Virtual Instrumentation: First Step Towards a Virtual Laboratory

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Abstract

In this paper the use of virtual instrumentation in radio frequency educational laboratories is discussed.

In these laboratories students can use instruments in the classic way (looking at the display and changing the controls on the front panel), and they also use new virtual instruments based on PC that add specific measurement capabilities to the stand-alone instrument. They can create their own virtual instrument using one or more instruments. In some cases, acquisition boards with the appropriate software can substitute traditional or specific instruments.

Software and hardware problems of virtual instruments are described and solutions are suggested.

Many of the problems related to the high cost of buying and maintaining RF instrumentation for a complete educational laboratory can be minimized.

The steps to make a virtual laboratory are suggested.

Although the origin of the suggestions and solutions provided by this paper are based on an educational laboratory, they can be applied to a research laboratory or to other situation where instrumentation is used.

1. Introduction.

Electronic (communications) engineering curricula must contain the learning and use of specific and general instrumentation.

The different situations related to the use of virtual instrumentation in an educational radio laboratory are described next.

Students must fluently use basic instruments as multimeters, scopes, power sources or spectrum analysers and know more specialized ones as vector network analysers. The main difficulty related with the implementation of a new instrumentation laboratory is the high cost required per each bench. Besides, some instruments have too high prices to be at each bench, for example, a vector network analyser or a RF sweep generator.

Some other times, specific instruments must be used. For example, a SWR meter for a microwave waveguide set. Some microwave kits for laboratory are older and today, manufacturing companies have disappeared. If this instrument fails, the measurements could not be taken and all the microwave kit can not be used.

If repetitive measurements have to be taken, a computer control of the instrument is very useful. Or, even complex measurements are difficult or impossible to make using directly the instrument front panel.

In other cases, some practices do not use all the equipment in the laboratory, and may use only the PC or the oscilloscope or the microwave bench, leaving all the other instruments unused during the practice period.

The situations mentioned before are some of the problems that can be found in a laboratory and this paper describes how they can be solved using virtual instrumentation.

Some of these recommendations have been used in the Radiocommunications Educational Laboratory of the Departmento de Comunicaciones of the Universidad Politécnica de Valencia, Spain.

2. Virtual instruments front panel.

In an educational laboratory, intensive use of instrumentation is made. Front panel keys and buttons are widely used, pressed and stressed. Standard instrument life time is rapidly reduced. When a key fails there are two big problems:

1) instrument can not be used for a long time till it is

repaired. Typically two months. So if you have a number of students in each bench, the problem of redistributing the students appears.

2) any reparation is very expensive. An unexpected reparation can spoil any laboratory budget.

These problems can be resolved in two ways:

A) Using an external keyboard and an external monitor. The only problem is that this solution depends on the instrument equipment. Only if the instrument has a keyboard connector (usually a PC compatible keyboard) and a display connector (preferently a VGA type), you can do it.

A display connector has been added because if you have to look at the display in the instrument front panel, you usually forget the external keyboard and push the front panel buttons.

And this solution (external display and keyboard) is not fine because many instruments use soft menus (screen menus) and the menu options appear in the bottom and/or in the side of the screen so you must translate a specific position on the screen to a specific key on your keyboard (A little sticky paper can be put in the frame of the display to indicate the key to be pressed).

B) using a virtual instrument front panel [1]. A PC controls the instrument through a program [2]. An example can be viewed in figures 1 and 2.

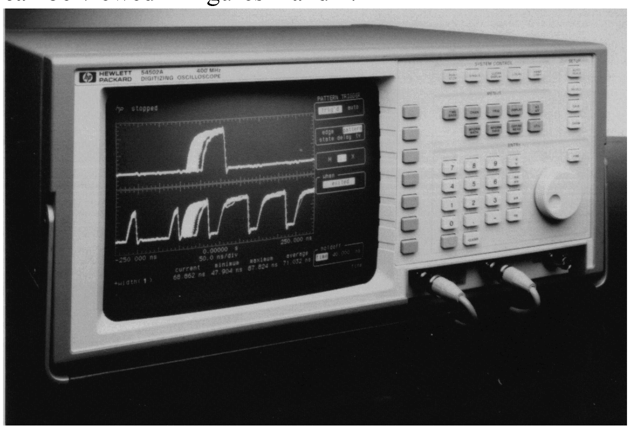

Figure 1. Real instrument front panel.

Figure 1 shows a photograph of a digitizing oscilloscope where the display can be seen in the left side of the front panel and the buttons in the right side.

This front panel has been substituted by a virtual instrument (front panel) as can be shown in figure 2.

All the buttons are in the same position in both real and virtual, so anyone who learns the use with one of them, can use the other immediately.

Due to the size of a computer display, one thing has been slightly changed from the original: The scope screen. In the virtual instrument it appears at the bottom of the screen instead of at the left. Screen menus appear at the right of the instrument screen in the real instrument. In the virtual one they appear exactly at the same position relative to the buttons to be pressed, out of the signal window.

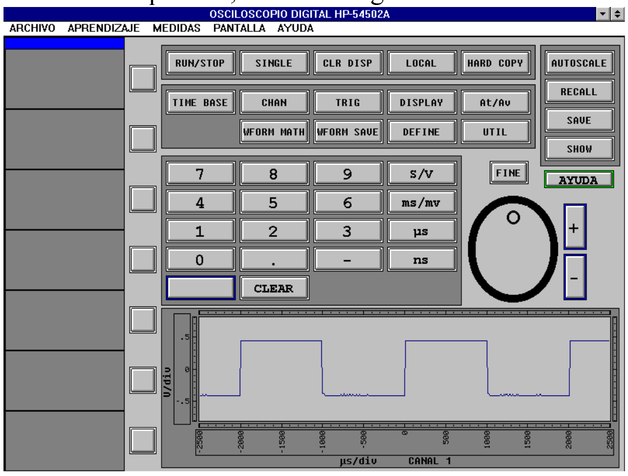

Figure 2. Virtual instrument front panel.

The virtual front panel can be controlled with the mouse. An IEEE 488 (HPIB or GPIB) bus [3] connects the PC with the instrument. The physical contact of the instrument with the student is reduced to connect the device under test to the instrument connectors.

As can be shown in figure 2, some menus and buttons have been added to enhance original instrument.

One of this buttons is AYUDA (Help) that offers a help on the required button like the "?" icon in upper right corner of some standard windows .

A menu bar has been added with some useful functions like data save in some formats (Matlab ascii) in ARCHIVO (File), some training utilities in APRENDIZAJE (Training), specific measurements and programs in MEDIDAS (Measurements), waveform screen zoom in PANTALLA (Screen), and general help in AYUDA (Help).

Programming language used for this instrument is HP Instrument Basic on a PC. It is a simple translation of well known HP Basic program for workstations (and now also for PCs) with graphic utilities. It allows the use of a IEEE 488 interface card from Hewlett Packard and from National Instruments. It is an interpreted programming language and therefore has the speed problems of any interpreter, but with today's computer speeds, it is not a problem. Unfortunately, HP has discontinued this programming language. It is only used in instrument internal processors. It permits executing programs to control the instrument without an external controller. The instrument has the controller.

3. Remote use of a single instrument through the virtual instrument front panel.

When there is only one instrument of some kind in the laboratory, as could happen with an expensive one like a vector network analyser of figure 3, students have two options to use it:

A) Move from their workbench to the network analyser workbench. Make all the measurements, and when finished, return to the original bench to make next measurements with other instruments. The problems of touching the front panel mentioned before can also be applied to this case.

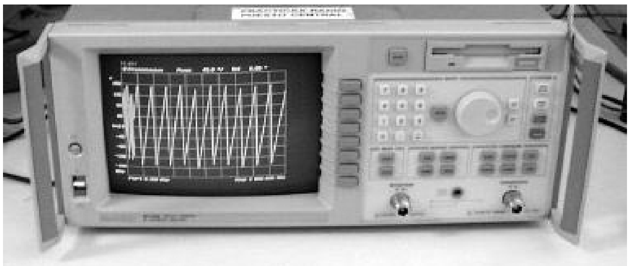

Figure 3. Real Network analyser.

B) The network analyser can be accessed from each student group from their bench. Each bench needs:

1- the PC with the virtual front panel of the vector network analyser [4] as can be seen in figure 4.

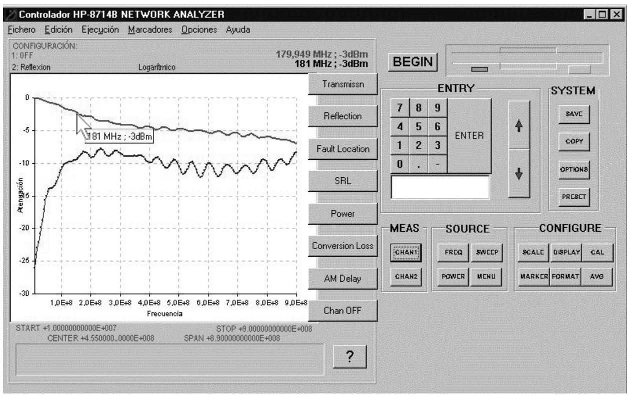

Figure 4. Virtual network analyser.

2- a GPIB network. A switch changes the connections so the active bus controller is the PC of the students bench. Each bench can sequentially remote control the instrument.

3- a signal distribution network. RF cables that interconnect the analyser bench with each student workbench. Students have in their bench the two ports of the network analyser.

With this three requirements, each student group from their bench can take measurements and show the results neither moving from the bench nor touching the instrument.

The calibration routines of the network analyser must be used to take faultless measurements in each student bench.

The programming language used for this instrument is Borland's Delphi. Now, a new problem appears. Libraries to talk through the IEEE 488 card are manufacturer dependent. So if the card is changed, the program does not work. A new kind of libraries, like VISA or SICL (not available when the program was written) permit the card change.

4. Virtual instrument for a traditional instrument.

One typical element in a RF laboratory is a microwave waveguide set. Many different experiments can be done with waveguides. One of the measurement instruments used is a standing wave ratio (SWR) meter.

A SWR meter for a waveguide bench consists of a voltmeter with several scales (set of buttons) that amplify the input and a specific linear or dB printed scale in the display.

THe intensive use of the instrument usually leads to broken button mechanical parts, with the added problem, in some cases, of no spare parts.

Figure 5 shows the SWR front panel.

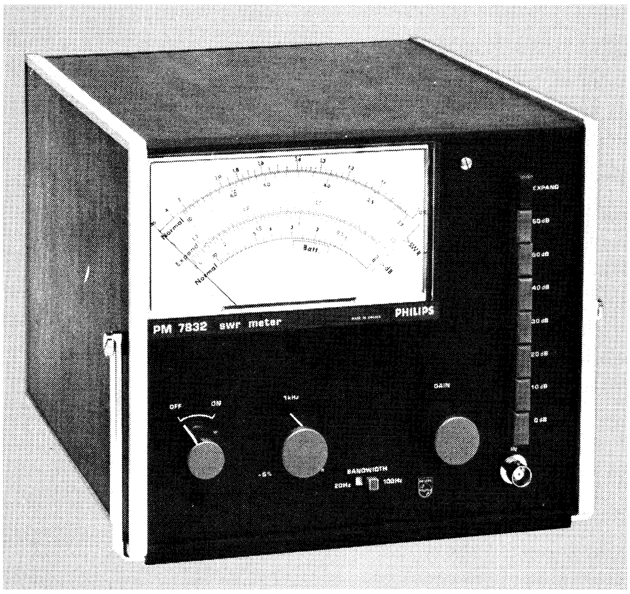

Figure 5. Real SWR meter.

This problem can be solved with a full change. An acquisition board [5] can be used to take the voltage samples and a program [6] can make the calculations and show in an indicator panel, exactly equal to the old instrument panel, the measurements taken.

Instead of an acquisition board, a simple sound card can be used. It's the cheapest adquisition board and today is installed in almost all computers. It permits sampling frequencies till 44 kHz and input rms voltage till 2 V. As the SWR is a ratio, an absolute tension value is not needed so the values given by the sound card can be directly used to do the SWR calculations.

Figure 6 shows the virtual instrument front panel of the SWR meter.

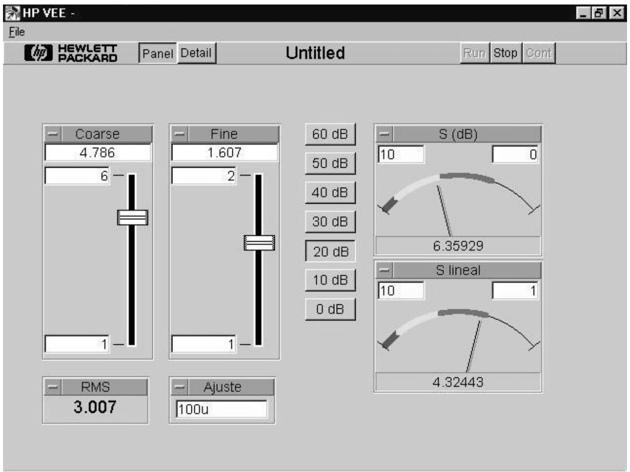

Figure 6. Virtual SWR meter.

5. Virtual scalar network analyser and calibration.

A spectrum analyser with a tracking generator can be used as a scalar network analyser. A program can be the interface, so in the PC display an image of a network analyser appears. And the calibration procedure for

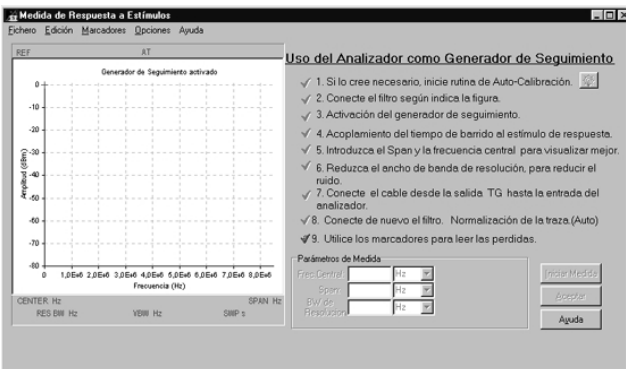

Figure 7. Scalar network analyser virtual instrument for transmission measurements.

transmission or reflection measurements can be programmed to help the user to make it carefully, step by step, with pictures and explanations [4].

Figure 7 shows the main panel of a virtual scalar network analyser calibration and measurement. The configuration showed is for transmission measurement. The steps are indicated and a red mark shows the step of the measurement to be performed.

For reflection measurements an external coupler is required, and the calibration procedure is different. Figure 8 shows the virtual instrument for reflection measurements.

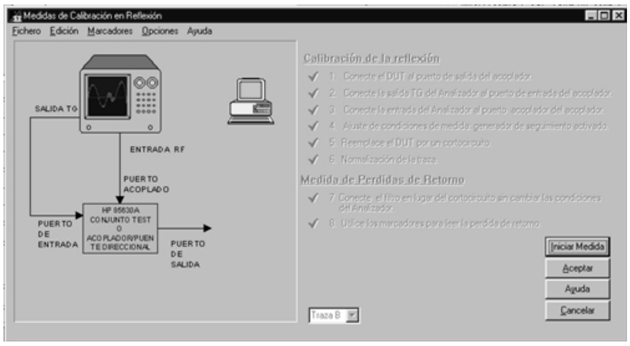

Figure 8. Scalar network analyser virtual instrument for reflection measurements.

An schematic drawing of the connections is showed to assist in assembling the measurement system. In each step a red arrow indicates the connection points. Finally the graphic window changes to the typical coordinate axis of frequency and gain/loss.

6. Towards a virtual laboratory.

With all the explanations given before, who needs to be present in the laboratory to make some measurements? It's only needed some kind of connection between the instrument and the PC that wants to be used as the virtual instrument.

Internet can offer this connection. It is only a programming task that the instrument responds to queries from a network instead of a GPIB traditional control [6],[7].

So students can make their practice and measurements easily at home or in any place, at any hour. It is only a question of scheduling the instrument control to remote users.

Remote control through internet can be designed thinking in two possibilities related to the software requirements of the remote user:

1) The user has a specific program to control the instrument(s).

2) The user has a generic program like an internet navigator (browser).

First option requires a specific program loaded and executed by the user. Any typical language can be used to

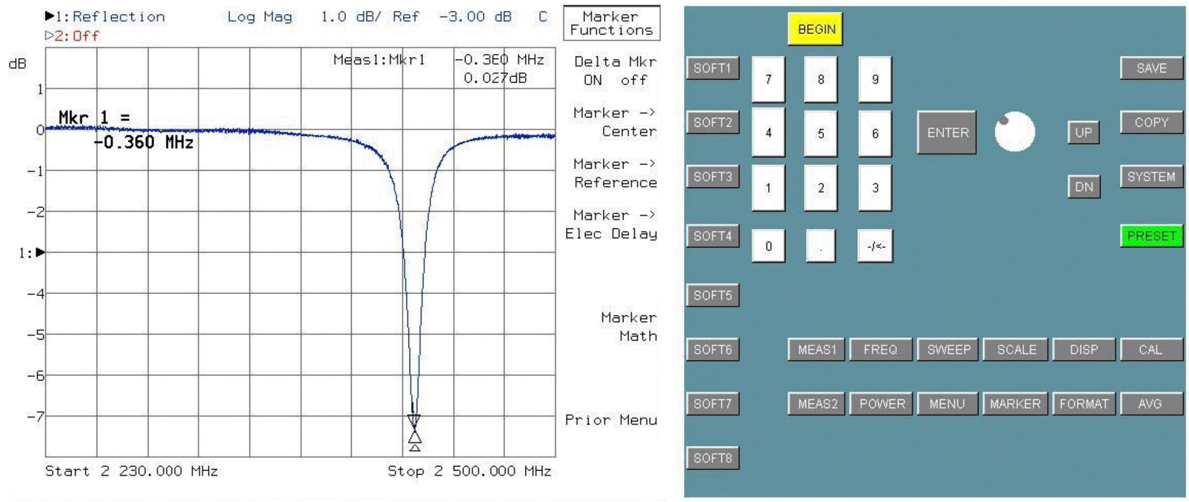

Figure 9. Virtual Network analyser controlled through a web browser.

make that program. Only the internet libraries are required to make the special remote operations. All the other programming questions are the same as in a traditional programming through a GPIB connection.

Second option requires only an internet navigator from the user. Any revision of software is immediately applied to the next measurement because the program is not in the user computer but in the server. The problem is the complete programming change. The language has to change because it has to be browser compatible. And the problems of remote internet connections (delay, data loss,..) can be a drawback that involves new programming skills.

Figure 9 shows a web controlled instrument [8]. Some instruments already have a network adapter besides the traditional GPIB adapter. This element eliminates in some cases the need of a PC because they can be directly and fully controlled through the LAN connection.

7. Summary

Practical solutions using virtual instrumentation used in the educational radiocommunications laboratory have been presented.

They permit to improve the laboratory education and reduce the initial equipment and maintenance costs.

Besides, they allow to extend the laboratory scheduling to a 24 hour open virtual laboratory with a great reduction of costs.

8. References

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