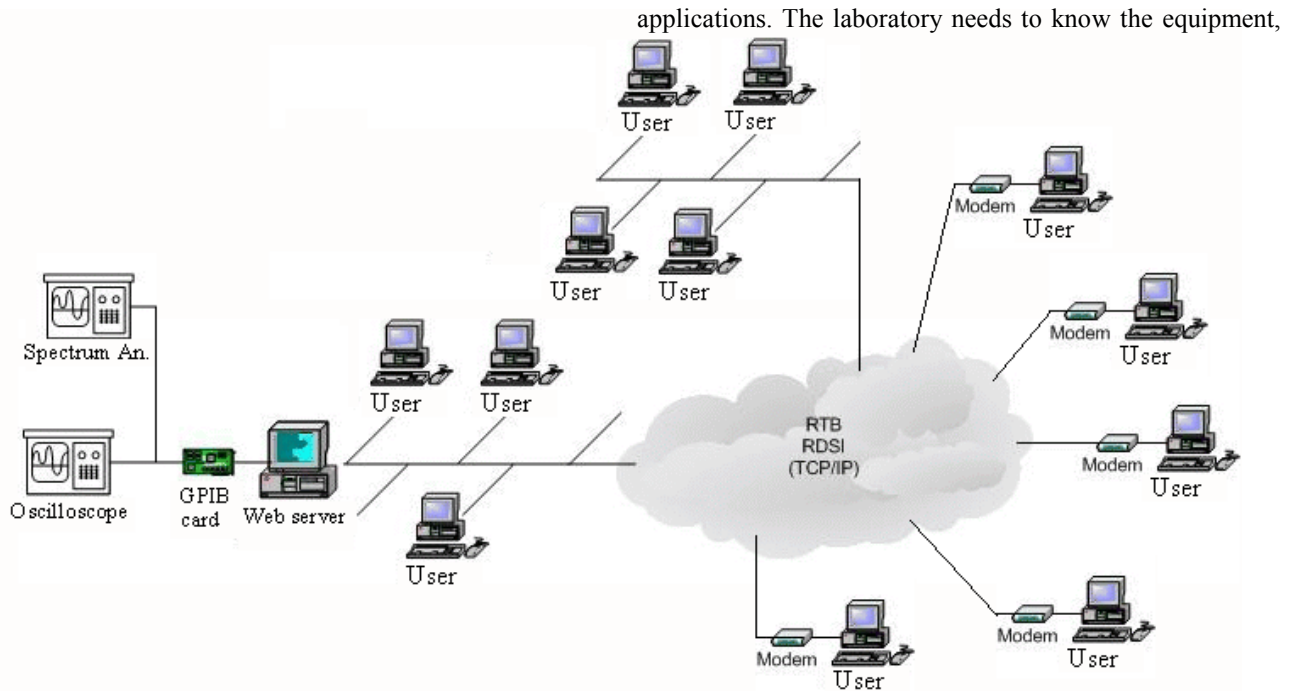


FIGURE 5. THE INTERNET IS THE WAY TO ACCESS THE VIRTUAL LABORATORY.

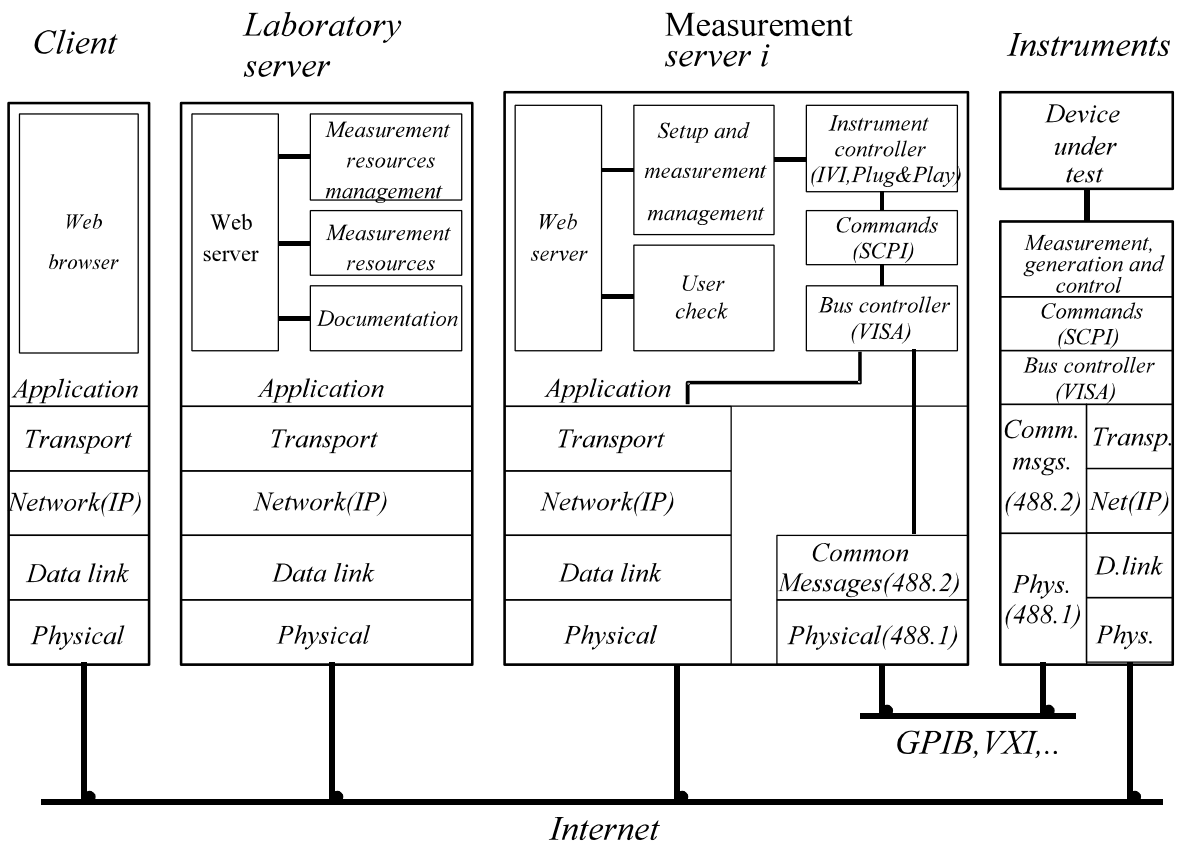


FIGURE 6. ARCHITECTURE OF A VIRTUAL LABORATORY.

instruments, setups, users, so a resource manager is the main application needed. It checks the measurement servers connected to the laboratory, and gets from them the data about instruments and setups available in each measurement server. The manager needs to know the users authorised to enter the laboratory or some experiments.

All the documentation needed for the laboratory should be available through the web server: instrument manuals, examples or practice guides.

Measurement server *i*

The measurement server is the computer that joins the instrument with the virtual laboratory. There may be multiple measurement servers (that's why the *i* index in the name). Each measurement server must have information about instruments and setups available for measuring. This information of all the measurement servers will be transmitted to the laboratory server to obtain the virtual laboratory capabilities.

Once checked and authorised the user access by the laboratory server, it transfers the user control to the measurement server. Proceeding in this way, the lab server is released so all measurement transactions travel directly from the measurement server to the user.

The measurement server provides the users with a graphical interface to control the instruments or the setup for the different measurements. The results can be offered in a graphical or numerical way, so the user can save the results in the desired way.

The interface with the instrument will be based on standard drivers and connections. The instrument driver may be Plug&Play [12], IVI [13] or any other, and the interface bus

driver can be for instance GPIB, which must comply with VISA or be easily configurable.

Instrument

Instrument control commands will be standard like SCPI [14] and will have drivers for an easy configuration and use. The most common connection with the computer is performed through GPIB, but any others like VXI, PXI, RS-232 are also valid.

The instrument includes the signal routing block. This block is very important in order to provide a single instrument with multiple devices for making measurements. The test signal must be routed to the right device, and the output signal must reach the measuring instrument through the adequate routing.

RESULTS ACHIEVED

Successful experiments have been developed into two laboratory subjects: microwaves and transmission lines. In figure 7 the setup for a measurement can be seen. Different solutions can be found for measuring multiple devices and multiple user access to the laboratory. Here we present some of our implementations.

Single device under test

Microwave laboratory experiments require an intensive use of the network analyser. This is an expensive instrument, so there is only two in the laboratory. The number of students registered in this subject is around 200, so they do not have many time to learn their use and make different measurements. Last year a voluntary experiment was developed based on the virtual

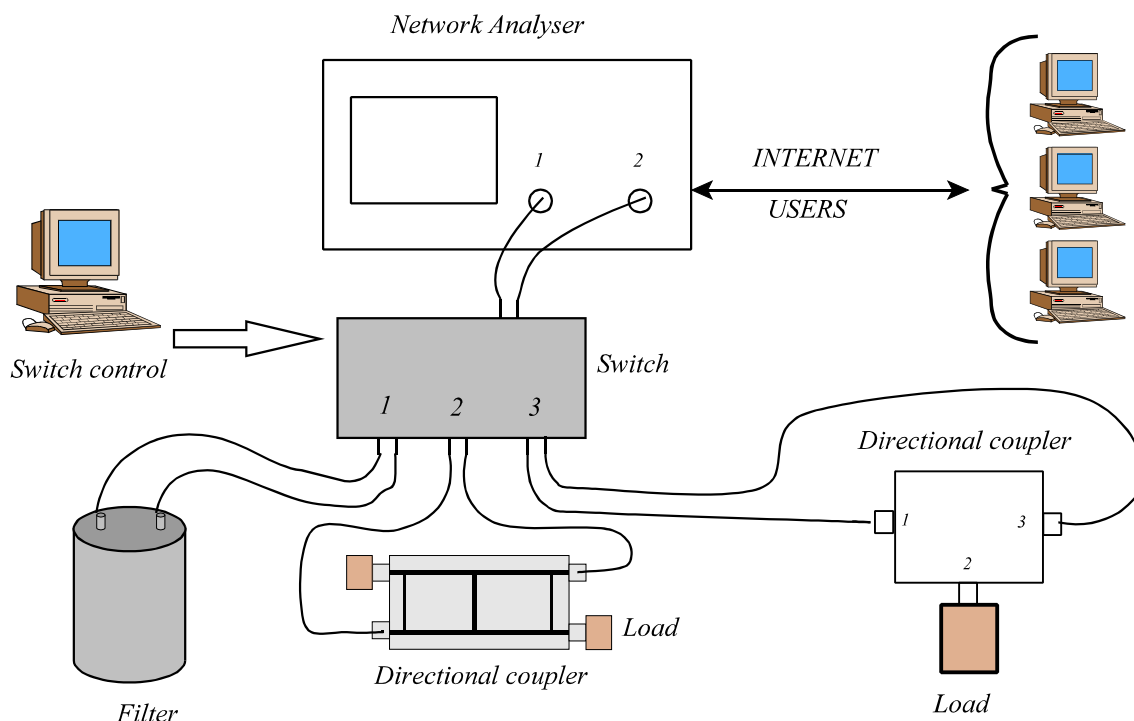


FIGURE 7. EXAMPLE OF MICROWAVE MEASUREMENTS USING SWITCH CONNECTIONS THROUGH INTERNET

laboratory concept. The network analyser was available on line at any time out of ordinary laboratory schedule. One device, a directional coupler, was properly connected to the analyser. 48 students made the virtual experiment, and afterwards they filled a little survey. The answers were clear: all students thanked the extra time for using the instrument, as well as the 24 hour availability of the experiment, so they could use the instrument following their own schedules. The user time assignment can be seen as long time multiplex as figure 8 shows.

This kind of laboratories can be found working in some Universities and Institutions [8, 11].

Multiple devices under test

Microwave laboratory has a reflectometry experiment. It makes use of a function generator and an oscilloscope as instruments, and a long cable where multiple loads are connected. This experiment presents an additional problem for the virtual laboratory: Changing the loads from the end of the cable. This problem has been solved using a programmable switch. This switch is connected to the end of the cable and different loads are connected to their outputs. A program automatically switches every 10 minutes the load connected to the end of the cable. So, the students have this time to measure and characterise each curve from the oscilloscope.

Multiple user access to a single instrument

The traditional way for accessing laboratories can be used in virtual laboratories: each user controls the instrument in a long period as can be seen in figure 8. And each week, or day, the schedule is repeated. It is called long time multiplex as time is split between users in long time periods. This method is simple to implement for a virtual laboratory.

Taking benefit of computers and programming, a short time multiplex can be used in some cases to improve user access: each user seems to have all the time for using the instrument instead of only one time slot as it was with long time multiplex. Figure 9 shows this mode. A system management program must be included in the virtual instrument to permit this way of switching.

In the reflectometer experiment time-division multiplexing has been introduced. The oscilloscope (figure 10) splits its time between the users connected to it. A program manages all the changes: it saves instrument state for user 1, it recovers the instrument state for user 2, it makes any measurements for user 2, it saves the instrument state for user 2, and so on. With this approach, the instrument time availability increases, so it seems to have n instruments available to the users (n is the maximum number of users that can be connected to the real instrument) instead of the real 1 instrument [15].

LIMITATIONS OF THIS APPROACH

There are some limitations due to the absence from the laboratory: The connexions can not be changed as the user is not in the laboratory. So that kind of experiments that require changing the set up physical configuration, have to be changed or they can not be performed. Some times a movement could be needed. In that case an adapted remote controlled device producing that movement should be used.

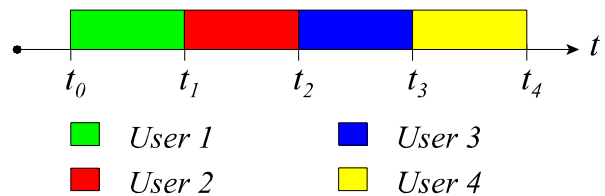


FIGURE 8. LONG TIME MULTIPLEX

An example can be the calibration process of a system, that requires making some measurements without the device under test (or connecting some reference loads) and then insert the device to make the measurement. It can be changed in two ways to be able for remote use:

- Making a local calibration and then store it in memory. The user does not need to make the calibration. Only load correction parameters from memory.

- Using a switch with very good specifications so connecting a different device or load changes to switch to different port. In this case we are supposing the switch does not introduce any change to affect the measurement.

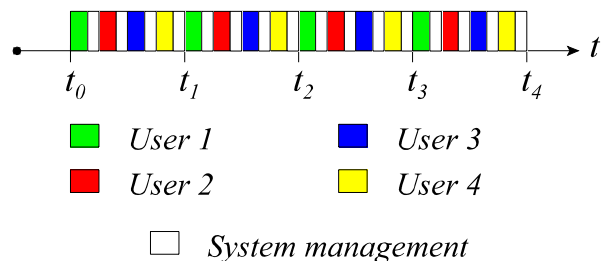


FIGURE 9. SHORT TIME MULTIPLEX

CONCLUSIONS

In this paper we have demonstrated the use of a virtual laboratory with real instruments making real measurements. This kind of laboratory can be used at any time and at any place, so the users can take benefit of making experiments on their own schedules.

Multiple devices under test can be used with the adequate switching devices, so changing the device under test is not a problem.

Finally, a new concept of instrument use is introduced: time-division multiplexing. Multiple users can access the same instrument, so with only one instrument a complete lab can be set up. This is useful not only for distance learning but also for traditional learning because expensive instruments, not available in all laboratory benches, can be accessed from all students present in the lab.

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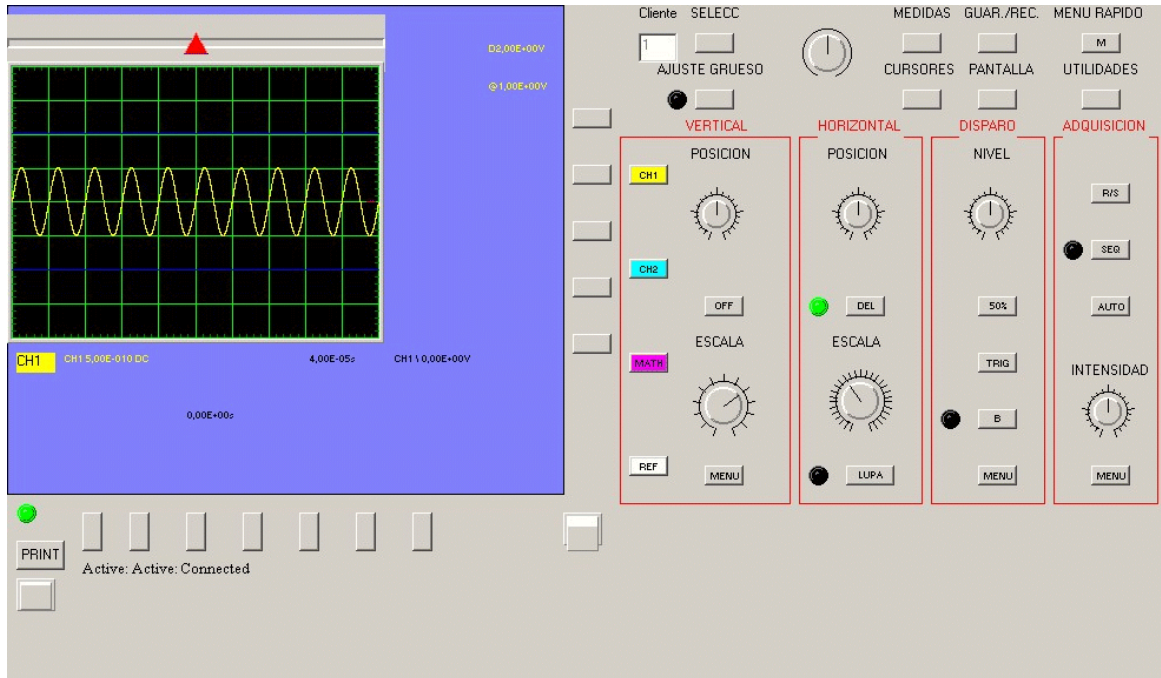


FIGURE 10. MULTIPLE USER VIRTUAL OSCILLOSCOPE

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